Department of Economics

# Three Essays in Macro Labor Theory

**Renato Faccini**

*Thesis submitted for assessment with a view to obtaining the degree of Doctor of Economics of the European University Institute*

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EUROPEAN UNIVERSITY INSTITUTE
**Department of Economics**

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**Jury Members:**

Prof. John Driffill, Birkbeck College, University of London
Prof. Salvador Ortigueira, EUI, supervisor
Prof. Christopher Pissarides, London School of Economics
Prof. Morten Ravn, EUI and University of Southampton



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*To Aurora and my parents*

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# Part I

# Introduction



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This thesis presents three papers in macro labor theory. All of them share the particular approach to the theory of unemployment pioneered by Dale Mortensen and Chris Pissarides. In these models unemployment is frictional, and emerges as an equilibrium outcome in an economy where workers and firms are value-maximizing agents trading labor services. To date, the Mortensen-Pissarides search and matching model has become the standard framework for the macroeconomic analysis of labor markets. The heart of its success lies in its ability to offer an appealing description of the functioning of the labor markets together with analytical flexibility. In my thesis I exploit these virtues of the canonical framework in order to study different topics of interest in the macro labor literature.

The first two chapters of the thesis build on the theoretical literature on labor market institutions and macroeconomic performance. Typically, this literature has investigated the role of institutions such as minimum wages, unemployment benefits, employment protection or centralization in wage bargaining. In my thesis I rather focus on all the institutions which affect the equilibrium of the labor market by hindering screening procedures. Mainly, I think about limitations on the use of temporary contracts and probationary periods, which are extensively used by firms to screen workers on-the-job. In addition, I also focus on the most extreme case of institutions preventing firms from screening hires. I refer to the post-war Italian labor market, where the allocation of blue-collar workers to the firms was decided by government placement offices on the basis of a set of criteria totally unrelated to productivity. Despite the old-standing interest for issues related to information in labour economics, little work has been done to understand how labor market institutions affect macroeconomic performance by affecting the disclosure of information about match quality. This is the gap I try to fill with the first two chapters of my thesis.

The motivation for the **first chapter** lies in the deep transformation of the Italian labor market institutions that occurred during the 1990s. Prior to 1991, the cornerstone of the Italian labor market regulation, Act 264 of 1949, prevented firms from choosing directly the workers they wanted to hire. Instead, workers could be hired only through public placement agencies. In the case of manual workers, firms could only make a numerical request to these agencies, specifying the number of workers they needed. The public agencies would have then selected the workers to be hired, on the basis of their economic need to find a job. Besides hindering screening procedures prior to forming a match, the Italian legislator restricted access to temporary contracts and limited the duration of probationary periods. Briefly, firms could only draw up permanent contracts, having little information on the characteristics of the workers. Since the beginning of the 1990s, major reforms of the labor market were implemented, which have substantially increased the ability of the firms to screen workers.

The main result of the first chapter is to show that when workers have private information about their type, institutions that prevent firms from screening workers generate wage compression within groups of observationally equivalent workers and higher average wages at the cost of higher unemployment. The theoretical predictions that can be derived from the model are in line with some stylized facts on the Italian labor market before and after the reforms of the 1990s. Technically, the main contribution of the paper is in bargaining theory. The model requires solving a bargaining game of incomplete information. This is necessary since the standard Nash bargaining assumption is no longer applicable with one-sided imperfect information on the payoffs. The standard way of modeling bargaining in this case is to assume that either the worker or the firm makes a take-it-or-leave-it offer with given probabilities. One feature of this game which makes it particularly attractive is that under the limit case of perfect information the solution is the commonly used Nash bargaining criterion.

The **second chapter** builds on the vast literature investigating the impact of the reforms of temporary contracts. Most of the models in this field embed the mainstream view that temporary contracts are an instrument which offers more flexibility to the firms to adjust employment faced with changing aggregate labor market conditions or idiosyncratic demand shocks. This view has always been well rooted among both academics and policy-makers, as historically, the main reason temporary contracts were introduced into Europe was the idea that higher labor market flexibility would permanently decrease unemployment. However, in the recent years, several empirical studies in the literature suggest that the main reason why firms use temporary contract is not to use temporary workers as a buffer stock, but rather to screen them for permanent positions. In my second chapter I embed this idea into an equilibrium model of the labor market in order to assess the macroeconomic implications of this perspective.

The model provides a framework which is suited to address most of the questions raised in this literature, that is, how temporary contracts interact with other labor market institutions, and how they affect unemployment rates, productivity, hiring practices, turnover rates, wage differentials, career prospects and welfare. As opposed to the model in the first chapter, there is no private information about match quality, but bilateral imperfect information. The main mechanism of the model through which temporary contracts affect the labor market equilibrium is very simple. In a framework where most of the separations at short tenure are driven by learning about match quality, temporary contracts increase the value of posting vacancies since they allow workers to be screened without incurring any cost if a bad match


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is terminated. The quantitative analysis of the model exploits estimates for the process of learning about match quality by Pries (2004). Again, the reforms of the Italian labor market implemented in the late 1990s provide an ideal laboratory for the calibration. Since Italy is the OECD country with the lowest probation period, it is where the effects of temporary contracts through the screening device are expected to be the largest. It is found that the model is successful in matching a number of stylized facts including the transition rates into permanent employment, the size of the wage differential, the turnover rates, and the drop in the unemployment rate following the reforms. If temporary contracts are used as a screening device, they can lead to a substantial increase in welfare, but their quantitative impact crucially hinges on dismissal costs and minimum wages.

In the **third chapter** of my thesis, which is a joint work with my supervisor Salvador Ortigueira, we investigate instead the unemployment volatility puzzle, the most popular subject of analysis in the macro labor literature of the last few years. It is well known in this field that the standard textbook matching model is not able to account for the observed magnitude of fluctuations in labor market tightness. As discussed in Pissarides (2008), up to now the most successful attempts to solve the puzzle still present major flaws. Alternative calibrations which can generate volatility deliver an excess sensitivity of unemployment to unemployment benefits, and models which have introduced wage stickiness are incompatible with the high correlation between wages and productivity observed in new matches.

In our paper we retain the assumption of Nash negotiation of wages, and contribute to the literature by endogenizing labor productivity to the firm's investment and hiring decisions. With this aim, we remove the assumption of employer-worker pair and assume instead the standard neoclassical firm that employs many workers and owns capital. An additional important assumption, is that we introduce adjustment costs, meaning that accomodating new units of labor and capital within the firm is costly. We then explore the ability of the model to amplify fluctuations in labor market variables following shocks to both neutral and investment-specific technology. An important consequence of the large-firms assumption is the so called intra-firm bargaining, that is, the fact that the firm anticipates the wage effects of its hiring and investment policy. By virtue of intrafirm bargaining, we show that the wage function becomes increasing in the level of neutral technology and decreasing in investment specific technology.

We find that shocks to investment-specific technology account for about 40% of fluctuations in labor productivity. Within our model, this type of shock exibits considerable propagation and amplification properties, which are very close to what is found in the data. The heart of the mechanism is rooted in the interactions between employment and capital in

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the adjustment cost function and their impact on wages. Unlike shocks to neutral technology, investment-specific shocks introduce a bias in favor of capital by lowering its price. Thus, a decrease in the price of the investment good yields an immediate sharp increase in investment with a consequent increase in adjustment costs. In order to spread out these (convex) costs over time, the firm's optimal policy calls for a delay in the increase of hiring after the shock. That is, the firm builds up first the capital stock, taking advantage of its lower price, and then creates more vacancies. Indeed, both net labor productivity and vacancies are hump-shaped, showing an initial drop followed by a subsequent prolonged increase. The delayed increase in vacancies is fostered by the dampening effect of investment technology shocks on wages. Intra-firm wage bargaining implies that the firm shares adjustment costs with the workers, and thus, investment-specific shocks do not create a perfect correlation between labor productivity and wages.

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# Part II

# Chapters



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# CHAPTER 1

# UNEMPLOYMENT AND WITHIN-GROUP WAGE INEQUALITY: CAN INFORMATION EXPLAIN THE TRADE-OFF?

## 1.1 Introduction

To explain the different performance of OECD countries in terms of unemployment and wage inequality, the theoretical and empirical literature has investigated the role of different institutions such as minimum wages, unemployment benefits, employment protection and centralization in wage bargaining. Many of these studies have documented the existence of a trade-off between unemployment and wage inequality, and for the most part they have focused on total inequality in the aggregate wage distribution.[1] Little research instead has investigated the sources of within group wage inequality, i.e., wage dispersion within groups of observationally equivalent workers. As Acemoglu (2002, p.14) points out "we know relatively little about the determinants of residual inequality,...[or] about cross-country differences in the behavior of wage inequality... [and] much more research in this topic is needed".

This paper contributes to fill the gap on the theoretical side by presenting a novel determinant of unemployment and within-group wage inequality which implies a trade-off between the two. The focus is on the broad set of institutions which prevent firms from screening workers. Lazear (1995) shows that firms can extract information about the non-observable determinants of workers' productivity through the use of screening tests. I argue that the amount of information that can be extracted is affected by labor market institutions. I thus define institutions preventing screening (hereafter IPS) as all the rules and regulations that may, directly or indirectly, prevent firms from obtaining information which is useful to predict workers' productivity.

As it is carefully documented in the next section, IPS had a fundamental importance in the functioning of the Italian labor market. Following WWII, the cornerstone of the Italian labor market regulation, Act 264 of 1949, prevented firms from choosing directly the workers they wanted to hire. Instead, workers could be hired only through public placement agencies. In the case of manual workers, firms could only make a numerical request to these agencies,

[1] See Blau and Kahn (1999) for a review and Bertola, Blau and Kahn (2001).



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specifying the number of workers they needed. The public agencies would have then selected the workers to be hired, on the basis of their economic need to find a job. Besides hindering screening procedures prior to forming a match, the Italian legislator, following post-war European standards, restricted access to temporary contracts and limited the duration of probationary periods. As a consequence, firms in the Italian labor market were also hindered in screening workers on the job. Briefly, firms could only draw up permanent contracts, having little information on the characteristics of the workers. IPS can be thus considered as a distinctive feature of the Italian labor market, and to some extent of the European labor market, as opposed to the US labor market. Nevertheless, as documented in the next section, the evolution of the Italian juridical system suggests that the influence of IPS has been strongly declining since the beginning of the 1990s.

In order to assess the effects of IPS, the standard matching model presented by Pissarides (2000) is extended in the following directions. First, workers are no longer identical: heterogeneity across workers reflects permanent differences in individual productivity. Second, as is common in adverse selection models of the labor market, individual productivity is known to the worker but not to the firm at the time the worker is hired. Third, contracts are bargained once and for all, and they cannot be conditional on future performance. Finally, it is assumed that a worker must take a screening test upon matching. The outcome of the screening test is for the firm a noisy signal over the productivity type. Labor market institutions affecting the information content of the screening procedures are modeled as a parameter defined over a continuous support which represents the precision of this signal. IPS are associated with a relatively low degree of precision. Changes in the parameter representing labor market institutions will allow all intermediate scenarios of incomplete information to be represented, ranging from the case in which the signal is completely uninformative to the case in which the signal reveals the worker's type perfectly.

The model requires solving a bargaining game of incomplete information. This is necessary since the commonly used Nash bargaining criterion is no longer applicable with one-sided imperfect information on the payoffs. The standard way for modeling bargaining in this case is to assume that either the worker or the firm makes a take-it or leave-it offer with given probabilities. This approach has been exploited in the context of macroeconomic models of the labor market also by Kennan (2006) and Tawara (2005), but for the opposite case in which the firm has private information over the productivity of the worker. In the modeling of this bargaining procedure, I add on their work by considering signal extraction. One feature of this game which makes it particularly attractive is that under perfect information the solution is the commonly used Nash bargaining criterion (Cahuc and Zylberberg 2004).

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The model builds on the literature of asymmetric information in matching models with heterogeneous agents. Three papers that are worth mentioning in this field of study are Strand (2000), Montgomery (1999) and Pries and Rogerson (2005). Strand (2000) shows that a lack of information on workers' characteristics may lead firms to employ too few workers. His work is based on the assumption that in a market with no frictions firms can reward workers for their productivity after having paid a fixed screening cost. This paper departs from his study in two directions: frictions are introduced to analyze the behavior of unemployment at equilibrium, and imperfect screening to study the effects of IPS.

Montgomery (1999) builds a dynamic matching model with heterogeneous agents and adverse selection. While he assumes an exogenous wage rate, wage compression arises endogenously in this framework and reacts both to the composition of the unemployment pool and to the nature of labor market institutions.

Pries and Rogerson (2005) build a model to account for the fact that worker turnover in Europe is much less than in the US. While they assume workers to be homogeneous before matching, and information about match-specific productivity to be unobservable upon bargaining both for the worker and for the firm, in this paper workers are allowed to be ex-ante heterogeneous and to have private information about their type. Although Pries and Rogerson (2005) recognize the importance that screening procedures might have on the aggregate labor market equilibrium, they only investigate the role of standard labor market institutions, and do not analyze how the equilibrium changes with the precision of the screening procedures. This is the task I take up in this paper.

This work identifies two sources of within-group wage inequality. The first is random bargaining power and stems from the assumptions about the bargaining game: workers with the same observable and non-observable characteristics might be paid differently as they could have different bargaining powers upon matching. The second source is the precision of the signal, which measures how labor market institutions affect the information content of the screening procedures. It is shown that the bargaining game yields two different equilibria depending on this. The main result is that when institutions prevent firms from screening so that the precision of the signal is low, within-group wage dispersion is low, the average wage is high and the unemployment rate is high. On the contrary, when the precision of the signal is accurate, within-group wage dispersion is high, the average wage is low, and the unemployment rate is low. The model also gives the following predictions. Increasing the information content of the screening procedures from the lowerbound to the upperbound of the support of admissible values, shows a jump in within-group wage inequality, but not in the unemployment rate. This jump is the result of a shift in the equilibrium strategies of the

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game. Further increases to the right of the threshold that triggers the shift strictly decrease the unemployment rate.

In order to test the predictions of the model, using micro-data from the Historical Archive of the Bank of Italy's Survey of Household Income and Wealth, I compute the behavior of the residual wage inequality four years before and after the removal of the system of numeric placement lists, in 1991, for the workers passing through the lists. The pattern of wage inequality shows a jump of about 30% following the reforms of the placement agencies. Within this framework, the jump can be interpreted as the outcome of different equilibrium strategies in the bargaining game, produced by different labor market institutions affecting the information content of the screening procedures.

The results of the paper have also two other important implications. Concerning cross-country differences in residual wage inequality, the model can offer an alternative explanation for the findings of Flinn (2002), who shows that residual wage inequality in 1989 was considerably lower in Italy than in the US. Concerning the behavior of the unemployment rate in Italy, the model can contribute to explain the drop in the unemployment rate that followed the reforms of 1997 and 2003, which enhanced access to temporary contracts.

The paper is organized as follows. Section 1.2 documents IPS in Italy. The model is presented in Section 1.3 and it is solved numerically in Section 1.4. Section 1.5 presents the empirical evidence, and Section 1.6 concludes.

## 1.2 An interesting example of IPS: the case of Italy

Following WWII, in Italy, the economic inequalities brought about by the war and the spread of the communist ideology sharply oriented the legislator towards the target of social justice. These historical and political considerations, together with the desire to prevent labor exploitation and fraud, explain the creation of Act 264 of 1949, which was, until recent years, the cornerstone of the Italian labor market regulation.[2] In principle, Act 264 of 1949 prevented employers from hiring directly, or through private placement agencies, the workers they needed. Following international labor standards of the time, any private intermediation activity between labor supply and demand was penally forbidden. Firms were therefore obliged to resort to public placement agencies. In the case of manual workers, firms could only make a numerical request to these agencies, specifying the number of workers they needed, while the selection of the workers to be hired was up to the agencies. Job-seekers were sorted into different lists according to their professional category, the so-called *liste di*

[2] See "Temporary Work and Labour Law of the European Community and Member States", 1993, Kluwer Law and Taxation Publishers, Deventer, The Netherlands.

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*collocamento,* and within each classification they were graded according to their economic need to find a job. This grading had to take into consideration ranking criteria such as the number of children and the family income of the job-seeker. Among two equally graded job-seekers, the one that enrolled first prevailed. If a firm hired workers outside the numerical lists, it would incur in penal and administrative sanctions. Moreover, a labor contract signed between the parties in violation of Act 264 of 1949 was null and void if the local organisms of the Ministry of Labor reported it within a year from the signature. Since 1949, the scope of the act has been partially reduced by a number of additional acts (Act 300 of 1970, Act 79 of 1983, Act 863 of 1984 and Art.17 of Act 56 of 1987) implementing derogations to this rigid system and allowing in some cases for individuals to be specifically requested, rather then derived from the numerical lists. The system of numerical requests was finally abrogated by Act 223 of 1991. It is clear that as long as the firms could not hire workers on the grounds of their ability, they were *de jure* prevented from screening.

The Italian legislator went even further in preventing firms from screening, by limiting both the duration of probation periods and access to temporary contracts. According to the indicators reported by the OECD (1999), by the end of the 1990s the Italian legislation provided for the lowest probation period among all OECD countries. It is very likely that such a short time span hampered the ability of employers to collect relevant information on the productivity of the workers.[3]

As an alternative to hiring on probation for a permanent position, fixed-term contracts can be used by firms to test the ability or the motivation of a worker. In this sense temporary contracts have been considered, in a series of recent papers, as screening devices that are similar to probation. In particular, Varejao and Portugal (2003), in a study on the Portuguese labor market, find that screening workers for permanent positions is the single most important reason why firms use these types of contracts. In general, this view has been supported by strong empirical evidence.[4] The importance of fixed-term contracts as a screening device has been discovered only recently, and its implications at the macro level are not yet clear. However, the new body of empirical evidence looks like a challenge for the standard macroeconomic perspective that has always considered temporary work mainly as an instrument capable of guaranteeing separation at low or zero firing costs.[5] Unlike other

[3]Ichino and Muelheusser (2004) show that if the length of the probation period is too short, shirkers have an incentive to mimic the behavior of high type workers in order to pass the hiring test. In this case the test is uninformative on workers' characteristics and worthless as a screening device.

[4]See, among many others, Autor (2001), Autor and Houseman (2005), Boockman and Hagen (2005), Houseman (2001), Ichino, Mealli and Nannicini (2004), and Storrie (2002).

[5]Cahuc and Postel Vinay (2002) p.64, write: "It is generally concluded that the introduction of fixed duration contracts is equivalent to the reduction of firing costs and that its impact on unemployment is therefore ambiguous".

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countries in Europe, Italy had no specific regulation for temporary work and private placement agencies until the *Treu law* was approved, in 1997.[6] As a result, this reform had an enormous impact on the Italian labor institutions. More recently, with the Act 30 of 14 February 2003, better known as *Legge Biagi*, the regulation of temporary contracts introduced in 1997 was extended to further enhance labor market flexibility.

Given that the institutions above have played a key role in shaping the functioning of the Italian labor market, it is possible to consider them as marking a major institutional difference with respect to US-style labor markets. In the next section a model is presented that embeds these institutions into a standard matching framework.

## 1.3 The model

### 1.3.1 The economy

*The agents*:

The economy is characterized by a continuum of identical firms and heterogenous workers, both risk neutral and infinitely lived. The set of workers $I$ has unit measure. Each worker $i \in I$ can be either employed or unemployed and has private information over her type profile, $\lambda_i \in \Lambda$, where $\Lambda = \{l, h\}$ is the space of type profiles, and $l$ and $h$ denote low and high type workers, respectively. A fraction $x$ of workers are low types, and a fraction $1 - x$ are high types. High and low types differ in their productivity, which is denoted by $y_\lambda$, and in the opportunity cost of employment, denoted by $z_\lambda$, for $\lambda = l, h$. It is assumed that $y_l < y_h$ and $z_l \leq z_h$. It is possible to think about the productivity of high and low types as parameters capturing individual heterogeneity within groups of observationally equivalent workers, i.e., workers with the same profession, education, age, and gender. Both types search in the same labor market.

The labor market is frictional, and firms which want to fill a job post a vacancy. It is assumed that each firm can post one vacancy at most. Labor is the only factor of production, and all agents discount future income at the exogenous rate $r$. Employment relationships end exogenously at rate $q$ leaving the worker unemployed and the firm with a vacant position.

*The matching technology*:

The matching process is described by the function $M(v, u)$, which represents the aggregate flow of hires in a unit period. $v$ denotes the measure of vacancies, and $u$ denotes aggregate unemployment, which is the sum of high and low type unemployed workers, de-

[6] Act 196 of 24 june 1997, "Norme in materia di promozione dell'occupazione.", Gazzetta Ufficiale n. 154, July 4, 1997 - Supplemento No. 136.

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noted, respectively, by $u_h$ and $u_l$. Time is assumed to be discrete, but since I am only interested in characterizing the behavior of the economy at the stationary equilibrium, I omit the time subscript. The function $M(v,u)$ is assumed to be strictly increasing with respect to each of its arguments and such that $M(v,0) = M(0,u) = 0$. Lastly, it is assumed that the matching function exhibits constant returns to scale. The probability that a vacancy contacts a worker per every unit of time is:

$$\frac{M(v,u)}{v} = M\left(1, \frac{u}{v}\right) \equiv m(\theta), \qquad \theta \equiv \frac{v}{u},$$

where $\theta$ represents the "tightness" of the labor market. The probability that a worker contacts a firm is:

$$\frac{M(v,u)}{u} = \frac{v}{u}\frac{M(v,u)}{v} = \theta m(\theta),$$

and it is assumed to be equal for high and low type workers.

### 1.3.2 Workers and Firms

$E_{\lambda_i}(\omega_i)$ denotes the discounted expected income of the worker $i \in I$ of type $\lambda_i \in \Lambda$ employed at wage $\omega_i$, and $U_{\lambda_i}$ the expected discounted income of the same worker when unemployed. In each period, the employed worker $i \in I$ loses the job with exogenous probability $q$. At the stationary equilibrium, the flow value of employment for a type $\lambda$ worker satisfies the following condition, where the subscript $i$ is omitted hereafter for notational clarity:

$$rE_\lambda(\omega) = \omega + q\left[U_\lambda - E_\lambda(\omega)\right], \quad \lambda = l, h. \tag{1.1}$$

Let us denote by $\Omega^{\mathtt{w}}_\lambda$ and $\Omega^{\mathtt{f}}$ the payoff expected upon contact by a worker of type $\lambda$ and by a firm, respectively. Both of these values will be defined later as the equilibrium outcomes of the bargaining game. The flow value of unemployment for a worker of type $\lambda$ satisfies:

$$rU_\lambda = z_\lambda + \theta m(\theta)\left(\Omega^{\mathtt{w}}_\lambda - U_\lambda\right), \; \lambda = l, h. \tag{1.2}$$

$c$ denotes the cost of holding an open vacancy and looking for an employee per unit of time, and $V$ the value of having a vacancy opened. The flow value of a vacancy satisfies the following Bellman equation:

$$rV = -c + m(\theta)\,\Omega^{\mathtt{f}}.$$

Using the free entry condition, $V = 0$, the expression above can be rewritten as follows:

$$c = m(\theta)\,\Omega^{\mathtt{f}}, \tag{1.3}$$

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which implies that the expected profits of an entrant firm must equal the expected costs of keeping a vacancy open.

The flow value for the firm of having a worker of type $\lambda$ employed at wage $\omega$ is denoted by $J_\lambda(\omega)$, and satisfies the following equation:

$$rJ_\lambda(\omega) = y_\lambda - \omega - qJ_\lambda(\omega). \tag{1.4}$$

### 1.3.3 Wage bargaining

It is assumed that wage bargaining is decentralized, and that workers and firms are too small to influence the market wage rate. Wages are set once and for all, and they cannot be conditional on future performance. It is also assumed that firms do not directly observe the productivity of the workers upon matching, but that they know the composition of the unemployment pool and can observe the realization of a signal $\sigma \in \Sigma$, where $\Sigma = \{0, 1\}$ is the set of signals. It is possible to interpret the signal as the outcome of a screening test which workers must take upon contact. We can think about job interviews, probation periods or temporary contracts as examples of screening tests. When $\sigma = 1$, the worker passes the test, while if $\sigma = 0$ the worker fails. $\pi(\sigma|\lambda)$ denotes the probability that a worker of type $\lambda$ sends the signal $\sigma$. The conditional probability $\pi(\sigma|\lambda)$, for $\sigma \in \Sigma$ and $\lambda \in \Lambda$, can be expressed as a simple function of the parameter $s \in [1/2, 1]$, which represents the precision of the signal:

$$\begin{aligned} \pi(1|h) &= \pi(0|l) = s \\ \pi(0|h) &= \pi(1|l) = 1 - s. \end{aligned} \tag{1.5}$$

The parameter $s$ is the probability that the test reveals the true type of a worker. When $s = 1/2$, the signal is completely uninformative, while if $s = 1$ the signal reveals perfectly the type of worker. More in general, the higher the value of $s$, the more informative is the signal. In this framework the exogenous parameter $s$ captures the way institutions affect the predictability of worker types; IPS are associated with relatively low values of $s$. More in particular, the benchmark case of $s = 1/2$ can be considered as a quite close characterization of the Italian labor market for manual workers in the 1980s, when the system of numerical placement lists prevented *de jure* any screening activity. In this framework, whether the test is useful as a screening device ultimately depends only on labor market institutions.

The timing of the action is the following: wages are bargained at the beginning of the period when a worker and a firm are matched. At the end of the period, production takes place and wages are paid. If the firm makes negative profits the worker is fired and the match is destroyed, while if profits are positive the firm decides to keep the worker.

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The bargaining game is the following: Nature moves first, and decides whether the worker with probability $\gamma$ or the firm with probability $1-\gamma$, makes a take-it or leave-it offer. An interesting feature of the model resulting from this bargaining protocol is that workers with the same productivity may receive different wages at equilibrium, since they might be given different bargaining powers upon matching. The subgame in which the firm makes the offer is denoted by $\Gamma^{\mathtt{f}}$, and the subgame in which the worker makes the offer is denoted by $\Gamma^{\mathtt{w}}$. The next subsections characterize the equilibria of the two subgames restricting attention to equilibria in pure strategies. The extensive form representation of the subgames and all the proofs of the propositions that follow are presented in the Appendix.

#### 1.3.3.1 The worker makes the take-it or leave-it offer

The structure of this subgame is as follows. First, the type of worker matched is selected with endogenous probabilities $p(\lambda) = u_\lambda/u$, for $\lambda = l, h$. Second, Nature decides whether the signal sent by the worker is 0 or 1, with probabilities given by (1.5). Third, the worker makes the offer, and fourth, the firm *accepts* or *rejects*. Finally, when production takes place, the firm decides whether to $fire$ or $keep$ the worker.

*Strategies:*

I denote by $\omega^{\mathtt{w}} \in \mathbb{R}^+$ a wage offer made by the worker and chosen from the set $\mathbb{R}^+$. A pure strategy for the worker is a map $\omega^{\mathtt{w}}_\lambda : \Lambda \to \mathbb{R}^+$ from her type space $\Lambda$ to her wage offer space $\mathbb{R}^+$. An equilibrium wage offer for the worker is denoted by $\hat{\omega}^{\mathtt{w}}_\lambda$.

A pure strategy for the firm is a pair of decision rules mapping from its information set to the available actions $a \in A$ and $b \in B$ chosen from the set $A = \{accept,\ reject\}$ and $B = \{fire, keep\}$ at the relevant information sets. The decision rule $\bar{a} : \mathbb{R}^+ \to A$ is a mapping from the worker's wage offer space $\mathbb{R}^+$ to the firm's action space $A$. The decision rule $\bar{b} : \{\mathbb{R}^+, \Lambda\} \to B$ is a mapping from the worker's wage offer space $\mathbb{R}^+$ and type space $\Lambda$ to the firm's action space $B$.

*Payoffs*:

If the firm *rejects* the offer, the worker gets $U$ and the firm gets zero. If the offer of a worker of type $\lambda$ is accepted and the worker is not fired at the end of the period, the worker gets $E_\lambda(\omega^{\mathtt{w}})$ and the firm gets $J_\lambda(\omega^{\mathtt{w}})$. If the worker is fired, the firm gets $(y_\lambda - \omega^{\mathtt{w}})/(1+r)$ and the worker gets $(\omega^{\mathtt{w}} + U_\lambda)/(1+r)$.

*Beliefs*:

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Let $\mu(\lambda|\omega^{\mathtt{w}})$ denote the belief for the firm that the wage offer $\omega^{\mathtt{w}}$ is sent by a worker of type $\lambda$. The system of beliefs $\mu$ is derived from the strategy profile $\omega_{\lambda}^{\mathtt{w}}$ through Bayes' rule whenever possible.

ASSUMPTION 1: the firm decides to *accept* the wage offer and to *keep* the worker if indifferent.

ASSUMPTION 2:

$$E_l(y_l) \geq (y_h + U_l)/(1+r).$$

If Assumption 2 holds, a low type worker prefers to earn $y_l$ until job destruction occurs exogenously rather than earn $y_h$ for one period only and be successively fired. In section 1.4, I assign reasonable parameter values to the model and check that this assumption is always satisfied. As I prove formally in the next Proposition, the assumption that the firm can fire workers if profits are negative acts as a credible threat and induces workers to separate their wage offers at equilibrium. As a consequence, the equilibrium strategy for the wage offers of high and low type workers is separating, independently of the precision of the signal $s$.[7]

**Proposition 1.1** *Suppose Assumption 1 and Assumption 2 hold. Then the wage offers* $\hat{\omega}_{\lambda}^{\mathtt{w}} = y_{\lambda}$ *together with the beliefs* $\mu(\lambda|y_{\lambda}) = 1$ *for* $\lambda = l, h$*, the decisions of the firm to accept both offers and to keep the worker once productivity is revealed is the unique Perfect Bayesian (Nash) equilibrium satisfying forward induction in subgame* $\Gamma^{\mathtt{w}}$.

#### 1.3.3.2 The firm makes the take-it or leave-it offer

This subgame has the following structure. First, the probabilities $p(\lambda)$ decide the type of worker that is hired. Second, Nature chooses the signal, with probabilities given by (1.5). Third, the firm makes the offer, and fourth, the worker *accepts* or *rejects*. Finally, at the end of the period, the firm decides whether to $fire$ or $keep$ the worker.

*Strategies:*

I denote by $\omega^{\mathtt{f}} \in \mathbb{R}^{+}$ a wage offer made by the firm and chosen from the set $\mathbb{R}^{+}$. A pure strategy for the firm is a map $\omega^{\mathtt{f}}(\sigma) : \Sigma \to \mathbb{R}^{+}$ from the signal space $\Sigma$ to the firm's wage offer space $\mathbb{R}^{+}$ together with a decision rule $\bar{b} : \{\mathbb{R}^{+}, \Lambda\} \to B$ mapping from the firm's wage

[7] The condition written in Assumption 2 would not hold if firms were unable to fire workers, or if productivity could only be discovered after a long period of time. Relaxing this assumption would only increase the complexity of the model without changing the qualitative results.

offer space $\mathbb{R}^+$ and the worker's type space $\Lambda$ to the firm's action space $B = \{fire, keep\}$. An equilibrium wage offer for the firm is denoted by $\hat{\omega}^{\mathtt{f}}(\sigma)$.

A pure strategy for the worker is a decision rule $\bar{a} : \{\mathbb{R}^+, \Lambda\} \rightarrow A$ mapping from the firm's wage offer space $\mathbb{R}^+$ and the worker's type space $\Lambda$ to the worker's action space $A = \{accept, reject\}$.

*Payoffs*:

Payoffs follow the same structure as in the subgame $\Gamma^{\mathtt{w}}$.

*Beliefs*:

The firm uses Bayes' rule to update its prior beliefs, which are given by the matching probabilities. The firm's posterior beliefs, conditional on the observation of the signal are:

$$\mu(\lambda|\sigma) = \frac{p(\lambda)\pi(\sigma|\lambda)}{\sum\limits_{\lambda'=l,h} p(\lambda')\pi(\sigma|\lambda')}. \tag{1.6}$$

ASSUMPTION 3: workers *accept* the wage offer if indifferent.

ASSUMPTION 4:

$$y_l \geq rU_h.$$

ASSUMPTION 5:

$$U_h > U_l.$$

Assumption 4 imposes a restriction on the choice of the parameters $y_h$ and $y_l$. Since $rU_h$ strictly increases with $y_h$ at equilibrium, Assumption 4 imposes an upper bound on the difference between $y_h$ and $y_l$. This assumption ensures that the surplus created by a match be positive when the wage $\hat{\omega}^{\mathtt{f}}(\sigma) = rU_h$ is offered to a low type worker. If Assumption 4 holds, the firm's option to fire workers is never exercised at equilibrium, and therefore a match can only break down for exogenous reasons.

Assumption 5 does not impose any parametric restriction. When the model is solved numerically, I check that this assumption is satisfied for all the parameter values that support an equilibrium solution.

The economic intuition for the bargaining problem of the firm is the following. When information is perfect, i.e., $s = 1$, the outcome of the test perfectly reveals the type of a worker. If this is the case, when the firm makes the offer, a worker of type $\lambda$ gets $rU_\lambda$, which is the lowest wage she is willing to accept. When instead information is incomplete, the outcome of the screening test is no longer perfectly correlated with with the type of the

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worker. Under this scenario the firm has to compare expected costs and benefits associated with each offer. If the low wage $rU_l$ is offered, the firm enjoys high future profits $J_l(rU_l)$ if the type of worker receiving the offer is low, but it forgoes any profit if the type of the worker turns out to be high. This follows since it is optimal for a high type worker to reject any offer lower than $rU_h$. If instead the high wage $rU_h$ is offered, the firm enjoys lower future profits $J_l(rU_h)$ if the worker is low, but it still makes positive profits $J_h(rU_h)$ if the worker is high. To put it differently, the firm trades-off insurance against the breakdown of wage negotiations with high type workers versus higher future profits with low type workers. Conditional on the observation of the signal, it will be therefore optimal for the firm to offer $rU_h$ whenever the following condition holds:

$$\mu(h|\sigma)J_h(rU_h) \geq \mu(l|\sigma)\left[J_l(rU_l) - J_l(rU_h)\right], \tag{1.7}$$

where the l.h.s. represents the expected gains from insurance and the r.h.s. represents the opportunity cost of offering $rU_h$. Whether condition (1.7) holds or not depends, in general, on the distribution of worker types in the unemployment pool, on the outcome of the test, and on the precision of the signal.

**Proposition 1.2** *Suppose Assumption 1, Assumption 3, Assumption 4 and Assumption 5 hold. Then the wage offer* $\hat{\omega}^{\mathtt{f}}(\sigma) = rU_h$*, together with the conditional posterior beliefs system in (1.6), the decision to accept for both low and high type workers, and the firm's decision to keep the worker, is the unique Perfect Bayesian (Nash) equilibrium of the subgame* $\Gamma^{\mathtt{f}}$ *for any* $\sigma \in \Sigma$ *such that condition (1.7) holds.*

**Proposition 1.3** *Suppose Assumption 3, Assumption 4 and Assumption 5 hold. Then the wage offer* $\hat{\omega}^{\mathtt{f}}(\sigma) = rU_l$*, together with the conditional posterior beliefs system in (1.6), the low type worker's decision to accept, the high type worker's decision to reject, and the firm's decision to keep the worker, is the unique Perfect Bayesian (Nash) equilibrium of the subgame* $\Gamma^{\mathtt{f}}$ *for any* $\sigma \in \Sigma$ *such that condition (1.7) fails to hold.*

#### 1.3.3.3 The solutions of the bargaining game as a function of $s$

This section investigates how the equilibria of the whole game change with the quality of information embodied in the signal. Since the equilibrium of the subgame $\Gamma^{\mathtt{w}}$ is independent of $s$, a change in the equilibrium of the whole bargaining protocol can only follow from a change in the equilibrium of the subgame $\Gamma^{\mathtt{f}}$. I contrast the case in which the signal is uninformative with the case in which the signal is perfectly informative and I show that the

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bargaining game exhibits different equilibria. These two equilibria are characterized with the payoffs expected by the players upon engaging in the bargaining game and with the flows in and out of the unemployment pool. Section 1.4 then shows numerically that for all the reasonable parameter values supporting an equilibrium solution there exists a unique threshold value of $s$, denoted by $s^*$, such that the bargaining game exhibits two different sets of equilibrium strategies, one for $s \in [1/2, s^*]$, and another for $s \in (s^*, 1]$.

**CASE 1** The signal is uninformative: $s = 1/2$.

By (1.5) and (1.6), if $s = 1/2$, $\mu(\lambda|\sigma) = p(\lambda)$ for $\lambda = l, h$. When the signal is uninformative the firm's beliefs are given by the matching probabilities and are therefore independent of the realization of $\sigma$. Consequently, also condition (1.7) must be independent of $\sigma$. The next section shows that condition (1.7) is always satisfied for $s = 1/2$ when reasonable parameter values are assigned to the model. The equilibrium wage offer of the firm is therefore pooling when $s = 1/2$, with the firm offering $\hat{\omega}^{\mathbf{f}}(\sigma) = rU_h$ for both $\sigma = 0, 1$.

**Proposition 1.4** *Suppose condition (1.7) holds for both $\sigma = 0, 1$. Then a matched worker is of type $\lambda$ with probability:*

$$p(\lambda) = x_\lambda.$$

When the signal is uninformative both types of workers enter and exit from the unemployment pool at the same rates. This has two implications. The first is that the relative measure of type $\lambda$ workers in the unemployment pool is equal to their relative measure in the labor force, $x_\lambda$. The second is that the equilibrium unemployment rate is the same for high and low type workers.

We are now ready to characterize the expected payoffs for workers and firms when $\hat{\omega}^{\mathbf{f}}(\sigma) = rU_h$ is offered to a worker independently of the outcome of the test, $\sigma$.

**Proposition 1.5** *Suppose condition (1.7) holds for both $\sigma = 0, 1$. Then a worker of type $\lambda$ expects a payoff*

$$\Omega_\lambda^{\mathbf{w}} = [\gamma y_\lambda + (1-\gamma) rU_h + qU_\lambda] / (r+q)$$

*upon engaging in the bargaining game, and the firm expects*

$$\Omega^{\mathbf{f}} = (1-\gamma)[(1-x) y_h + x y_l - rU_h] / (r+q).$$

In the next section we will see that condition (1.7) holds in the interval of $s \in [1/2, s^*]$ for both $\sigma = 0, 1$. The equilibrium of the labor market is therefore described by equations (1.1) to (1.4) together with the equations in Proposition 5 whenever $s \in [1/2, s^*]$.

**CASE 2** The signal is perfectly informative: $s = 1$.

It is easy to show that when $s = 1$ condition (1.7) holds for $\sigma = 1$ but does not hold for $\sigma = 0$. Substituting (1.4) into (1.7), condition (1.7) can be rewritten as follows:

$$\mu(h|\sigma)(y_h - rU_h) - \mu(l|\sigma)(rU_h - rU_l) \geq 0 \quad for\ \sigma \in \Sigma.$$

By (1.6) and (1.5) $\mu(h|1) = \mu(l|0) = 1$ and $\mu(l|1) = \mu(h|0) = 0$ for $s = 1$. Then (1.7) is satisfied for $\sigma = 1$ since $y_h > y_l$, and $y_l \geq rU_h$ by Assumption 4. On the contrary, when $\sigma = 0$ condition (1.7) fails to hold by Assumption 5. The equilibrium wage offer of the firm is therefore separating when $s = 1$, with the firm offering $\hat{\omega}^{\mathtt{f}}(1) = rU_h$ and $\hat{\omega}^{\mathtt{f}}(0) = rU_l$.

**Proposition 1.6** *Suppose condition (1.7) holds for $\sigma = 1$ but does not hold for $\sigma = 0$. Then the probability that a low and a high type worker contacts a firm is $p(\lambda) = u_\lambda/u$ for $\lambda = l, h$, where*

$$u_l = \frac{qx_l}{q + \theta m(\theta)}$$
$$u_h = \frac{qx_h}{q + \theta m(\theta)\left[\gamma + (1-\gamma)s\right]}.$$

By Proposition 6 it is possible to note that when $s = 1$ the unemployment rate $u_\lambda/x_\lambda$ is identical for both high and low type workers. For every value of $s \in (s^*, 1)$ such that condition (1.7) holds only for $\sigma = 1$, the unemployment rate will be higher for high than for low type workers. When the signal is relatively informative high type workers who send the bad signal *reject* the wage offer. Therefore, they search more than low type workers, on average, who *accept* any wage offer at equilibrium independently of the outcome of the screening test.

We can now characterize the expected payoffs for workers and firms when the wage offer is conditional to the outcome of the screening test, so that a worker gets $rU_h$ upon passing the test, and $rU_l$ otherwise.

**Proposition 1.7** *Suppose condition (1.7) holds for $\sigma = 1$ but does not hold for $\sigma = 0$. Then a worker of type $h$ expects a payoff*

$$\Omega_h^{\mathtt{w}} = \left[\gamma y_h + (1-\gamma)\, rU_h + qU_h\right]/(r+q)$$

*upon engaging in the bargaining game, a worker of type $l$ expects a payoff*

$$\Omega_l^{\mathtt{w}} = \left[\gamma y_l + s\,(1-\gamma)\, rU_l + (1-s)\,(1-\gamma)\, rU_h + qU_l\right]/(r+q)$$

*and the firm expects*

$$\Omega^{\mathtt{f}} = (1-\gamma)\left[p(h)s(y_h - rU_h) + p(l)s(y_l - rU_l) + p(l)(1-s)(y_l - rU_h)\right]/(r+q).$$

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By Proposition 7 it is possible to note that in the special case in which $s = 1$, when information is perfect the average wage bargained by a worker of type $\lambda = l, h$, $\gamma y_\lambda + (1-\gamma) rU_\lambda$, is the outcome of the generalized Nash criterion. When the model is solved numerically in the next Section, we will see that condition (1.7) holds for $\sigma = 1$ but does not hold for $\sigma = 0$ in the interval of $s \in (s^*, 1]$. The equilibrium of the labor market is therefore described by equations (1.1) to (1.4) together with the equations in Proposition 6 and Proposition 7 whenever $s \in (s^*, 1]$.

## 1.4 Numerical analysis

In this section numerical values are assigned to the model in order to analyze how the equilibrium of the labor market is affected by a change in labor market institutions. The parameters used for the exercise are reported in the table below.

| $y_h$ | $y_l$ | $x$ | $r$ | $c$ | $\gamma$ | $q$ | $z_\lambda$ | $\alpha$ |
|---|---|---|---|---|---|---|---|---|
| .53 | .47 | .5 | .025 | .3 | .5 | .1 | $.4y_\lambda$ | .5 |

Table 1.1: Benchmark parameter values

One unit of time in the model equals one quarter. Average productivity is normalized to .5, and both types of workers are assumed to be equally distributed, so that $x = .5$. The spread between high and low productivity is set arbitrarily, without any effect on qualitative considerations. In line with the vast majority of studies, the matching process is represented by a Cobb-Douglas function, written $M(v, u) = u^\alpha v^{1-\alpha}$. The elasticity of the matching function with respect to unemployment is assumed to be $\alpha = .5$, as in Mortensen and Pissarides (1999). The bargaining power of the workers is selected to respect the Hosios condition, and so $\gamma = .5$. Following Shimer (2005), the income value of an unemployed worker equals 40% of her productivity. Quarterly job destruction is set to $q = .10$ as in Shimer (2005), and the cost of a vacancy is $c = .3$. The quarterly interest rate is set to .025 as in Italy during the late '80s.

Numerical solutions of the model show that the game exhibits two sets of equilibrium strategies satisfying assumptions 1 to 5. The equilibrium of the subgame $\Gamma^{\mathbf{f}}$ is pooling when the precision of the signal is low and $s \in [1/2, s^*]$, with the firm offering $\hat{\omega}^{\mathbf{f}}(\sigma) = rU_h$ for both $\sigma = 0, 1$; the equilibrium is separating when the precision of the signal is high and $s \in (s^*, 1]$, with the firm offering $rU_h$ when $\sigma = 1$, and $rU_l$ when $\sigma = 0$. The intuition for the result is the following: so long as the screening device is not sufficiently reliable, i.e., $s$ is below the threshold, it is not profitable for the firm to condition the wage offer to the outcome of the


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test. If a firm offers a high type worker a wage equal to the outside option of a low type worker, the match breaks down, and its surplus is wasted. Therefore, the firm will not offer $rU_l$ unless it perceives that the probability of facing a low type worker is sufficiently high. This can only happen if the worker fails the test, and if the test is sufficiently informative about the type of the worker, that is, if $s$ is high enough. The equilibrium of the subgame $\Gamma^w$ is instead independent of $s$, so that a worker of type $\lambda$ is paid $y_\lambda$ whenever she makes the offer.

The equilibrium of the labor market in terms of wages, unemployment rates and wage dispersion is reported in Figure 1 in the Appendix for the parameter values in Table 1 and for $s \in [1/2, 1]$. For every value of $s$, I computed the standard deviation of wages as an index of wage dispersion. Given the benchmark parametrization, all the parameter values were changed one at a time as a robustness check for the qualitative results. The results proved robust to all the changes which support an equilibrium solution and I summarize them below.

1. When the precision of the signal is relatively low so that information is noisy, wages are more compressed and unemployment rates are high; when the precision of the signal is relatively high, information is accurate, wages are more dispersed, and unemployment rates are low. A trade-off emerges between unemployment and wage inequality, which is produced only by the quality of information.

2. When the quality of information embedded in the signal is very low, small variations in $s$ have no impact on the labor market equilibrium. Given the baseline parametrization, firms condition their wage offer to the outcome of the test provided that the signal reveals the true type of the worker with a probability higher than 74%. At any lower degree of precision, the signal is considered as uninformative.

3. The average wage drops at the threshold $s^*$ and strictly decreases with the precision of the signal in the interval of $s \in (s^*, 1]$. For values of $s$ below the threshold, both types of workers receive $rU_h$ when the firm makes the offer. To the right of the threshold, low type workers receive a wage offer equal to $rU_h$ only if they pass the test, and get $rU_l$ otherwise. Since $U_l < U_h$, the shift in the equilibrium strategies played by the firm explains why the average wage drops at the threshold. This effect largely dominates the following counteracting effect: while all wage negotiations succeed for $s \in [1/2, s^*]$, to the right of $s^*$ instead, negotiations fail whenever the firm offers $rU_l$ to a high type worker who failed the test. Therefore, at the threshold the fraction of high type employed workers who receive $y_h$ is higher than to the left of $s^*$. This effect

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tends to increase the average wage, although its quantitative importance is relatively minor. To the right of the threshold, both the fraction of low type workers receiving $rU_l$, and the fraction of high type workers receiving $rU_h$ increase with the precision of the signal. Both effects therefore contribute to lower the average wage to the right of the threshold.

4. The value of search for a low type worker drops at $s^*$ and its behavior is ambiguous to the right of $s^*$. As the equilibrium strategies played by the firm change at the threshold, low type workers expect to receive lower wages upon contact, and their value of search drops. Further increases in the precision of the signal decrease the expected wage even more, but increase the tightness of the labor market and the exit rate from unemployment so that the two effects offset each other. When the equilibrium strategies played by the firm change at the threshold, high type workers expect a higher rate of break-down in the wage negotiations but the same value of the match, since they are indifferent between working at the wage $rU_h$ or searching in the labor market. The value of search for a high type worker strictly increases to the right of $s^*$ since the exit rate from unemployment strictly increases with $s$.

5. At the threshold $s^*$ it is possible to observe a strong discrete change both in wage dispersion and in the average wage, but not in the unemployment rate. While wage dispersion jumps and the average wage drops at the threshold as a direct consequence of the change in the equilibrium strategies played by the firm, the behavior of the unemployment rate at $s^*$ is ambiguous since it is driven by two offsetting forces. The decrease in the average wage tends to increase the value of opening a vacancy, but the increase in the failing rate of the wage negotiations tends to decrease it. Further increases in $s$, instead, decrease both the average wage and the rate of break-down of the wage negotiations with high type workers. Therefore, the unemployment rate decreases without ambiguity at the right of $s^*$, although the average productivity of the workers in the unemployment pool decreases with $s$, since high type workers exit unemployment at a higher rate. To the right of the threshold the behavior of wage dispersion is in general ambiguous, and depends on the parametric specification of the model. As the precision of the signal increases, the increase in spread between the wage offers $rU_h$ and $rU_l$ tends to increase wage dispersion. On the other hand, as the rate of break-down in the wage negotiations with high type workers decreases with $s$, a lower fraction of high type workers is employed at the wage $y_h$, and a higher fraction is employed at the wage $rU_h$. This effect tends to decrease wage dispersion. As a result,

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the index of wage dispersion is roughly constant to the right of $s^*$.

6. When the precision of the signal is relatively high, $s \in (s^*, 1)$, the unemployment rate is higher for high type than for low type unemployed workers. Intuitively, when the test is relatively informative on the nature of worker types, high type workers who fail the screening test prefer to reject the low wage offer and look for a new wage offer. For both types of workers the unemployment rates are strictly decreasing with the precision of the signal since an increase in the efficiency of the bargaining process increases the profits expected upon entry and the matching probability. The unemployment rate is decreasing faster for high type workers since an increase in $s$ decreases their failing rate in the screening test and increases their rate of exit from the unemployment pool. In the particular case in which $s = 1$, information is perfect, and both types of workers flow out of the unemployment pool at the same rate.

The next section presents some empirical evidence which is consistent with the predictions of the model.

## 1.5 Empirical Evidence

The main result of the model is that when individual heterogeneity is no longer predictable at the time of bargaining, the unemployment rate is higher and wage compression arises endogenously within groups of observationally equivalent workers. Since IPS clearly characterized the Italian labor market with respect to the US labor market, the model can then offer an alternative explanation about why within-group wage inequality was much lower in Italy than in the US, as measured by Flinn (2002), using sample data of 1989.

Simulations of the model for the values of $s \in [1/2, 1]$ show that increasing the precision of the signal, from the lowerbound to the upperbound of the support, leads to a jump in wage dispersion. Given that this jump reflects the increased ability for the firms to extract information on the unobservable characteristics of the workers, what should be observed in the data is a jump in residual wage inequality following a major increase in the precision of signal extraction, provided that the initial condition for $s$ is "low enough". A natural candidate for this type of reform is the abolition of the system of numerical placement lists, as seen in 1991.

The micro-data from the Historical Archive of the Bank of Italy's Survey of Household Income and Wealth (SHIW) that allows for the computation of hourly wages is available only after 1987. Survey data are collected every two years from 1987 to 1995. Since the next survey available after 1995 is 1998, which is after the new wave of reforms that took place

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in 1997, I restrict attention to the symmetric time interval of four years before and after the reform of 1991, the period 1987-1995.

I consider only full-year manual workers. Hourly wages are computed using information on gross yearly income and average weekly hours worked, and assuming 48 working weeks per year. Real hourly wages are then obtained by deflating the nominal hourly wages with the base 1991 CPI. I further restrict the sample to the category of workers who are less than 30 years of age, for whom the likelihood of observing new entry-level bargained wages is higher. The sample consists of approximately 4000 observations. Real hourly wages are then regressed on a set of observable characteristics such as age, education, gender and regional area, using dummy variables also for part-time jobs and survey years. The standard deviation of the residuals, reported in Figure 2 in the Appendix by year, shows a jump of about 30% following the removal of the numerical placement system in 1991. These findings seem consistent with the predictions of the model.

However, other explanations could potentially be compatible with this behavior of residual wage inequality, such as the abolition in the early 1990s of the *scala mobile*, a wage indexation mechanism granting the same absolute wage increase to all employees as prices rose. It is generally believed that starting from the 1970s, the *scala mobile* played an important role in shaping the behavior of wage inequality in Italy. Yet, the *scala mobile* hypothesis seems hard to reconcile with the jump in Figure 2 since, as shown in a study by Manacorda (2004), already by the mid-1980s this indexation mechanism had ceased to produce any equalizing effect.

As described in section 1.2, the reforms of 1997 and 2003 were important in favoring further access to screening devices by regulating temporary contracts. The model predicts that these reforms would be followed by a decrease in the unemployment rate. The pattern of the data is also consistent with these predictions: the unemployment rate started to decrease in 1997, from 11.3%, to reach 6.8% in 2006. Furthermore, the unemployment rate steadily decreased in this period, even during downturns in economic activity.

## 1.6 Conclusions

The microeconomic literature in personnel economics has thoroughly investigated the importance of screening procedures such as job interviews, probationary periods and temporary contracts in the firms' hiring policies. Yet, labor market institutions can affect these hiring policies by either preventing firms from testing the workers or by making the test ineffective as a screening device. In the case of Italy, these institutions played a central role in the functioning of the labor market. This paper embeds such institutions into a standard

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matching model to analyze their macroeconomic consequences. The main finding is that by preventing firms from screening workers, these institutions can reduce inequality among observationally equivalent workers, at the cost of higher unemployment rates. The model therefore offers an explanation for the well-documented trade-off between unemployment and wage inequality. It also identifies, in the institutions affecting the information content of the screening procedures, a determinant of within-group wage inequality.

These results were obtained under standard assumptions on the bargaining protocol. Following the literature on bargaining with asymmetric information, it was assumed that either the worker or the firm makes a take-it or leave-it offer. Beyond ensuring tractability, this assumption allows for the recovery of the Nash bargaining solution for the limit case of perfect information. It is possible, though, that alternative bargaining protocols might induce truth-telling equilibrium strategies for the workers, which can undue the perverse effects of asymmetric information. Pursuing mechanism designs in this framework is beyond the scope of this paper and is left for future research.

This paper takes a first step towards understanding the macroeconomic impact of labor market institutions influencing firms' screening activity. Such institutions cover a wide range of rules and regulations governing disparate juridical issues such as probation periods, the space for possible contractual arrangements or the functioning of employment placement agencies. All these institutions were condensed through the modeling strategy into a single parameter representing the precision of the screening procedures. Although this allows for the development of a simple framework to derive general conclusions, more specific modeling of institutions might help uncover, in future studies, new mechanisms through which information affects the labor market equilibrium.

## 1.7 Appendix

**Proof of Proposition 1.** Let's prove first that the candidate equilibrium defined in Proposition 1 is a PBE. Consider the beliefs $\mu(\lambda|y_\lambda) = 1$ for $\lambda = l, h$. Given these beliefs, the firm *accepts* the offers $\omega_\lambda^{\mathtt{w}} = y_\lambda$ by Assumption 1. A high type worker would not offer more than $y_h$ since the firm would *reject* whatever the beliefs off equilibrium path. The same worker would not offer less since $E_\lambda(\omega^{\mathtt{w}})$ is increasing in $\omega^{\mathtt{w}}$. When making the offer a low type worker knows that the best response of the firm is to *fire* her if profits are negative. Then, she would not offer more than $y_l$ by Assumption 2, whatever the beliefs off equilibrium path. Obviously, the low type worker would not offer less than $y_l$. Given this strategy profile, the firm *keeps* the workers by Assumption 1. Given the beliefs, the separating wage offer $\hat{\omega}_\lambda^{\mathtt{w}} = y_\lambda$ is therefore sequentially rational, and the beliefs are consistent with this equilibrium strategy profile. The candidate equilibrium is therefore a PBE. To show that this equilibrium is unique, it is possible to concentrate on the set of offers $\omega^{\mathtt{w}} \in [y_l, y_h]$ . Any offer below this range would not be sequentially rational since the offer $y_l$ would be accepted by the firm independently of the beliefs. Similarly, any offer above the range would be rejected by the firm independently of the beliefs. Within this range, I will first show that no pooling nor separating PBE can exist in which a low type worker offers $\omega_l^{\mathtt{w}} \neq y_l$. Then I will show that the pooling offer $\omega_\lambda^{\mathtt{w}} = y_l$ and any separating offer in which $\omega_l^{\mathtt{w}} = y_l$ and $y_l < \omega_h^{\mathtt{w}} < y_h$ can only be sustained as a PBE with beliefs off equilibrium path which violate forward induction. The first set of strategies are not sequentially rational since, whatever the off equilibrium path beliefs associated with the offer $\omega^{\mathtt{w}} = y_l$ the firm would *accept*, and by Assumption 2 a low type worker would have an incentive to deviate and offer $\omega_l^{\mathtt{w}} = y_l$. A PBE for the second set of strategies could exist only if the beliefs associated with all offers $\omega^{\mathtt{w}} : \hat{\omega}_h^{\mathtt{w}} < \omega^{\mathtt{w}} \leq y_h$ which lie off the equilibrium path, are such that the firm optimally *rejects* them. This can only happen if the belief that the low type makes this offer is positive and "large enough". However, while a high type worker would be better off by having such an offer accepted, a low type worker would be worse off by Assumption 2. Hence, if the firm receives such an out of the equilibrium offer, it must be sent by a high type worker. By forward induction, the firm can only assign probability 1 that a high type worker sends any offer $\omega^{\mathtt{w}} : \hat{\omega}_h^{\mathtt{w}} < \omega^{\mathtt{w}} \leq y_h$. Therefore, it must be optimal for the firm to *accept* any of these offers, and a high type worker would always have an incentive to deviate and offer $y_h$.The separating offer $\hat{\omega}_\lambda^{\mathtt{w}} = y_\lambda$ is therefore the unique PBE satisfying forward induction. ■

**Proof of Proposition 2.** By backward induction. When making the offer, the firm knows that for a worker of type $\lambda = l, h$ the best response is to *accept* any wage offer $\omega^{\mathtt{f}} : E_\lambda(\omega^{\mathtt{f}}) \geq U_\lambda$, where the equality sign follows from Assumption 3. Then, by eq.(1.1) a worker of type $\lambda$ *accepts* any offer $\omega^{\mathtt{f}} \geq rU_\lambda$ and otherwise *rejects*. By Assumption 5, while both types of workers *accept* the offer $\omega^{\mathtt{f}} = rU_h$, only low type workers *accept* the offer $\omega^{\mathtt{f}} = rU_l$. Since the value of a job filled with a worker of type $\lambda$, $J_\lambda$ in eq.(1.4), strictly decreases with the wage, given the best response of the worker, the firm would never offer any $\omega^{\mathtt{f}}(\sigma) > rU_h$. By Assumptions 4 the firm knows that whatever is the type of worker receiving an offer $\omega^{\mathtt{f}}(\sigma) \leq rU_h$, profits will be non-negative and the firm will *keep* the worker by Assumption 1. If condition (1.7) holds for a given realization of $\sigma$, the profits expected from the offer $rU_h$, which both types of workers *accept*, are higher than the profits expected from the offer $rU_l$, which only low type workers *accept*. Consequently, it must be that the profits expected from $\omega^{\mathtt{f}}(\sigma) = rU_h$ are higher than the profits expected from any $\omega^{\mathtt{f}}(\sigma) < rU_h$. If this is the case, $\hat{\omega}^{\mathtt{f}}(\sigma) = rU_h$ is the unique optimal wage offer for the firm

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given the best response of the worker and the system of beliefs in eq.(1.6), for each value of $\sigma$ that satisfies condition (1.7). This wage offer together with the Bayesian system of beliefs, the decision of the workers to *accept* the offer, and the decision of the firm to *keep* the worker therefore define the unique PBE of this subgame provided that condition (1.7) is satisfied. ■

**Proof of Proposition 3.** The Proof follows the same steps of the previous one. By Assumption 3 and eq.(1.1) the best response for a worker of type $\lambda = l, h$ is to *accept* any wage offer $\omega^{\mathtt{f}} \geq rU_\lambda$ and otherwise *reject*. If condition (1.7) fails to hold, the profits expected from the offer $rU_h$ which both types of workers *accept*, is lower than the profits expected from the offer $rU_l$, which only low type workers *accept*. Since $J_\lambda(\omega)$ is strictly decreasing in the bargained wage it follows that, for a given realization of $\sigma$, the wage offer $\hat{\omega}^{\mathtt{f}}(\sigma) = rU_l$ is optimal and unique given the best response of the workers and the Bayesian updating of beliefs. By Assumption 4 and Assumption 5 whatever is the type of worker receiving the equilibrium offer $rU_l$, profits are strictly positive, and it is optimal for the firm to *keep* the worker. ■

**Proof of Proposition 4.** If condition (1.7) holds for both $\sigma = 0, 1$, by Proposition 1 and Proposition 2 all agents *accept* the wage offer at equilibrium. Both types of workers therefore exit unemployment at rate $\theta m(\theta)$. At the stationary state, when job creation equals job destruction, $q(x_\lambda - u_\lambda) = \theta m(\theta) u_\lambda$. From the former, $u_\lambda = qx_\lambda / [q + \theta m(\theta)]$. Since the probability that a matched worker is of type $\lambda$ equals $p(\lambda) = u_\lambda / u$, substituting the expression for $u_\lambda$ yields $p(\lambda) = x_\lambda$. ■

**Proof of Proposition 5.** By Proposition 2 the equilibrium wage offer of the subgame $\Gamma^{\mathtt{f}}$ is $\hat{\omega}^{\mathtt{f}}(\sigma) = rU_h$ for both $\sigma = 0, 1$. By Proposition 1 the equilibrium wage offer of the subgame $\Gamma^{\mathtt{w}}$ is $\hat{\omega}^{\mathtt{w}}_\lambda = y_\lambda$ for both $\lambda = l, h$. Then, using eq.(3.11) the expected payoff of the whole game for a worker of type $\lambda = l, h$ is:

$$
\begin{aligned}
\Omega^{\mathtt{w}}_\lambda &= \gamma E_\lambda(y_\lambda) + (1-\gamma) E_\lambda(rU_h) = \\
&\quad [\gamma y_\lambda + (1-\gamma) rU_h + qU_\lambda] / (r+q).
\end{aligned}
$$

By Proposition 1, Proposition 2 and Proposition 4, and making use of eq.(1.4), the expected payoff of the whole game for the firm is:

$$
\begin{aligned}
\Omega^{\mathtt{f}} &= (1-\gamma)\left[p(h) J_h(rU_h) + p(l) J_l(rU_h)\right] = \\
&\quad (1-\gamma)\left[(1-x) y_h + x y_l - rU_h\right] / (r+q).
\end{aligned}
$$

■

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**Proof of Proposition 6.** By Proposition 1, Proposition 2 and Proposition 3, a low type worker is matched any time she contacts a firm. Low type workers therefore exit from the unemployment pool at rate $\theta m(\theta)$. The equilibrium of flows implies that $q(x_l - u_l) = \theta m(\theta) u_l$, which can be rearranged as $u_l = qx_l / [q + \theta m(\theta)]$. By Proposition 1, Proposition 2 and Proposition 3, the contact between a high type worker and a firm results in a match any time the worker makes the offer and when the firm makes the offer and the worker sends the signal $\sigma = 1$, with probability $s$. A high type worker therefore exits unemployment at rate $\theta m(\theta)[\gamma + (1-\gamma)s]$. When job creation equals job destruction it must be that $q(x_h - u_h) = \theta m(\theta)[\gamma + (1-\gamma)s] u_h$, which can be rewritten: $u_h = qx_h / \{q + \theta m(\theta)[\gamma + (1-\gamma)s]\}$. ■

**Proof of Proposition 7.** By Propositions 2 and Proposition 3, it must be that $\hat{\omega}^{\mathtt{f}}(1) = rU_h$, and $\hat{\omega}^{\mathtt{f}}(0) = rU_l$. By Proposition 1, $\hat{\omega}^{\mathtt{w}}_{\lambda} = y_{\lambda}$. Using (1.1) it is possible to write the payoff expected by a high and a low type worker upon contact as:

$$\begin{aligned}\Omega^{\mathtt{w}}_h &= \gamma E_h(y_h) + (1-\gamma)[sE_h(rU_h) + (1-s)U_h] = \\ &[\gamma y_h + (1-\gamma) rU_h + qU_h]/(r+q),\end{aligned}$$

$$\begin{aligned}\Omega^{\mathtt{w}}_l &= \gamma E_l(y_l) + (1-\gamma)[sE_l(rU_l) + (1-s)E_l(rU_h)] = \\ &[\gamma y_l + s(1-\gamma) rU_l + (1-s)(1-\gamma) rU_h + qU_l]/(r+q).\end{aligned}$$

Using (1.4), the payoff expected by the firm is:

$$\begin{aligned}\Omega^{\mathtt{f}} &= (1-\gamma)[p(h) sJ_h(rU_h) + p(l) sJ_l(rU_l) + p(l)(1-s) J_l(rU_h)] = \\ &(1-\gamma)[p(h)s(y_h - rU_h) + p(l)s(y_l - rU_l) + p(l)(1-s)(y_l - rU_h)]/(r+q).\end{aligned}$$

■

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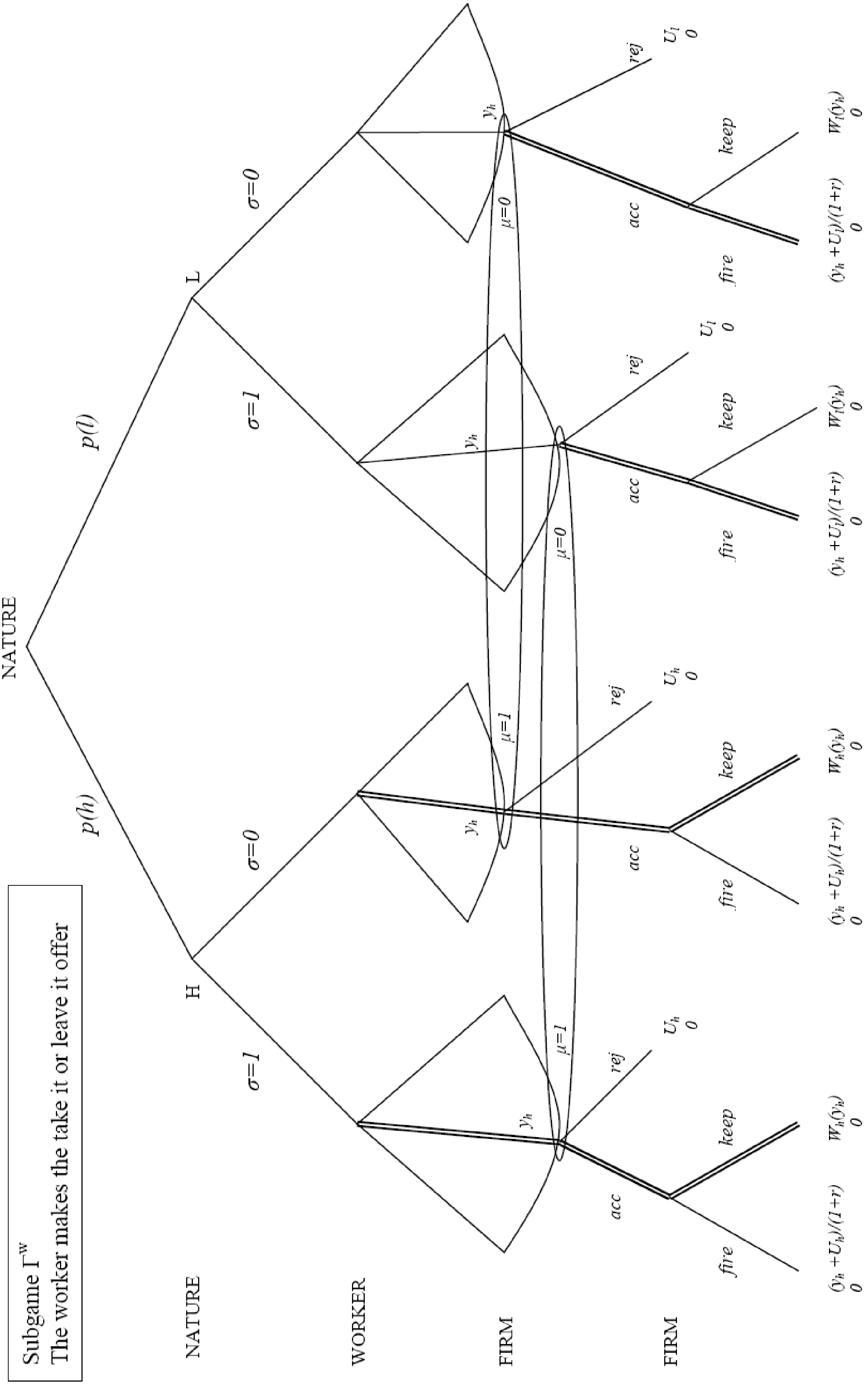



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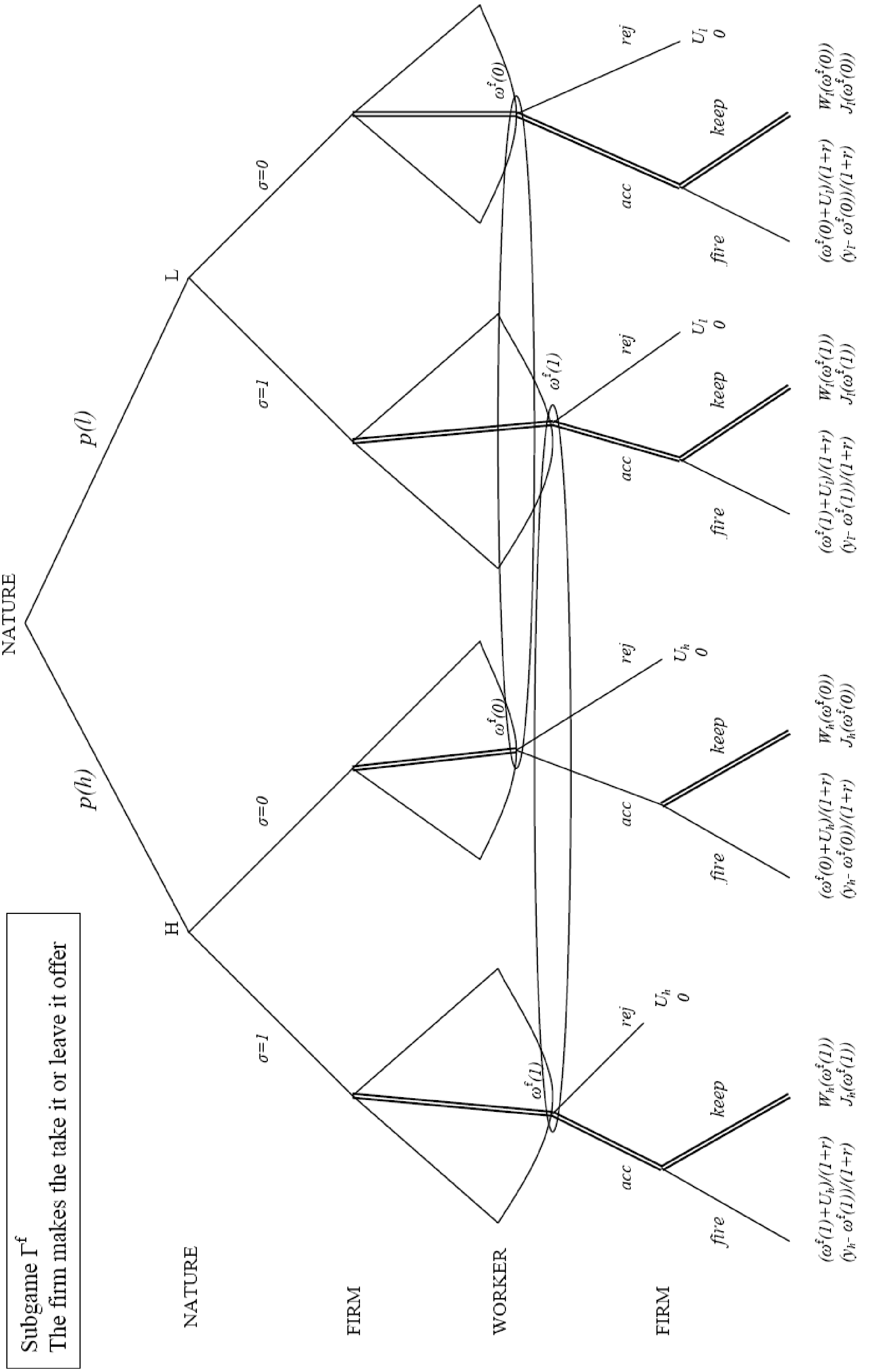
Subgame Γ^f
The firm makes the take it or leave it offer
NATURE
FIRM
WORKER
FIRM
NATURE
H
L
p(h)
p(l)
σ=1
σ=0
σ=0
σ=1
acc
rej
fire
keep

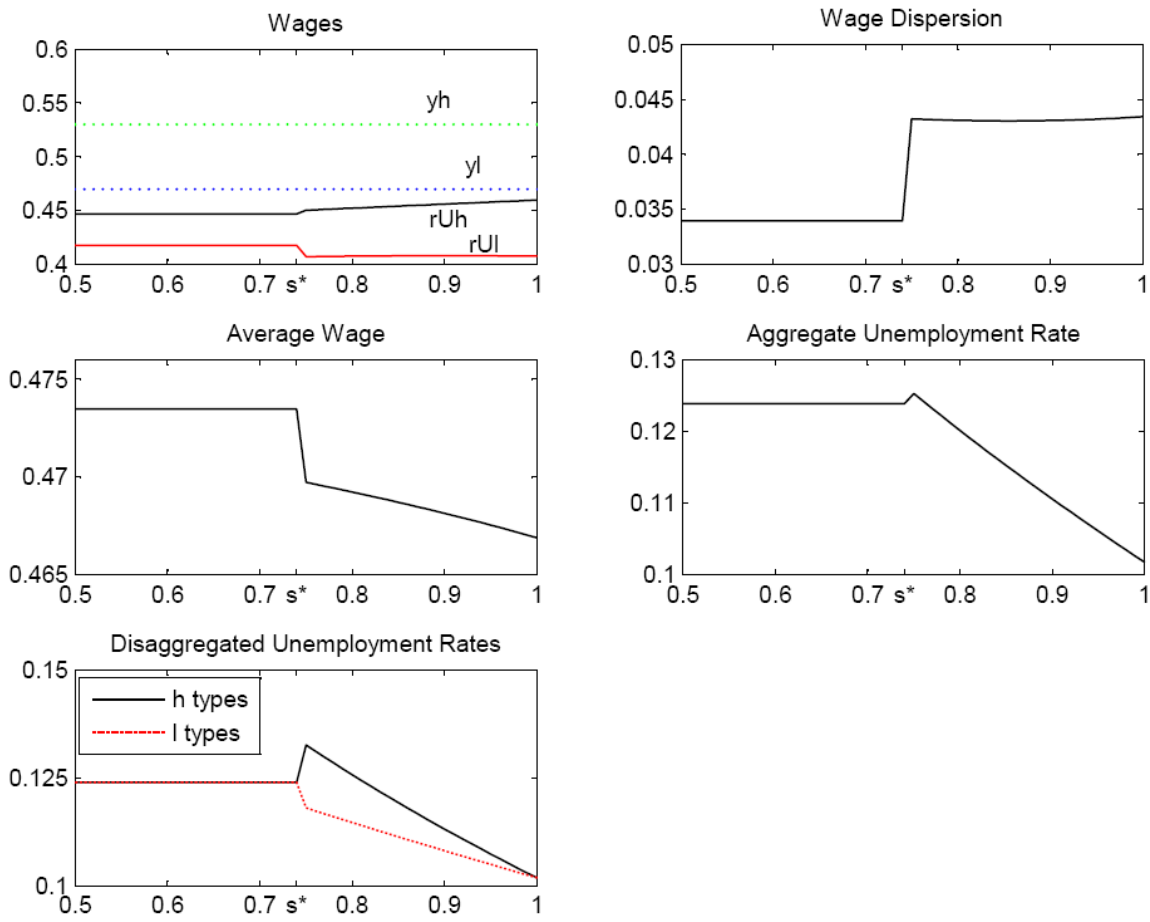


*Figure 1*: Simulation results for the parameter values in Table 1.

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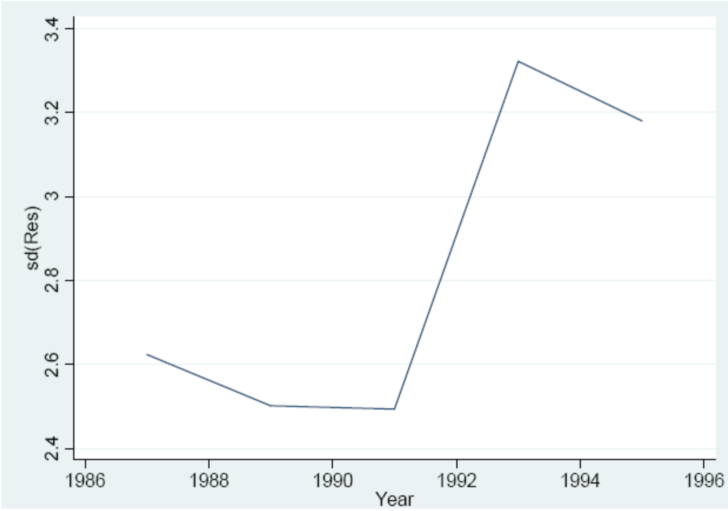


*Figure 2*: Residual wage dispersion for full-year manual workers younger than 30 years of age in Italy. Author's calculations from the SHIW panel of the Bank of Italy.

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# CHAPTER 2

# REASSESSING LABOR MARKET REFORMS: TEMPORARY CONTRACTS AS A SCREENING DEVICE

## 2.1 Introduction

Labor market rigidities are believed to be at the heart of the surge and persistence in European unemployment after the mid 1970s. To date, the major policy response to high unemployment rates has been the reduction of employment protection for new hires through the liberalization of temporary contracts. However, theoretical models investigating temporary contracts are either inconclusive about the effects on employment and unemployment, or predict an increase in the unemployment rate. Furthermore, several studies have also pointed out that two-tier labor market reforms are likely to create segmented labor markets, in which part of the workers are trapped in low-paid, low-productivity temporary jobs, with little prospect of upward mobility. These predictions are in conflict with recent empirical evidence showing that, in Europe, temporary contracts correlate positively with employment rates, and temporary workers enjoy considerably high rates of transition into permanent employment.

This paper presents an equilibrium model of the labor market which is able to account for this empirical evidence. Furthermore, it provides a useful framework which is suited to address most of the questions raised in the literature, that is, how temporary contracts interact with other labor market institutions, and how they affect productivity, hiring practices, turnover rates, wage differentials, career prospects and welfare. The central assumption is that firms use temporary contracts to screen workers for permanent positions. As I show in the paper, this hypothesis has been recently supported by a large amount of empirical evidence.

The model extends the matching framework of Pries and Rogerson (2005) by introducing the possibility for the firms to offer both temporary and permanent contracts. In particular, it is assumed that firms can offer a temporary contract with an exogenous probability, which depends on the strictness of labor market regulations. It is further assumed that the two contracts differ only in the associated dismissal costs. With Pries and Rogerson (2005), the model shares the assumption that workers are both an inspection good and an experience



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good. At the time of matching, both the employer and the worker receive a signal over the true quality of the match. A match is formed only if this signal exceeds a certain threshold. If the match is formed, both parties learn about the true quality of the match over time. A temporary match which turns out to be good is upgraded to a permanent position, while a match which turns out to be unsuitable is destroyed. The main mechanism of the model, which drives all welfare gains, is very simple and can be summarized as follows. In a framework where most of the separations at short tenure are driven by learning about match quality, temporary contracts increase the value of posting vacancies since they allow workers to be screened on the job without incurring any cost if a bad match is terminated.

The main contribution of this paper is to present a model which, embedding the screening hypothesis, can account both for the transition rates observed in most European countries and for the evidence that temporary contracts correlate positively with the employment rate. The model also offers a new explanation for the existence of wage differentials between temporary and permanent workers. Since the firm does not face dismissal costs if a temporary worker is fired, the threshold signal required to hire a worker is lower for temporary positions. Temporary workers are therefore less productive and earn lower wages. Besides explaining wage differentials, the dynamic properties of the model are also consistent with the finding that workers starting their career in temporary positions are expected to catch up over time with the wages of workers starting in permanent positions. Another important contribution of this paper is that it offers a rationale for the finding that temporary contracts seem to act as an important screening device in European countries but not in the US. In Europe, where it is expensive to destroy a permanent position, temporary contracts increase the expected profits of a vacancy by allowing firms to screen new hires on the job at no cost; in an economy -the US- with no firing restrictions, on the other hand both types of contracts are equivalent and there is no reason to resort to temporary contracts to screen workers. In general, the model shows that temporary contracts can reverse most of the negative effects associated with permanent-employment protection and with its interactions with minimum wages. Overall it is found that temporary contracts increase the worker turnover rate, the average quality of the matches and welfare. For each of these results, I will elaborate on the intuition below.

The model is calibrated to the Italian economy. Italy is a sensible choice to judge the performance of the model for a number of reasons. First, Italy is the OECD country with the lowest probation period on permanent positions. Second, Italy ranks second in terms of the OECD (1999) employment protection index and undertook major liberalizations of temporary contracts in the last ten years. For these reasons, Italy is the country where the gains from screening through temporary contracts are expected to be the largest, and offers the best available laboratory to test the screening hypothesis. When the model is calibrated with parameter values reflecting labor market institutions in Italy, the simulated economy can account for the transition probabilities from temporary to permanent positions, the worker turnover rate and the existence of a wage gap between temporary and permanent workers. Furthermore, a simple exercise of comparative statics can quantitatively replicate the behavior of the unemployment rate in Italy in the last ten years.

The paper is organized as follows: the next Section relates the paper to the literature, while Section 2.3 discusses some stylized facts. Section 2.4 presents the model. Section 2.5 calibrates the model and presents the quantitative analysis. The results are discussed in Section 2.6, and Section 2.7 concludes.

## 2.2 Literature review

This paper brings together the investigations initiated by Pries (2004) on how learning about match quality affects separations in the labor market and the vast literature that analyzes the macroeconomic effects of temporary contracts. Most of the existing models in this field embed the mainstream view that temporary contracts are an instrument which offers more flexibility to the firms to adjust employment faced with changing business cycle conditions or idiosyncratic demand shocks. This perspective has always been well rooted among both academics and policy-makers, as historically, the main reason temporary contracts were introduced into Europe was the idea that higher labor market flexibility would permanently decrease unemployment.

Most studies in this literature have analyzed the impact of temporary contracts within the traditional partial equilibrium framework of labor demand under uncertainty, pioneered by Nickell (1986), and extensively analyzed by Bentolila and Bertola (1990) and Bertola (1990). In this class of models the firm has a stable permanent workforce, and adjusts the stock of temporary workers to fluctuations in economic activity (Bentolila and Saint Paul, 1992; Boeri and Garibaldi, 2007). The main reason firms use temporary contracts, in these frameworks, is therefore to maintain a *buffer stock* of workers who can be readily dismissed when there is a need to adjust to economic downturns. Typically, in these models workers are segregated according to their employment contract and enjoy no upward mobility. The most important contribution that these papers have made in the literature is to show that higher turnover and higher volatility over the business cycle is as much as one could reasonably expect from the very much advocated flexibility in the labor market. In an application to the Swedish labor market, Holmund and Storrie (2002) find evidence of temporary employment

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being more volatile. While this class of models is typically inconclusive on the long-term impact on employment and unemployment rates, Alonso-Borrego et al. (2005) present a general equilibrium model following the same perspective and show that when it is calibrated, unemployment should unambiguously increase following the liberalizations of TC.

Another important contribution in the literature is the paper by Blanchard and Landier (2002). They take a different angle on the analysis of temporary contracts, and show that besides failing to reduce unemployment, TC might also create segmented labor markets with low transition into permanent employment. The main idea is that due to the existence of non-renewal clauses, if firing costs on permanent positions are high compared to search costs, when a temporary contract expires a firm is better off not renewing the contract, even if the temporary match was of relatively high quality. In this case, high turnover on temporary positions becomes part of the firm's personnel policies. In other words, temporary contracts are mainly used as *instruments of churning policies*, implying that workers may go through different spells of unemployment before finding a permanent job. As a result, transition rates into permanent employment are low. Under this scenario, two-tier reforms of the labor market decrease welfare, and most likely increase the unemployment rate at the steady state. Similar conclusions have been reached by Cahuc and Postel-Vinay (2002).

Both the buffer stock and the churning hypotheses have cast serious doubts on the gains that can be obtained through the liberalization of temporary contracts. However, both perspectives lead to predictions which are, to some extent, counterfactual. The fact that most OECD countries are characterized by massive yearly flows from temporary to permanent employment, that temporary workers enjoy substantial continuity in employment, and that temporary contracts are found to correlate positively with employment rates within European countries, cannot be accounted for within these frameworks of analysis. I will discuss these findings in more detail in the following section. Furthermore, a growing body of empirical evidence in recent years, based on the observation of most European countries, has suggested that there might be another important reason behind the use of TC whose implications are still relatively unexplored in macro theory. There is now substantial evidence supporting the hypothesis that firms use temporary contracts to screen workers for permanent positions.

There are a series of papers, as surveyed by Ichino et al. (2008), showing that being assigned to a temporary position has a large causal effect on the probability of finding a permanent match. The bottomline of this empirical literature is that temporary contracts are stepping stones into permanent employment rather than dead-end jobs, and has been interpreted as evidence in favour of the screening hypothesis. While these results are robust

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across European countries[1], they are in contrast with those found for the US (Autor and Houseman, 2005). Furthermore, a recent paper by Nunziata and Staffolani (2007) using data on the 15 major European countries, shows that measures of temporary-employment protection are negatively correlated with the rate of employment in permanent positions. This finding has also been interpreted as evidence in favour of the screening hypothesis. Finally, Varejao and Portugal (2003), using data on the Portuguese labor market, show that "screening workers for permanent positions is the single most important reason why firms use these types of contracts". This paper embeds the screening hypothesis documented by these studies into an equilibrium model of the labor market.

To sum up, the literature has identified the following three main reasons for the use of temporary contracts:

1. as a buffer stock against downturns in economic activity;
2. as instruments of churning policies;
3. as a screening device.

While the macroeconomic effects of temporary contracts under the first two hypotheses have received a great deal of attention in the literature, the implications of temporary contracts as a screening device have sofar been analyzed only by Nagypal (2002). With respect to her contribution, this paper shares the result that as experimentation in the economy increases with the use of temporary contracts, so does the productivity of the workers and welfare. However, this paper differs in several ways from Nagypal's (2002). First, it uses a simpler process to describe the process of learning about match quality, and abstracts from learning-by-doing. Second, the assumptions of an all-or-nothing learning process together with the use of hiring practices produces a different mechanism through which firing costs affect the equilibrium and reverse her findings that temporary contracts increase the unemployment rate. Third, this paper calibrates the model on the Italian labor market. Finally, this paper differs in the scope of the analysis, investigating the interactions of temporary contracts with other labor market institutions, the transition rates implied by the model, and the impact on hiring practices, turnover rates and wage differentials.

This paper is also directly related to the work of Pries (2004), who estimates for the US labor market the process of learning about match quality. Pries (2004) shows that the

[1] Among other European countries, evidence in this direction is available for Italy (Adam and Canziani, 1998 and Ichino et al., 2005), for the United Kingdom (Booth et al. 2002), for Germany and the Netherlands (Lechner et al. 2000; Dekker, 2001; Zijl et al., 2004), and for Sweden (Holmund and Storrie, 2002).

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estimated process of learning by matching the high rates of job destruction at short tenures, is key to reconciling the remarkable persistence of the unemployment rate over the business cycle with the high job finding rate measured in the data. Pries and Rogerson (2005) exploit the process of learning about match quality estimated by Pries (2004) to build up a model which is able to explain differences in turnover rates between Europe and the US. In this paper, I investigate how the process of learning about match quality estimated by Pries (2004) can contribute to improving our understanding of the macroeconomic implications of temporary contracts.

## 2.3 Stylized facts

### 2.3.1 Stylized facts for European countries

This section highlights some important stylized facts accounted for by the model, which refer to cross-sectional studies on European countries.

As reported by the OECD (2002), for most European countries workers employed on a temporary contract in 1996 had at least a probability of about 40% to be employed in a permanent position one year later[2]. In other words, close to half of the total stock of temporary workers moves into permanent employment within a year of time. Further more, quoting the OECD (2002), p.131, "the evidence for European countries suggests that the majority of temporary workers have considerable continuity in employment: being in employment one year earlier and remaining in employment one and two years later". These statistics reveal that most European countries are characterized by massive yearly flows from temporary to permanent employment and by substantial continuity in employment, suggesting that only a relatively small fraction of the workforce might be trapped into recurring spells of temporary employment and unemployment. This considerable degree of upward mobility and integration in the labor markets is difficult to reconcile with the idea that temporary contracts are used as instruments of churning policies. The yearly transition probabilities among European countries range between 36% and 56% with only two notable exceptions, Spain and France. In these countries a worker on a temporary contract had in 1996 only about a 20% chance of being in a permanent contract one year later. Only in these two countries have the reforms created a rather segmented labor market with low mobility from temporary to permanent employment, suggesting that alternative forces leading to market

[2] The OECD (2002) computes transition probabilities across the states of unemployment, temporary employment and permanent employment. They restrict the sample to the individuals beginning in dependent employment or unemployment in 1996 and moving neither in self-employment nor in inactivity during 1997-98. This makes their statistics directly comparable to our model.

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segmentation and churning could be dominant. I therefore summarize the first stylized fact as follows:

**Stylized Fact 1:** European countries appear to be characterized by high rates of transition into permanent employment.

While there has been considerable empirical literature focusing on firing costs and severance payments, little empirical work has investigated the effects of temporary contracts on employment and unemployment. A recent paper by Nunziata and Staffolani (2007) provides the most careful multi-country analysis aiming to identify the correlations between employment rates and a set of employment regulation reforms, including two-tier reforms, implemented over the period 1983-1999 in 15 European countries. The regression analysis controls for a large set of institutions, which include union density, bargaining coordination, the tax wedge, and unemployment benefits, and for interaction effects between these institutions. Importantly, following Nickell et al. (2005), the regressions also control for a number of factors that can influence employment and unemployment rates in the short run. These control variables include labor demand shocks, long-term interest rates, acceleration in money supply, and terms of trade shocks. The authors find that looser regulations on fixed-term contracts and lower dismissal costs on permanent positions are significantly correlated with an increase in the employment rate. In particular, fixed-term contracts, which constitute the bulk of all types of temporary contracts, seem to be associated with increases in the employment rate in permanent positions, and this has been interpreted as suggestive evidence in favor of the screening hypothesis. These results are robust to various changes in the econometric specification. Previous studies focusing on broad indicators of employment protection have often found positive correlations with the unemployment rate, although this result is not always significant across studies (Howell et al., 2007). I summarize these findings as follows:

**Stylized Fact 2:** Fixed-term contracts are found to correlate positively with the employment rate at the European level.

Another important finding in the literature of temporary contracts, which has prompted research in the field, is the existence of wage differentials between temporary and permanent workers. The OECD (2002) reports evidence of wage penalties associated with temporary contracts for all European countries. The average wage gap ranges from 17% in Germany, to 47% in Spain. Controlling for worker and job characteristics, the average wage penalty for the countries surveyed by the European Commission Household Panel is 15%, and ranges from 7% in Austria to 24% in the Netherlands. Findings on the wage penalties for temporary workers have been reported also by Booth et al. (2002) for Britain, by Dekker (2002) for the Netherlands, Germany and the United Kingdom, by Blanchard and Landier (2002) for France and by Houseman (1997) for the US. I summarize these findings as follows:

**Stylized Fact 3:** Controlling for worker and job characteristics, workers on temporary contracts are paid less than workers on permanent contracts.

There are a couple of papers in the literature which provide an explanation for the existence of wage differentials. Güell (2005) presents a theory based on an efficiency wage perspective. The basic idea is that firms do not need to offer an efficiency premium in order to provide workers with non-shirking incentives, since the possibility of non-renewal for temporary contracts can achieve the same results. Alternatively, Bentolila and Dolado (1994) suggest that if unions are dominated by permanent workers subject to firing restrictions, the existence of a buffer stock of temporary workers might increase their bargaining power and their wages. This paper offers a different explanation for the existence of wage differentials. Since firms that offer a temporary contract incur no dismissal costs, should the match turn out to be of low quality, firms have an incentive to use less selective hiring practices. Therefore, temporary workers are paid less simply because they are less productive.

### 2.3.2 The case of Italy

In the model, learning that a match is bad entails costs of dismissal that are to be paid only on permanent positions, not on temporary positions. However, it is known that in the real world, no dismissal costs are to be paid if a worker employed on a permanent position is fired during the probationary period. This trial period, which follows the beginning of a new relationship, usually ranges in Europe between three and six months. Therefore, from the perspective of this paper, there are gains to be obtained from temporary contracts so long as it takes more than three or six months to discover the true productivity of a worker. The shorter the period of probation, the larger the gains expected from screening workers through temporary contracts.

Italy is the OECD country with the lowest probationary period and with the second highest index of employment protection. In Italy, the common length for trial periods, as established in the enforceable collective agreements, ranges between one and two weeks for blue collar workers and between three to eight weeks for white collar workers (OECD 1999, p.103). Italy is therefore the country where the effects produced by temporary contracts

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through the screening channel are expected to show up most clearly in the data. Furthermore, in the last ten years, major liberalizations of temporary contracts have been implemented.

In Italy, the first important wave of reforms of temporary contracts took place in 1997. As discussed by Boeri and Garibaldi (2007), the adoption of temporary contracts had already been partially liberalized in 1984 and 1987, but unions were given the power to hinder their diffusion. Only when this obstacle was finally removed in 1997, could the use of temporary contracts be adopted. A second wave of reforms, in 2003, further enhanced access to temporary contracts. The picture in the Appendix describes the behavior of the labor market, in terms of both the share of temporary contracts and the quarterly unemployment rate, between 1996 and 2007. Both 1996 and 2007 were periods of expansionary economic activity, and reflect comparable business cycle conditions.

What emerges is a clear-cut negative association between temporary contracts and the unemployment rate. In the ten years following the beginning of the reforms, the share of temporary contracts almost doubled, increasing from 7.5% to 13%, while the unemployment rate halved, dropping from 11.3% in 1997 to 5.7% in the second quarter of 2007, which is below the European average. Furthermore, the quarterly unemployment rate steadily decreased also during the downturns of economic activity early after the turn of the century. This decrease in the unemployment rate was mirrored by an increase in the employment rate, from 60.2% in 1996 to 65.9% in 2006. This increase in the employment rate is, to some extent, a phenomenon that has characterized other European labor markets in the last ten years. However, the magnitude of the phenomenon in Italy largely outweighs the European experience. Moreover, in the last ten years Italy has been among the countries in Europe with the highest employment content of growth, exceeding by far the average European performance. The participation rate also increased over the period, from 59% in 1996 to 63% in 2006[3]. However, it is difficult to tell what impact this increase has had on the unemployment rate. To the extent that the increase in the participation rate reflects the regularization of immigrant workers or, more generally, an emerging hidden economy, this increase should reduce the unemployment rate. To the extent that it reflects an increase in the number of job seekers, attracted by the existence of new contractual arrangements, the increase in the participation rate should increase the unemployment rate. Both phenomena have certainly been relevant in the last decade.

The picture that arises is therefore one of a permanent decrease in the long-run unemployment rate. The thesis put forward in this paper is that the drop in the unemployment rate

[3]The statistics in this paragraph have been reported by the Italian national institute of statistics, Istat (2006).

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was mainly produced by the liberalization of temporary contracts, which was, undoubtedly, the major labor market reform of the last decade. Furthermore, the impact on unemployment and employment rates might have been more apparent in Italy than in other European countries because of the unique combination of high employment protection and low probationary period. Up to date, very few models in this literature are calibrated, and none can qualitatively account for a decrease in the unemployment rate. Section 2.5 shows that when our model is calibrated to reflect labor market institutions in Italy, it is able to qualitatively and quantitatively account for the drop in the unemployment rate that occurred in the ten years following the reforms of 1997.

## 2.4 The model

### 2.4.1 The Economy

This section presents a matching model of the labor market that builds on Pries and Rogerson (2005).

*The matching technology:*

There is a frictional labor market and a unit mass of workers who can be either employed or unemployed. On-the-job search is ruled out so that workers can only search for a job if unemployed. Firms must post a vacancy to fill a job, and the cost of keeping a vacancy open per period is denoted by $c$. The measure of vacancies and unemployed workers at time $\tau$ is denoted by $v_\tau$ and $u_\tau$. A standard constant-returns-to-scale matching technology, $M(v_\tau, u_\tau)$, determines the number of job matches per unit of time as a function of vacancies and unemployed workers. Every period, a vacancy meets a worker with probability $M(v_\tau, u_\tau)/v_\tau = M(1, u_\tau/v_\tau) = m(\theta_\tau)$, where $\theta_\tau = v_\tau/u_\tau$ denotes labor market tightness. Similarly, a worker meets a firm with probability $M(v_\tau, u_\tau)/u_\tau = \theta_\tau m(\theta_\tau)$. It is assumed that $m(\theta_\tau) \to 1$ and $\theta_\tau m(\theta_\tau) \to 0$ as $\theta_\tau \to 0$, and $m(\theta_\tau) \to 0$ and $\theta_\tau m(\theta_\tau) \to 1$ as $\theta_\tau \to \infty$.

*Production technology and learning about match quality:*

The production technology and the process of learning about match quality are identical to Pries (2004), and Pries and Rogerson (2005). A unit of production is a matched worker-firm pair. All workers are ex-ante identical, but ex-post different, since productivity is match-specific. The output of a match at any time $\tau$ is only observed at the end of the period, and is given by $y_\tau = \bar{y} + \epsilon_\tau$, where $\epsilon_\tau$ is a mean zero random variable, uniformly distributed over the domain $[-z, z]$. $\bar{y}$ denotes the true quality of a match, which can either be good or bad: if good $\bar{y} = y_g$, while if bad $\bar{y} = y_b$. When a worker and a firm meet, the true productivity of the match is unknown both to the worker and to the firm, but they both

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observe the realization of a signal $\pi$, which denotes the probability that the match turns out to be good. Any draw of $\pi$ is taken from a cumulative distribution $H(\pi)$ and is independent across matches. The hiring decision takes place at the beginning of the period, and is based only on the realization of this signal.

If a match is formed, each period the unit of production will try to infer the true quality of the match by observing realized output. Whenever production falls in the range of $y_\tau \in (y_b + z, y_g + z]$, the worker and firm pair learn that the match is good, since a low type worker is not able to produce such a high level of output. Similarly, if output falls in the range of $y_\tau \in [y_b - z, y_g - z)$ the match is revealed to be of low quality, since none of such realizations is compatible with a high type worker. With probability denoted by $\alpha = (y_g - y_b)/2z$, the true quality of the match is therefore discovered. With the complement probability $1 - \alpha$ nothing is learned since, due to the assumption of a uniformly distributed noise term, the posterior probability equals the prior. The process of learning about match-specific productivity therefore takes an "all-or-nothing" form. Since I am only interested in characterizing the stationary equilibrium of this economy, in what follows I will omit the time subscript.

*Contracts:*

There are two types of contracts in the economy: temporary contracts and permanent contracts. The existence of a dismissal cost $d > 0$, which is specific for permanent positions, is the only difference between the two contracts. The productivity of a match is therefore independent of the contract, and remains unchanged throughout the duration of the relationship, unless an exogenous shock of job destruction denoted by $\lambda$, and identical across contracts, renders the match unproductive. Every period, a relationship ends either if the quality of the match is discovered to be bad, or if an exogenous shock renders the match unproductive.

The model is built to embed the hypothesis that firms screen suitable workers for permanent positions. If a worker is hired on a temporary basis, the contract is then maintained until the true productivity of the match is revealed. At that time, it is assumed that the contract is either transformed into a permanent one, if the match turns out to be good, or the relationship is severed at no cost, if the match turns out to be bad.[4] If instead the

[4]Endogenizing the decision to upgrade temporary contracts into permanent contracts is beyond the scope of this paper. The most cited reason for the conversion of a temporary contract is the existence of non-renewal clauses. Usually, among European countries temporary contracts are no longer renewable after two or three years. Given the learning process estimated by Pries (2004), and embedded in this model, by the end of two years of tenure, virtually all of the matches would be classified as good or bad. At that time, all good matches and only the good matches would be upgraded into permanent positions. In order to keep the model as simple as possible, I do not explicitly model an up-or-out clause, and assume that temporary matches are upgraded as soon as they are discovered to be good. It is important to notice that this simplification,

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worker is hired on a permanent contract, the relationship is severed whenever the match is discovered to be bad, at the cost $d$. Temporary contracts then allow employers to save on the dismissal costs which would otherwise be paid if bad workers were hired on permanent contracts. Therefore, firms always prefer to hire on temporary positions. Yet, it is assumed that the firm is allowed to offer a temporary contract only with probability $\phi$. This parameter thus represents the strictness of the regulation on temporary contracts. Labor market reforms enhancing access to temporary contracts can therefore be represented by an increase in $\phi$.[5]

*Wages:*

There is an exogenous minimum wage in the economy, which is denoted by $\bar{\omega}$. Wages are negotiated at the beginning of each period and cannot be conditional on the observation of output at the end of the period. The wage of a worker in a match that is expected to be good with probability $\pi$ is denoted by $\omega_i(\pi)$, for $i = T, I$ and is the solution of the generalized Nash bargaining criterion for values of $\pi$ at which the minimum wage does not bind. The subscripts $T$ and $I$ are used to denote temporary and permanent contracts respectively. For reasons that will become clearer below, $I$ is an indicator function equal to zero if the contract is new, and equal to one if the contract is renegotiated.

### 2.4.2 Workers and firms

This section characterizes the steady-state behavior of workers and firms. Both are risk-neutral.

*The firms:*

The present discounted value of a vacancy, denoted by $V$, solves the following Bellman equation:

$$V = -c + \beta m(\theta) \left[ \phi \int J_T(\pi) dH(\pi) + (1-\phi) \int J_0(\pi) dH(\pi) \right], \tag{2.1}$$

where $\beta$ is the discount factor, and $J_i(\pi)$ for $i = T, 0$ denotes the value to the firm of having

which implies perfect screening ability, does not bias the selection of good matches into permanent positions. Furthermore, Güell and Petrongolo (2007) find that in Spain, most conversions into permanent employment take place before the end of their legal duration. They build a model where workers search on the job and prefer a permanent contract over a temporary contract, everything else equal. In their framework firms are willing to upgrade the contract to reduce the probability that temporary workers quit. Güell and Petrongolo (2007) provide evidence that conversion rates are higher for workers with a higher outside option, which increases their probability of quitting. Their interpretation is that "as soon as a job match is perceived to be productive enough, a firm may have a sufficient incentive to promote a temporary worker, instead of keeping him/her in a temporary contract for the entire legal duration " (Güell and Petrongolo 2007, p.160).

[5] The assumption that all firms prefer to hire a new worker with a temporary contract might seem restrictive. However, in Spain, which is the most deregulated country in Europe with respect to fixed-term contracts, the fraction of new hires that were signed under temporary contracts in the period 1985-2002 has constantly ranged between 91% and 97% (Guell and Petrongolo 2007).


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a worker matched with signal $\pi$ employed in a temporary contract or in a new permanent contract, respectively.

Let $b$ denote the disutility of work, and satisfy $b \geq y_b$. As long as the value of search for an unemployed worker is positive, this condition is sufficient to ensure that bad matches are terminated at equilibrium.

The value to the firm of having a worker employed on a temporary contract reads as follows:

$$J_T(\pi) = \max\{V, \pi y_g + (1-\pi)y_b - \omega_T(\pi) + \beta\lambda V + \beta(1-\lambda)\{\alpha[\pi J_0(1) + (1-\pi)V] + (1-\alpha)J_T(\pi)\}\}. \quad (2.2)$$

The first three terms represent current period expected profits. If the match breaks down, with probability $\lambda$, the firm is left next period with a vacant job, whose present value is given by the fourth term. The last term represents expected future discounted profits if the match does not break down. If the quality of the match is discovered, the firm upgrades the temporary contract into a permanent one if, with probability $\pi$, the worker is revealed to be good, and fires the worker if, with probability $1-\pi$, the worker is revealed to be bad. Therefore, the firm gets with probability $\pi$ the value of having a worker, who is good with probability one, employed in a new permanent contract, and with probability $1-\pi$ the value of a vacant job. If, on the contrary, the productivity of the worker is not revealed, the firm keeps the worker in a temporary position.

Following a standard practice in the literature, it is assumed that dismissal costs are a pure resource waste, which occurs whenever a job is destroyed. As such, firing costs can be considered as equivalent to a separation tax. When deciding whether to form a permanent match, the firm does not incur dismissal costs if the permanent match is not formed. Then, dismissal costs are only paid when an ongoing relationship is severed. The outside option of the firm will therefore be different whether the permanent contract is new or renewed. This asymmetry between new and ongoing matches implies that the matched firm-worker pair must also be indexed to indicate whether it is a newly formed match or whether it is a pre-existing match. The indicator $I$ is then used to indicate a new permanent match when it equals zero, and a pre-existing permanent match when it equals 1. The value to an entrepreneur of a match that has received the signal $\pi$, for new and continuing matches therefore satisfies:

$$J_I(\pi) = \max\{V - Id, \pi y_g + (1-\pi)y_b - \omega_I(\pi) + \beta\lambda(V-d) + \beta(1-\lambda)\{\alpha[\pi J_1(1) + (1-\pi)(V-d)] + (1-\alpha)J_1(\pi)\}\}. \quad (2.3)$$


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The interpretation of this equation is similar to the previous one, but here the negotiated wage $\omega_{_I}(\pi)$ depends on whether the match is new or pre-existing. The wage function $\omega_{_I}(\pi)$ equals the maximum between the minimum wage and the outcome of the generalized Nash criterion.

*The workers:*

The lifetime discounted value of an unemployed worker, denoted by $U$, satisfies the following equation:

$$U = \beta \left\{ \theta m(\theta) \left[ \phi \int W_T(\pi) dH(\pi) + (1-\phi) \int W_0(\pi) dH(\pi) \right] + [1 - \theta m(\theta)] U \right\}, \qquad (2.4)$$

where $\phi$ denotes the probability that the worker is offered a temporary contract, and $W_i(\pi)$ for $i = T, 0$ denotes the value to the worker of being employed with signal $\pi$ in a temporary contract or in a new permanent contract, respectively.

In the standard matching model, both the worker and the firm decide simultaneously whether to form a match. With Nash bargaining there is agreement on the decision of forming the match, and the match is formed as long as the surplus is positive. The wage then adjusts to split the surplus between the two parties according to a simple sharing rule. This is no longer the case in this model since the minimum wage is binding. It might therefore be possible, for some "low" values of $\pi$, that the worker would like to form a match, but the firm would not. If a match is formed only if both parties agree, then the decision of whether to form a match depends only on the firm, and the worker takes the decision rule of the firm as given.

The value to the worker of a temporary match that received the signal $\pi$, reads as follows:

$$\begin{aligned} W_T(\pi) = \max \{ U, \{ \omega_{_T}(\pi) - b + \beta\lambda U + \beta (1-\lambda) \\ \times \{ \alpha [\pi W_0(1) + (1-\pi) U] + (1-\alpha) W_T(\pi) \} \} X_T(\pi) \}, \end{aligned} \qquad (2.5)$$

where $X_T(\pi)$ is the firm's decision rule of forming a match, which is equal to 1 whenever $J_T(\pi) \geq V$, and equal to zero otherwise. Similarly, the value to the worker of a permanent position in a match that received the signal $\pi$ is written as follows:

$$\begin{aligned} W_I(\pi) = \max \{ U, \{ \omega_{_I}(\pi) - b + \beta\lambda U + \beta (1-\lambda) \\ \times \{ \alpha [\pi W_1(1) + (1-\pi) U] + (1-\alpha) W_1(\pi) \} \} X_I(\pi) \}, \end{aligned} \qquad (2.6)$$

where $X_I(\pi)$ is the firm's decision rule of forming a match, which is equal to 1 whenever $J_I(\pi) \geq V - Id$, and equal to zero otherwise.

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### 2.4.3 Equilibrium

The steady-state measure of temporary matches is denoted by $e_T$, the measure of permanent matches by $e_P$, the measure of matches known to be of good quality by $e_g$, the measure of matches of unknown quality by $e_n$, the measure of vacancies by $v$, and the measure of unemployed workers by $u$. At the stationary equilibrium job creation for each type of match must equal job destruction. Denoting by $E$ the expectation operator, the following equations must therefore hold:

$$[\lambda + (1-\lambda)\,\alpha]\, e_T = vm\,(\theta)\,\phi E[X_T\,(\pi)], \tag{2.7}$$

$$\lambda e_g = (1-\lambda)\alpha e_T E[\pi | X_T\,(\pi) = 1] + (1-\lambda)\,\alpha\,(e_P - e_g)\, E[\pi | X_0\,(\pi) = 1], \tag{2.8}$$

$$\begin{aligned}\lambda e_g + (1-\lambda)\,\alpha\,(e_P - e_g)\,\{1 - E[\pi | X_0\,(\pi) = 1]\} = vm\,(\theta)\,(1-\phi)\, E[X_0\,(\pi)] \\ + e_T(1-\lambda)\alpha E[\pi | X_T\,(\pi) = 1],\end{aligned} \tag{2.9}$$

$$e_n = e_T + (e_P - e_g), \tag{2.10}$$

$$u = 1 - e_T - e_P. \tag{2.11}$$

**Definition 2.1** *A stationary equilibrium is a list of prices* $\{\omega_T(\pi),\ \omega_I(\pi)\}$ *, quantities* $\{v,\ u,\ e_T,\ e_P,\ e_g$ *values* $\{V,\ J_T(\pi),\ J_I(\pi),\ U,\ W_T(\pi),\ W_I(\pi)\}$, *and rules* $\{X_T\,(\pi),\ X_I\,(\pi)\}$, *such that the following conditions hold:*

1. Value functions: Given $\omega_T(\pi)$, $\omega_I(\pi)$, $u$, and $v$, $V$, $J_T(\pi)$, $J_I(\pi)$, $U$, $W_T(\pi)$, and $W_I(\pi)$ satisfy the Bellman equations (2.1) to (2.6).

2. Temporary match formation: Given $\omega_T(\pi)$, $\omega_I(\pi)$, $u$ and $v$, $X_T\,(\pi)$ is an optimal decision rule for the firm.

3. Permanent match formation: Given $\omega_I(\pi)$, $u$ and $v$, $X_I\,(\pi)$ is an optimal decision rule for the firm.

4. Free entry: Given $\omega_T(\pi)$ and $\omega_I(\pi)$, the ratio $\theta$ must be such that $V = 0$.

5. Bargaining on temporary contracts: the wage function must be such that $\omega_T(\pi) = \max[\omega_T^N(\pi), \bar{\omega}]$, where the Nash wage function $\omega_T^N(\pi)$ solves

$$W_T(\pi) - U = \gamma\,[J_T(\pi) + W_T(\pi) - V - U]\,, \tag{2.12}$$

and $\gamma$ denotes the bargaining power of the workers.

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6. Bargaining on permanent contracts: the wage function must be such that $\omega_I(\pi) = \max[\omega_I^N(\pi), \bar{\omega}]$, where the Nash wage function $\omega_I^N(\pi)$ solves

$$W_I(\pi) - U = \gamma \left[ J_I(\pi) + W_I(\pi) - (V - Id) - U \right]. \tag{2.13}$$

7. Steady state: equations (2.7) to (2.11) hold.

*The permanent match formation rule:*

In order to solve for the equilibrium of the model, it is necessary to characterize the hiring rules for the firm. This implies finding two cutoff values for the signal, denoted by $\bar{\pi}_T$ and $\bar{\pi}_0$, below which the firms are unwilling to offer temporary contracts and permanent contracts, respectively. Let $S_I(\pi) = J_I(\pi) + W_I(\pi) - (V - Id) - U$ denote the surplus functions for permanent contracts. Then $S_1(\pi) - S_0(\pi) = d$. Intuitively, the surplus is higher for ongoing matches since the existence of dismissal costs lowers the combined outside option of the two parties. Substituting equations (2.3) and (2.6) together with the free-entry condition $V = 0$ yields:

$$S_I(\pi) = \max \{0, \pi y_g + (1 - \pi) y_b - b - (1 - \beta) U + (I - \beta) d \\ + \beta (1 - \lambda) \left[ \alpha \pi S_1(1) + (1 - \alpha) S_1(\pi) \right] \}.$$

In a non-trivial equilibrium where $\bar{\pi}_0 < 1$, the value of $S_1(1)$ can be easily obtained from the above expression, and equals:

$$S_1(1) = \frac{y_g - b - (1 - \beta) U + (1 - \beta) d}{1 - \beta (1 - \lambda)}.$$

At the calibrated equilibrium the minimum wage is binding only for all the new permanent contracts; for all the pre-existing permanent contracts and for all temporary contracts instead, the minimum wage is not binding. I briefly anticipate here the role played by the minimum wage in this model. Intuitively, with Nash bargaining workers and firms share the costs of employment protection, through an initial transfer of resources. In calibrated matching models of the labor market with employment protection, wages in the first period of the relationship are usually negative. However, in the real world we do not observe transfers of resources, and wages are never negative. A minimum wage in this setting simply puts an upper bound on the transfer of resources that can take place at the beginning of the relationship. The quantitative impact of the minimum wage and its interactions with the other labor market institutions will be extensively discussed in Section 2.5.

The value to the firm of having a worker employed on a new permanent contract can therefore be rewritten from eq.(2.3) substituting the wage function with the minimum wage,

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and substituting $J_1(\pi)$ with $(1-\gamma)S_1(\pi)-d$ using the Nash sharing rule. The value function now reads as follows:

$$J_0(\pi) = \pi y_g + (1-\pi)y_b - \bar{\omega} - \beta\lambda d + \beta(1-\lambda) \times \left\{(1-\gamma)\left[\alpha\pi S_1(1) + (1-\alpha)S_1(\pi)\right] - d\right\}. \quad (2.14)$$

Given that $J_0(\pi)$ is strictly increasing in $\pi$, setting $J_0(\bar{\pi}_0) = 0$ implicitly defines a unique threshold value of $\bar{\pi}_0$. The permanent match formation equation then reads as follows:

$$\bar{\pi}_0 y_g + (1-\bar{\pi}_0)y_b - \bar{\omega} - \beta\lambda d + \beta(1-\lambda)\left\{(1-\gamma)\left[\alpha\bar{\pi}_0 S_1(1) + (1-\alpha)S_1(\bar{\pi}_0)\right] - d\right\} = 0. \quad (2.15)$$

Since the surplus of pre-existing matches is higher than the surplus of new permanent matches, any given value of $\pi$ which is found acceptable at the beginning of a permanent relationship also remains acceptable in future periods. This implies that $\bar{\pi}_0$ is the single cutoff value which is relevant to characterize acceptance decisions in permanent matches.

*The temporary match formation rule:*

The match formation equation for temporary contracts can be found using a similar procedure. As before, it is convenient to define by $S_T(\pi) = J_T(\pi) + W_T(\pi) - V - U$ the surplus function for temporary contracts. Plugging equations (2.2) and (2.5) into the above expressions, and substituting $S_0(1) = S_1(1) - d$ the surplus reads as follows:

$$S_T(\pi) = \max\left\{0, \frac{\pi y_g + (1-\pi)y_b - b - (1-\beta)U + \beta(1-\lambda)\alpha\pi\left[S_1(1) - d\right]}{1 - \beta(1-\lambda)(1-\alpha)}\right\}.$$

Since the minimum wage is not binding for temporary contracts at the calibrated equilibrium, a match will be formed only as long as the surplus is positive, with common agreement between the parties. Given that $S_T(\pi)$ is strictly increasing in $\pi$, the match formation equation for temporary contracts can therefore be obtained by setting $S_T(\bar{\pi}_T) = 0$. This equation reads:

$$\bar{\pi}_T y_g + (1-\bar{\pi}_T)y_b - b - (1-\beta)U + \beta(1-\lambda)\alpha\bar{\pi}_T\left[S_1(1) - d\right] = 0. \quad (2.16)$$

*Free entry and job search:*

At the stationary equilibrium, with free entry the value of a vacancy is zero. Substituting $J_T(\pi) = (1-\gamma)S_T(\pi)$ using the Nash sharing rule, equation (2.1) reads:

$$c = \beta m(\theta)\left[\phi(1-\gamma)\int S_T(\pi)dH(\pi) + (1-\phi)\int J_0(\pi)dH(\pi)\right], \quad (2.17)$$

where $J_0(\pi)$ is given by (2.14).

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The value of unemployment can also be rearranged as follows, using the free entry condition, the Nash bargaining rule $\gamma S_T(\pi) = W_T(\pi) - U$ and substituting $W_0(\pi) - U = S_0(\pi) - J_0(\pi)$, and $S_0(\pi) = S_1(\pi) - d$:

$$U = \frac{\theta m(\theta)}{1-\beta}\left\{\phi\gamma\int S_T(\pi)dH(\pi) + (1-\phi)\int\left[S_1(\pi) - d - J_0(\pi)\right]dH(\pi)\right\}. \tag{2.18}$$

Duly substituting for the surplus equations and for $J_0(\pi)$, the equations (2.7) to (2.11) together with the equations (2.15) to (2.18) constitute a non-linear system of nine equations in the following nine unknowns: $v$, $u$, $e_T$, $e_P$, $e_g$, $e_n$, $\bar{\pi}_0$, $\bar{\pi}_T$ and $U$. This system can be solved numerically using Newton's method.

*The wage equations:*

When the system is solved, it is possible to recover the Nash wage equations for new and pre-existing permanent contracts by substituting (2.3) and (2.6) into (2.13). With a binding minimum wage for new permanent contracts, the equilibrium wage functions are $\omega_0(\pi) = \bar{\omega}$ for all $\pi \in [\bar{\pi}_0, 1]$ and $\omega_1(\pi) = \omega_1^N(\pi)$ for all $\pi \in [\bar{\pi}_1, 1]$. Even if $\bar{\omega}$ is binding for all new permanent contracts, the Nash wage equation $\omega_0^N(\pi)$ gives the shadow wage that would occur if wages were freely contractible, given the surplus at equilibrium. The Nash wage equations are written:

$$\omega_I^N(\pi) = b + (1-\beta)U + \gamma S_I(\pi) - \beta(1-\lambda)\left[\alpha\pi\gamma S_1(1) + (1-\alpha)\gamma S_1(\pi)\right].$$

Similarly, it is possible to recover the wage equation for temporary contracts by substituting (2.2) and (2.5) into (2.12). Since the minimum wage does not bind for temporary contracts, $\omega_T(\pi) = \omega_T^N(\pi)$, and the wage equation is written as follows:

$$\omega_T^N(\pi) = b + (1-\beta)U + \gamma S_T(\pi) - \beta(1-\lambda)\left\{\alpha\pi\left[W_0(1) - U\right] + (1-\alpha)\gamma S_T(\pi)\right\}.$$

## 2.5 Calibration

### 2.5.1 Parameter values

The model is calibrated to the Italian labor market in 1996, just before the first wave of major reforms of temporary contracts, which took place in 1997. The calibration strategy assumes that both Italy and the US share the same technology and the same process of learning about match quality. Alternatively, this assumption implies that any difference in the functioning of the two labor markets stems from different labor market institutions, namely firing costs, minimum wages, unemployment benefits and the degree of liberalizations of temporary contracts. In the special case in which $d = 0$, the minimum wage is no longer

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binding, temporary and permanent contracts become equivalent, and the equilibrium of this model collapses to the one in the benchmark economy of Pries and Rogerson (2005). The calibration strategy therefore allows me to use several parameter values which were calibrated in their paper to match US stylized facts.[6]

One period of time in the model equals one month in the calibration. Following Pries and Rogerson (2005), the distribution function for $\pi$ is obtained from a normal with zero mean and standard deviation $\sigma$, truncated below zero and above one and re-scaled to integrate to 1 in the support. The parameter values used for the benchmark calibration are represented in the following table:

| | | | |
|---|---|---|---|
| $\sigma$ | .32 | $A$ | .4 |
| $\alpha$ | .13 | $\eta$ | .5 |
| $y_b$ | 1 | $\gamma$ | .5 |
| $y_g$ | 1.9 | $\lambda$ | .0085 |
| $b$ | 1 | $\phi$ | .278 |
| $\beta$ | .9966 | $d$ | 5.16 |
| $c$ | .249 | $\bar{\omega}$ | 1.22 |

Table 2.1: Calibrated parameter values

The parameters $\sigma$ and $\alpha$ are crucial, since they capture the process of learning about match quality. Their values, $\sigma = .32$ and $\alpha = .13$, were calibrated by Pries and Rogerson (2005) in order to match relevant statistics estimated by Pries (2004) for the US labor market. Since the results of the calibration are left unchanged if $y_b$, $y_g$, $b$, $c$, $\bar{\omega}$ and $d$ are all multiplied by a constant value, the value of productivity in the bad state, $y_b$, can be normalized to one. $y_g$ is set to 1.9, as in Pries and Rogerson (2005). The spread in productivity was backed up to match the percentage spread between the lowest and the highest wage observed at the equilibrium with estimates by Topel and Ward (1992) on the wage increases associated with job changes in the US. The discount factor $\beta$ is set to match an annual interest rate of 4%.

Following a common practice in the literature, the matching function is assumed to be Cobb-Douglas, with the explicit functional form $M(v,u) = Au^{\eta}v^{1-\eta}$. Both the elasticity of the matching function with respect to unemployment, and the bargaining power of the

[6] More precisely, in the case of $d = 0$ and $\phi = 0$, a minor difference with respect to the bechmark model of Pries and Rogerson (2005) remains. As opposed to their paper, in this model I abstract from fixed costs of opening vacancies since I am not interested in distinguishing between job flows and worker flows. However, this detail is irrelevant for what concerns the calibration. With respect to the benchmark calibration of Pries and Rogerson (2005), a version of the model without vacancy fixed-costs simply requires setting the vacancy flow cost to .298; all other parameters must remain unchanged to match the same stylized facts.

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workers are set to .5. These parameters are selected in order to preserve comparability with Pries and Rogerson (2005) and with most of the literature in this field. The constant of the matching function is set to .4 also in accordance with Pries and Rogerson (2005). Yet, as pointed out by Shimer (2005), matching models of the labor market offer a degree of freedom in the choice of the constant of the matching function, as there exist infinite combinations of that constant with the flow cost of a vacancy which leave the equilibrium of the labor market unchanged.

The exogenous job destruction rate $\lambda$ is set to .0085 as in Pries and Rogerson (2005), implying a yearly job destruction rate of about 10%. As shown by Bertola and Rogerson (1996), the yearly job destruction rate is about 10% both for Italy - and more in general for most European countries - and for the US. The value for the cost of a vacancy is set to .249, in order to match an unemployment rate of 11.3%, as in Italy in 1997.

The value for the disutility of the working activity, $b$, is normalized to 1, implying that bad matches are severed at equilibrium. It is easy to show that in this setting an increase in the unemployment benefits, or in the value of leisure is equivalent to an increase in $b$ (Mortensen and Pissarides, 1999). If interpreted only as unemployment compensation, this value for $b$ implies a replacement ratio with respect to the average wage of about 58%. Selecting an appropriate value for the replacement ratio is often controversial, since $b$ includes, besides unemployment benefits, also non measurable entities such as the disutility and the opportunity cost of the working activity. In the literature, values for the replacement ratio in the US have been used, which range from 40% (Shimer, 2005) to 98.8% (Hagedorn and Manovskii, 2007). Costain and Reiter (2008) argue that an intermediate value of about 75% is more appropriate and consistent with the estimated elasticity of the unemployment rate to unemployment benefits for the OECD countries. As shown by Table 2.4 in the Appendix, Italy is characterized by a very low level of unemployment benefits. A somewhat lower value of 58% for Italy might therefore be appropriate. Moreover, changes in the value of $b$ show that the normalization in the benchmark parametrization is not essential for the quantitative conclusions.

The level of firing costs, $d$, is set to equal three months of the average wage observed in the equilibrium. Although there are no direct estimates for administrative costs of dismissal, this value for $d$ is often used to represent an average European country. Three months is a conservative choice in this framework since the higher the level of firing costs, the stronger the quantitative impact of temporary contracts. The values for the dismissal cost used in the literature to represent a Mediterranean country range from six weeks (Nagypal, 2002), to six months (Blanchard and Portugal, 2001), or even one year and a half (Blanchard and

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Landier, 2002).

In Italy, a set of minimum wages is determined in sectorial collective arrangements, and is then extended to all employers who were not parties to the original agreement. Therefore, as opposed to other countries in Europe, there does not exist a single minimum wage. Dolado et al. (1996) report values of the Kaitz index for many OECD countries. This index measures the ratio of the minimum wage to the average wage, weighted by the fraction of workers covered by the agreements, and it is used in this calibration to pin down a value for $\bar{\omega}$. As it is possible to see from Table 2.4 in the Appendix, the Kaitz index measured for Italy is higher than for other OECD countries. Finally, the last parameter to set in the calibration, the value of $\phi$, is targeted to match a share of temporary contracts equal to 7.5%, as in Italy, prior to the reforms of 1997.

### 2.5.2 Quantitative analysis

*The benchmark economy:*

I begin this section by judging how well the model in the benchmark parametrization performs along some important dimensions which are not a direct target of the calibration exercise. A crucial statistic to appraise the performance of the model is the transition rate from temporary contracts into permanent contracts. The hypothesis that firms use temporary contracts as instruments of churning policies was indeed criticized for implying excessively low transformation rates. On the other hand, excessively high transformation rates might shed doubts on the assumption that Europe and US share the same learning technology.

The model was therefore simulated generating 100 repetitions of 100000 employment-unemployment paths for a worker starting in a temporary job. It was found that a temporary worker has a probability of 41.3% to be employed in a permanent contract one year later.[7] The 95% confidence interval around the mean ranges from 41% to 41.65%. Calculations reported by the (OECD, 2002), based on the European Community Household Panel show that exactly 41.3% of temporary workers in Italy in 1996 had moved into permanent job positions one year later. For most European countries the same transition probabilities range from about 36% to 56%, with only two notable exceptions: Spain, 23.1% and France, 20.8%. Such a low degree of upward mobility in these two countries looks like an exception in the European scenario and suggests that alternative forces leading to market segmentations could be dominant.

The contact finding rate for a worker in the model economy is .47 per month. This

[7] See footnote 2.

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| | Benchmark | Post-Reforms |
|---|---|---|
| $\phi$ | 0.278 | 0.744 |
| $e_T/(e_T+e_P)$ | 0.075 | 0.13 |
| $\bar{\pi}_T$ | 0.16 | 0.20 |
| $\bar{\pi}_0$ | 0.44 | 0.51 |
| $1-H(\bar{\pi}_T)$ | 0.62 | 0.54 |
| $1-H(\bar{\pi}_0)$ | 0.17 | 0.11 |
| Wage gap | 0.21 | 0.21 |
| Productivity gap | 0.27 | 0.29 |
| Productivity change | 0 | 0.02 |
| Annual worker turnover (%) | 50 | 62 |
| Contact finding rate | 0.47 | 0.60 |
| Unemployment rate | 0.113 | 0.069 |
| Output | 1.63 | 1.70 |
| Output change (%) | 0 | 4.2 |

Table 2.2: Simulated results for the labor market reforms in Italy

value is close to the monthly job finding rate of .48 measured by Hall (2005) for the US. However, in this framework, the job finding rate does not depend uniquely on the contact finding rate, but also on the average probability of passing the hiring test. At the calibrated equilibrium, the acceptance rates for temporary and permanent positions is .62 and .17, respectively. As expected, the absence of dismissal costs for temporary contracts increases the willingness of the firms to experiment new workers, lowering the threshold value of expected productivity required for hiring. The job finding rate is .14 at equilibrium, implying an average unemployment duration of 7.3 months.

Since hiring practices are less selective for workers employed on temporary positions, temporary workers are on average less productive than permanent workers, and earn lower wages. The wage gap implied by the calibration is about 21%, and reflects a productivity gap of about 27%. The OECD (2002) reports that in 1997 the wage penalty for temporary workers in Italy was about 28%. Controlling for worker and job characteristics, the wage penalty decreases to 13% in Italy, and is ranging between 6% and 24% in Europe, with an average value of 15%. The wage gap implied by the model seems somewhat larger than in the data.

The performance of the model is also consistent with evidence on the dynamic relative

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wage profile for temporary and permanent workers. Having assumed that heterogeneity is only match specific implies that any temporary worker will sooner or later be employed in a high productivity permanent match. Consequently, temporary workers are expected to catch up completely with the wages earned by workers on permanent positions. This is consistent with the results of Booth et al. (2002) in a study on the British labor market. They find that the wage gap between workers who start working on temporary and permanent contracts substantially tapers off with full-time work experience. In particular, women who start in fixed-term employment and move to permanent jobs are found to fully catch up to those who start in permanent jobs.

Following the standard practice, I compute the gross annual worker turnover rate by multiplying the monthly turnover rate by 12. The monthly turnover rate is in turn computed as the sum of employment entry and exit rates, where a transition from a temporary to a permanent position is recorded as a simultaneous entry and exit. The gross annual worker turnover rate implied by the model is about 50 percent. In the data, Contini (2006) find a turnover rate of about 62 percent in Italy, for the period 1986-1999. If transitions from temporary to permanent contracts are not recorded, the turnover rate implied by the model is about 42 percent. Accounting for these types of transitions can therefore improve the fit of the model, which is able overall to capture a large fraction of the measured turnover rate.

*Comparative statics:*

I now turn to evaluate how well the model is able to replicate the performance of the Italian labor market in the last decade following the reforms of temporary contracts. As it is possible to see from Figure 1 in the Appendix, the unemployment rate decreased, in these ten years, from 11.3% in 1996 to 6.8% in 2006, while the share of temporary contracts increased over the same period from 7.5% to 13%. A simple exercise of comparative statics is then performed, in which the strictness of the regulation on temporary contracts is reduced in order to match a share of 13% in the total stock of contracts. The results of this exercise are summarized in Table 2.2.

The exercise is particularly successful at reproducing the pattern of the unemployment rate in Italy, which decreases to 6.9% following the reforms. The intuition for the decrease in unemployment is straightforward. When the share of temporary contracts in the economy is increased, screening workers on the job is less costly, on average, and more firms enter the market. A higher entry of firms together with a higher experimentation of workers in temporary contracts both contribute to increase the rate of exit from unemployment. In turn, this decreases both the rate and the duration of unemployment.

The exercise also predicts an increase in productivity of about 2%. The intuition is

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as follows. An increase in the share of temporary contracts generates two opposite effects on productivity. Since temporary workers are less productive than permanent workers, increasing their share will tend to decrease average productivity. However, as the expected cost of screening workers on the job decreases with the share of temporary workers, labor market tightness increases, and the combined outside option of workers and firms increases. In turn, this reduces the surplus of a match and translates into a higher threshold value of expected productivity required to form both temporary and permanent matches. This effect, which leads to lower acceptance rates and higher productivity, is found to dominate at the calibrated equilibrium, and proves robust to changes in the value of dismissal costs.

Given that total employment also increases at equilibrium, welfare, measured as total output in the economy, increases by 4.2%. If we consider the lifetime discounted value of search as an alternative measure of welfare, then welfare raises by 7.7%. This increase is due to lower unemployment duration, which in turn is triggered by higher contact rates, and by higher chances to pass the hiring test. Overall, the calibration clearly suggests that welfare gains derived from using temporary contracts as a screening device might be large, depending on firing restrictions on permanent positions and on the length of probationary periods. Given the process of learning about match quality estimated by Pries (2004), it takes more than seven months, on average, to discover the productivity of a worker. The probability that the true productivity of a match is still unknown after three months is about 66%, and after six months about 43%. Without access to temporary contracts, trial periods of three months, or six months, which are common across European countries, might therefore be too short to allow for an efficient reallocation of workers across existing jobs.

By generating a higher experimentation of workers in the economy, temporary contracts lead to a higher turnover rate, which is close to 62% in the calibration. The reason is that a higher share of temporary contracts increases both rejections of bad matches, and transformations into permanent employment. Finally, while the productivity gap increases by about 2%, the wage gap is not substantially affected by the reforms. The elasticity of the wage gap with respect to the productivity gap is only 5% at the calibrated equilibrium. The intuition is that the firm-worker pair in a temporary match has an option value on a permanent relationship which is exerted if the match turns out to be good. An increase in the productivity of permanent workers, raising the surplus of a permanent match, will then translate into an increase of the surplus of a temporary match. With Nash bargaining, both wages will then increase.

*The interactions of temporary contracts, dismissal costs, and the minimum wage:*

The results indicate that so long as temporary contracts are used as a screening device,

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| | Flexible wage Pre-reforms | Flexible wage Post-reforms |
|---|---|---|
| $\phi$ | 0.393 | 0.765 |
| $e_T/(e_T+e_P)$ | .075 | .13 |
| $\bar{\pi}_T$ | 0.12 | 0.14 |
| $\bar{\pi}_0$ | 0.24 | 0.26 |
| $1-H(\bar{\pi}_T)$ | 0.71 | 0.67 |
| $1-H(\bar{\pi}_0)$ | 0.45 | 0.41 |
| Wage gap (%) | 0.15 | 0.16 |
| Productivity gap | 30.0 | 30.5 |
| Productivity change | 0 | 0 |
| Annual worker turnover (%) | 56.6 | 64.9 |
| Contact finding rate | 0.29 | 0.30 |
| Unemployment rate | .113 | .104 |
| Output | 1.61 | 1.62 |
| Output change (%) | 0 | 0.6 |

Table 2.3: Simulated results for a flexible wage economy

their introduction in an economy with both firing costs and a minimum wage can have strong implications in terms of unemployment, productivity and welfare. In order to disentangle how dismissal costs and the minimum wage interact with each other, and how the two together in turn interact with temporary contracts, I calibrate, following the same procedure outlined above, a version of the economy with flexible wages. Next, I perform the same exercise of comparative statics in order to assess how much the minimum wage matters when temporary contracts are introduced in an economy with dismissal costs. The results are reported in Table 2.3.

If flexible wages are introduced in an economy otherwise identical to the one in the benchmark parametrization, the unemployment rate drops to 6.7%. It is therefore clear that the interaction of dismissal costs with the minimum wage has a strong negative effect on job creation. The intuition is simple: with Nash bargaining, wages in the first period adjust in order to equally split the burden of future firing costs between the parties. If such a transfer of resources from the worker to the firm is prevented, the negative impact of firing costs on expected profits is larger, and thus entry is lower. In order to match an initial unemployment rate of 11.3% in the model with flexible wages, the vacancy cost must then be increased to

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1. Furthermore, $\phi$ must be set to 0.393 to match a share of temporary contracts of 7.5% when all the other parameter values are left unchanged with respect to Table 2.1.

The strong increase in the vacancy posting cost with respect to the benchmark calibration implies a lower contact finding rate. Given that with a low contact rate the combined outside option of both workers and firms is lower, the threshold values for $\bar{\pi}_T$ and $\bar{\pi}_0$ are also lower, implying higher acceptance rates. When the share of temporary contracts is increased to 13%, the impact on productivity is negligible, output increases by only 0.6%, and the unemployment rate decreases by only 1%. With respect to the benchmark calibration, an economy with flexible wages can barely reproduce one fifth of the drop in the unemployment rate. The interaction between firing costs and the minimum wage is therefore crucial to account for the behavior of the Italian labor market following the reforms. In general, it seems that if temporary contracts are used as a screening device, labor market reforms enhancing flexibility at the margin can reverse most of the negative effects associated with employment protection, and with its interaction with the minimum wage.

In the case in which $d = 0$, the minimum wage is not binding and does not affect the equilibrium of the labor market. As firing costs increase, the wage bargained in the first period of a permanent relationship decreases, and the minimum wage eventually becomes binding. Therefore, in the model economy, minimum wages have no direct effect on the equilibrium, but only an indirect effect through the interaction with dismissal costs. Minimum wages affect the economy to the extent that they set an upper bound on the transfer of resources that can take place in the first period of a relationship. The higher the minimum wage, the stronger the impact of temporary contracts. However, reasonable changes in the minimum wage with respect to the value set in the benchmark calibration do not substantially affect the quantitative result.

## 2.6 Discussion

Numerical solutions of the model show that the effects produced by the introduction of temporary contracts hinge on labor market institutions. If screening workers for permanent positions is the main reason why firms use these types of contracts, liberalizing their use increases productivity and welfare and decreases the unemployment rate so long as firing workers with permanent contracts is costly. In general, the higher the dismissal costs, the higher the benefits associated with a reduction of employment protection at the margin. Moreover, the existence of a minimum wage strongly magnifies the negative effects associated with employment protection. Since the introduction of temporary contracts can reverse most of these effects, their impact on the economy will therefore be stronger in connection with a

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strong minimum wage legislation.

These results were also obtained under the assumption that firing costs are a pure resource waste. This is probably the most conventional way of modeling firing costs, although it is not unique. Alternatively, dismissal costs can be modeled as severance payments. In this case firing costs are simply a transfer of resources from the firm to the employee in case of dismissal. It is well-known that with flexible wages, severance payments have no impact on the labor market equilibrium since a transfer of resources conditional on a separation does not affect the size of the surplus. With flexible wages and severance payments, wages in the first period of a relationship adjust in order to fully compensate firms for future expected dismissal costs, without altering their incentives to enter the market. Yet, in the presence of a minimum wage, this transfer cannot take place, entailing a negative effect on job creation. The choice of modeling firing costs as a pure waste of resources is therefore not essential for the results.

It was noted that in the case in which $d = 0$, temporary contracts have no impact on the labor market equilibrium. Obviously, if there are no firing costs on permanent positions, temporary contracts and permanent contracts are equivalent in this setting, and there are no gains that can be obtained through screening workers for permanent positions. Thus, in an economy with no firing restrictions, such as the US, there is no reason why firms should resort to temporary contracts to screen workers. This can explain why temporary contracts are found to be a port of entry into regular employment in Europe, but not in the US.

A common result in the literature on temporary contracts is that enhancing flexibility at the margin is a second best solution, the first best being a reduction in firing costs. This holds true also in this framework, as long as some waste of resources is associated with firing permanent workers. Even in the case of $\phi = 1$, when only good workers are hired for permanent positions, the exogenous source of job destruction is still costly for the matched worker-firm pair, and is therefore a source of welfare drain.

The mechanism highlighted in this paper reverses some of the conclusions obtained through the standard models of temporary contracts, helping to reconcile the theory with the empirical evidence. However, the main policy implications remain in line with the common opinion expressed in the current debate. It cannot be excluded that some part of the workforce, of debatable magnitude, might be harmed by the introduction of temporary contracts, and remain trapped in recurring spells of temporary employment and unemployment. Several economists have therefore proposed replacing various chategories of temporary contracts with a unique permanent contract with extended probation. This view could be shared also in the light of this paper, as all the gains that arise through temporary contracts could

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likewise be generated by extended probationary periods on permanent positions.

## 2.7 Conclusions

A growing body of empirical evidence has recently documented that in most European countries, temporary contracts play a fundamental role in the labor market as a screening device. For the case of Portugal, Varejao and Portugal (2003) show that screening workers for permanent positions is the single most important reason why firms use these types of contracts. This paper presents a framework which embeds the screening hypothesis into an equilibrium model of the labor market. The aim is to understand how temporary contracts interact with other labor market institutions, and how they affect the labor market equilibrium and welfare.

The model can account for the relatively high mobility rates into permanent employment measured for most European countries, and for the recent empirical findings indicating that temporary contracts correlate positively with employment at the European level. These results are important since models assuming that firms use temporary contracts as instruments of churning policies have opposite predictions. Models which assume that firms use temporary contracts as buffer stocks are instead inconclusive on the long-run effects on employment and unemployment, and are unsuited to study the transition rates.

The paper also shows that when temporary contracts are used as a screening device, they can substantially increase both productivity and welfare. Temporary contracts can thus reverse most of the negative effects associated with employment protection, and with its interactions with the minimum wage. The calibration of the model can account for salient statistics of the Italian labor market, including the transition probabilities, the worker turnover rate, the wage gap between temporary and permanent workers and the drop of the unemployment rate, following the reforms.

The model presented in this paper isolates a single mechanism through which temporary contracts generate welfare gains. However, this story captures only a part of the whole picture. On the other hand, it is found that firms offer less training to temporary workers. By affecting the expected duration of a relationship, temporary contracts might presumably also influence workers' investment in firm-specific human capital. It is possible that in European labor markets, where systems of payment based on performance are scarce, employment protection provides an alternative incentive to exert effort, and invest in firm-specific human capital. Investigating how reductions of employment protection affect the pattern of human capital accumulation, is beyond the scope of this paper, and remains an important question to explore in future research.

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## 2.8 Figures and Tables

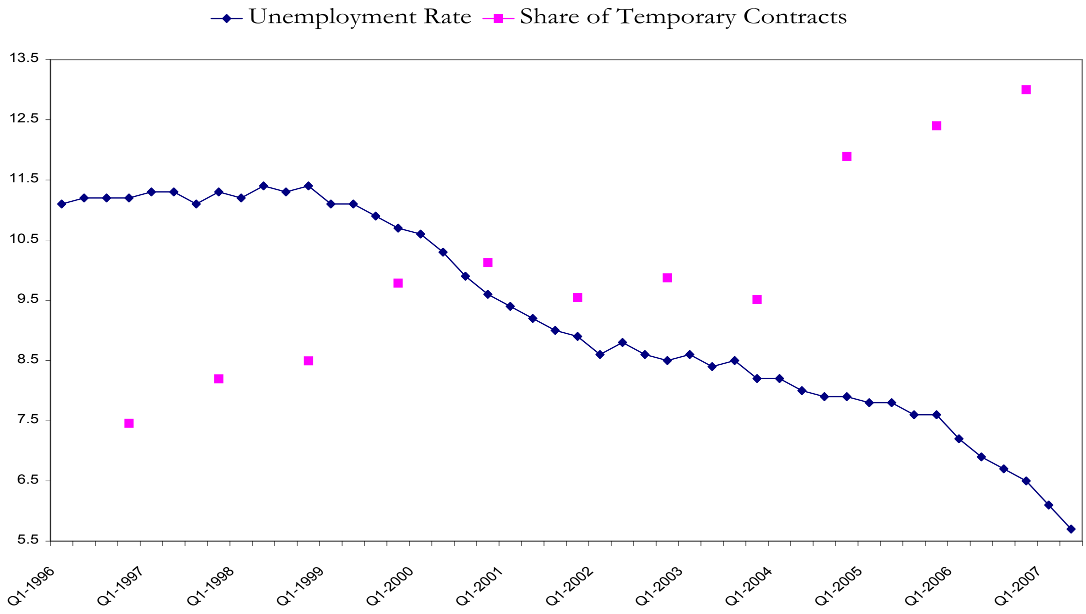


*Figure 1*: Share of Temporary Contracts and Unemployment Rate in Italy. 1996-2007

| Country | EPL Strictness | Kaitz index | Replacement ratio |
|---|---|---|---|
| United States | 0.7 | .39 | .50 |
| United Kingdom | 0.9 | .40 | .38 |
| Denmark | 1.5 | .54 | .90 |
| Finland | 2.1 | .52 | .63 |
| Sweden | 2.6 | .52 | .80 |
| Germany | 2.6 | .55 | .63 |
| France | 2.8 | .50 | .57 |
| Spain | 3.1 | .32 | .70 |
| **Italy** | **3.4** | **.71** | **.20** |
| Portugal | 3.7 | .45 | .65 |

Table 2.4: Sources: OECD (1999,table 2.5, pp.62) and Dolado et al. (1996)

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# CHAPTER 3

# LABOR MARKET VOLATILITY IN THE SEARCH AND MATCHING MODEL: THE ROLE OF INVESTMENT-SPECIFIC TECHNOLOGY SHOCKS

## 3.1 Introduction

[1]In the last few years, a large and active literature has emerged around the unemployment volatility puzzle. More precisely, this literature assesses the extent to which the search-and-matching model with Nash wage bargaining can account for the following three observations: 1) large fluctuations in labor market variables relative to the fluctuations of labor productivity; 2) low sensitivity of unemployment with respect to unemployment benefits, and 3) a high correlation between wages and productivity in new matches.

Shimer (2005) and Costain and Reiter (2008) have shown that the textbook version of the Mortensen-Pissarides model is unable to generate the observed relative fluctuations in labor market variables in response to shocks to labor productivity. The failure of the model is to be found in the surplus' sharing rule implied by Nash bargaining. That is, wages absorb most of the increases in labor productivity, thus reducing the procyclicality of the firm's share of the surplus and so the incentive for vacancy creation. Costain and Reiter (2008) and Hagedorn and Manovskii (2008) note that a different calibration of the model can generate large fluctuations in labor market variables. Indeed, with high, acyclical non-market returns to workers and low workers' bargaining power, wages become relatively rigid and the firm's share of surplus more procyclical, restoring the firm's incentives to create vacancies. However, as pointed out by Costain and Reiter (2008) and by Pissarides (2008), this calibration strategy implies a counterfactually high sensitivity of unemployment to non-market returns. A different line of research has advocated for the replacement of continuous Nash wage bargaining by some stickier sharing rule. Gertler and Trigari (2007), among others, propose wage stickiness à la Calvo. Hall (2005) argues in favor of efficient wage stickiness where wages do not react, or only partially, to high-frequency changes in labor productivity.[2] Objections to models with sticky wages have been raised by Pissarides (2008)

[1]This paper is a joint work with my supervisor Salvador Ortigueira.
[2]Different sources of wage rigidity in the search-and-matching model have been studied e.g. by Hall and



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and Haefke, Sonntag and van Rens (2008) by arguing that they fail to generate the high correlation between wages and productivity observed in new matches.

In this paper, we retain the assumption of continuous Nash renegotiation of wages and contribute to this literature by endogenizing labor productivity to the firm's investment and hiring policy. With this aim, we remove the assumption of employer-worker pairs producing without capital and assume instead the standard neoclassical firm that employs many workers and owns capital.[3] We then explore the ability of the model to amplify the volatility of labor market variables after shocks to both neutral and investment-specific technology. We model this latter type of technology as in Greenwood, Hercowitz and Krusell (1997, 2000) which allows us to calibrate investment-specific technology shocks using the cyclical component of the relative price of new capital goods. In our model economy, job separations within the firm occur exogenously and capital depreciates at a constant rate. To hire workers the firm must open vacancies and then negotiate wages for new and continuing workers. Adjusting the level of capital and employment is costly and these costs are jointly determined by investment and hiring rates. An important consequence of the large firm assumption is the so-called intra-firm bargaining, that is, the fact that the firm anticipates the wage effects of its hiring and investment policy.[4] By virtue of intra-firm bargaining, the wage function in our model becomes increasing in the level of neutral technology and decreasing in investment-specific technology.

In our calibrated economy, shocks to investment-specific technology account for 40 percent of the observed volatility in U.S. labor productivity. Moreover, these shocks generate relative volatilities in vacancies and the workers' job finding rate which match those observed in U.S. data. Relative volatilities in unemployment and labor market tightness are 55 and 75 percent of their empirical values, respectively. In other words, from this quantitative exercise we conclude that 40% of the volatility in labor productivity explains 22% of the observed volatility in unemployment, 40% of the volatility in vacancies, 30% of the volatility in tightness and 40% of the volatility in the job finding rate. These numbers are about one order of magnitude higher than those obtained by Shimer (2005) within the textbook version of the Mortensen-Pissarides model.

The mechanism for amplification in our economy works through the costly adjustment of capital and labor and its effect on the intra-firm bargained wage. There are two main forces shaping the response of vacancies to investment-specific technology shocks. In the first place,

Milgrom (2008), Kennan (2006), Menzio (2005), Moen and Rosen (2006) and Rudanko (2008).

[3] For early work on the search-and-matching model with large firms see Andolfato (1996) and Merz (1995).

[4] See Stole and Zwiebel (1996a, 1996b) for a general discussion of intra-firm bargaining. For studies of intra-firm bargaining within the search-and-matching model see, e.g., Cahuc and Wasmer (2001), Krause and Lubik (2007) and Rotemberg (2006).

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the firm needs to spread out the convex adjustment costs over time, which creates a tension between investment and hiring leading to a contraction in hiring. The second force comes from the compressing effect of these shocks on wages, which increases the procyclicality of the firm's share of the surplus with respect to these shocks and leads to an increase in hiring. We will elaborate further on this in the main text of this paper.

The increased volatility in labor market variables in our model economy is not at the cost of a counterfactually high sensitivity of unemployment to unemployment benefits. Since we calibrate the model to match a replacement rate of 45 percent, non-market returns are low compared to returns from employment. In our benchmark economy, the semi-elasticity of unemployment with respect to benefits is slightly above one, which is in the lower bound of estimated values. On the other hand, the correlation between wages and labor productivity in our economy with investment-specific technology shocks is 0.9, a value which is in line with the correlation estimated in new matches.

The way we introduce investment-specific technological change in our model economy closely follows the original idea of technology embedded in new investment goods, which the firm can acquire by devoting resources to investment. As in Greenwood, Hercowitz and Krusell (1997, 2000), we allow the firm to continuously invest in new capital, in contrast to the Schumpeterian view where only newly created firms have access to new technologies, with all its implications in terms of employment reallocation. In this regard, the mechanism we explore in this paper to generate volatility in labor market variables after shocks to investment-specific technology is different from the ones put forward recently by Reiter (2008), Hornstein, Krusell and Violante (2007) and Michelacci and Lopez-Salido (2007). Reiter (2008) abstracts from capital and retains the assumption of employer-worker pairs. This author models embodied technical change by assuming that the exogenous process for labor productivity has a permanent match-specific component. Hornstein, Krusell and Violante (2007) introduce capital into the employer-worker pair but assume that firms in an existing match can never adjust their capital stock in response to a change in the environment. In these two works, amplification in unemployment and vacancies is at the cost of an excessive volatility in wages. Michelacci and Lopez-Salido (2007) are interested on the effects of neutral and investment-specific technical change on job flows, especially on job destruction. They assume that while newly created jobs embody the most advanced technologies, existing jobs fail to upgrade their capital. They find that advances in investment-specific technology reduce job destruction.[5]

[5] Other papers with investment-specific technology shocks are Silva and Toledo (2007) and De Bock (2007). These authors assume that the output produced by a job within the firm is independent of the number of workers in the firm. Their setting does not generate amplification in labor market variables in response to

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Finally, the work of Elsby and Michaels (2008) and Yashiv (2008) also use the assumption of large firms, but they abstract from capital and from investment-specific technology. These authors study labor market volatility by introducing idiosyncratic labor productivity shocks.

The remainder of the paper is organized as follows. In Section 2 we lay out our search-and-matching model with large firms, we define the search equilibrium and derive the wage function for the parameterized economy. In Section 3 we carry out our quantitative analysis and assess the amplification of unemployment, vacancies, tightness and the job finding rate after shocks to neutral and investment-specific technology. This Section also addresses the sensitivity of unemployment to unemployment benefits and Section 4 concludes.

## 3.2 The Model

### 3.2.1 The labor market

There is a measure one of identical, risk-neutral workers and an equal measure of firms. Unemployed workers search for jobs and firms open vacancies in a frictional labor market. The total number of matches per period, $\mathcal{M}$, is given by an increasing, concave and homogeneous-of-degree-one matching function,

$$\mathcal{M} = \mathcal{M}(V, 1 - N),$$

where $V$ denotes the total number of vacancies created by all firms and $1 - N$ is the number of unemployed workers.

The vacancy matching rate, $\mu$, is thus given by $\mathcal{M}/V$, and the job-finding rate of an unemployed worker is $\mathcal{M}/(1 - N) = \theta\mu$, where $\theta$ denotes labor market tightness $V/(1 - N)$.

### 3.2.2 Firms

The production sector is described by a measure one of value-maximizing firms facing an infinite time horizon. Firms produce an identical, aggregate good with a production technology given by $F(z, k, n)$, where $k$ denotes capital, $n$ is the firm's level of employment and $z$ is the level of neutral technology. Function $F$ is assumed to be increasing, jointly concave and linearly homogeneous in capital and labor. Firms own the capital stock and thus both capital and labor are predetermined variables.

In a given period, the firm loses employment at the exogenous, stochastic rate $\lambda$, whose evolution is specified below, and it opens vacancies to hire new workers. Newly hired workers start producing in the next period. Firms expect vacancies to be matched with workers at

investment-specific shocks.

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the rate $\mu(S)$, where $S$ denotes the vector of aggregate state variables [we will use "small" $s$ to denote the vector of firm-level state variables]. The cost to the firm of advertising $v$ vacancies is given by the convex function $C(v)$. The evolution of employment within the firm is given by,

$$n' = \mu(S)v + (1 - \lambda)n. \tag{3.1}$$

The stock of capital depreciates at the constant rate $\delta$. The assumption of investment-specific technical change implies that one unit of the aggregate good invested in capital increases its stock by $q$ units. That is, the evolution of capital is,

$$k' = iq + (1 - \delta)k, \tag{3.2}$$

where $i$ denotes gross investment. Thus, factor $q$ represents the level of investment-specific technology, which is assumed to follow an exogenous, stochastic process. This particular modeling was first used by Greenwood, Hercowitz and Krusell (1997, 2000) in order to assess the role of investment-specific technical change in generating both postwar U.S. growth and U.S. aggregate fluctuations. Since $1/q$ is the relative price of capital, we will use de-trended price series to derive the volatility and persistence of the technology process $q$.

Accommodating $\mu v$ new workers and $iq$ units of new capital within the firm is costly. We assume that adjustment costs of labor and capital interact and represent total adjustment costs by the function $H(v, i, s, S)$, where $s = (z, q, \lambda, k, n)$ and $S = (z, q, \lambda, K, N)$ are the vectors of individual and aggregate state variables, respectively. Function $H$ is convex with $H_v > 0$, $H_i > 0$, $H_k < 0$ and $H_n < 0$, for $k > 0$ and $n > 0$. The assumption of interrelation between labor and capital adjustment costs implies that $H_{kn} \neq 0$. We will provide evidence supporting assumption below.

The firm's objective is the maximization of the present value of cash flows. First, the firm opens vacancies and invests in capital. Next, wages for new hires and existing workers are negotiated.[6] The standard Nash-bargaining solution is assumed. Since the firm is large —i.e. it employs a mass of workers— negotiated wages will depend on the firm's hiring and investment policy. Intra-firm bargaining implies that the firm anticipates the wage effects of its policy. Thus, if we denote by $\omega(v, i, s, S)$ the wage function that solves the wage bargaining problem of a firm that opened $v$ vacancies and invested $i$ in new capital, at

[6] This timing for investment is not relevant for our results. We carried out the analysis assuming that investment is decided upon simultaneously with wage negotiations and found no significant differences.

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individual and aggregate states $s$ and $S$, then the maximization problem of the firm is,

$$\begin{aligned}
\Pi(s,S) &= \max_{v,i} \{F(z,k,n) - \omega(v,i,s,S)n - i - C(v) - H(v,i,s,S) + \beta : \mathbb{E}[\Pi(s',S')|z,q,\lambda]\} \\
s.t. & \\
& \text{equations} : (3.1) \text{ and } (3.2) \\
& \ln z' = \rho_z \ln z + \epsilon_z \qquad (3.3) \\
& \ln q' = \rho_q \ln q + \epsilon_q \qquad (3.4) \\
& \ln \lambda' = (1-\rho_\lambda)\ln\hat{\lambda} + \rho_\lambda \ln \lambda + \epsilon_\lambda \qquad (3.5) \\
& (\epsilon_z, \epsilon_q, \epsilon_\lambda)^T \sim N(0,D), \text{ where } D \text{ is a diagonal matrix,} \qquad (3.6)
\end{aligned}$$

where $\Pi(s,S)$ is the value of the firm and where aggregate state variables are expected to evolve according to some function of the current levels. The firm discounts future cash flows at the rate $\beta$, which is the same rate risk-neutral workers use to discount income. Parameters $\rho_z$ and $\rho_q$ denote persistence of the neutral and investment-specific technology processes, respectively; $\hat{\lambda}$ and $\rho_\lambda$ denote the average and the persistence of the job separation rate, respectively. Vector $(\epsilon_z, \epsilon_q, \epsilon_\lambda)^T$ denotes the respective innovations with variance matrix $D$.

It should be noted that the concavity of the production function and the convexity of the adjustment cost and vacancy cost functions do not guarantee the concavity of the firm's maximization problem. Since the firm foresees the wage function that will solve the Nash-bargaining problem with the workers, the maximization problem may be non-concave. We will argue below that in our benchmark economy first-order conditions are necessary and sufficient.

The first-order condition to vacancies can be written as,

$$\omega_v n + C_v + H_v = \mu\beta\mathbb{E}\,\Pi'_n, \qquad (3.7)$$

where function arguments have been omitted as there is no risk of ambiguity. $\omega_v$ denotes the derivative of $\omega(v,i,s,S)$ with respect to vacancies; $C_v$ is the derivative of the vacancy cost function; $H_v$ is the derivate of the adjustment cost function with respect to $v$, and $\Pi'_n$ is the derivative of the value function with respect to employment, evaluated at next-period values. The term $\omega_v n$ on the left-hand side of (3.7) is a consequence of the assumption of large firms conducting intra-firm bargaining. The effect of vacancies on wages, *via* adjustment costs, is internalized by the firm when opening vacancies. That is, the firm takes into account the change in total wage costs, $\omega_v n$, when determining its hiring policy.

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The first-order condition to investment is given by,

$$\omega_i n + 1 + H_i = q\beta \mathbb{E}\, \Pi'_k. \tag{3.8}$$

As with vacancies, the firm also weighs the effect of investment on total wage costs, $\omega_i n$, when setting the level of investment. From the envelope condition, the value of capital for the firm, $\Pi_k$, satisfies the following non-arbitrage condition,

$$\Pi_k = F_k - \omega_k n - H_k + (1-\delta)\beta \mathbb{E}\, \Pi'_k, \tag{3.9}$$

which also embeds the effect of capital on the cost of labor.

Finally, the net value of employment for the firm, $J \equiv \Pi_n$, must satisfy the following non-arbitrage condition,

$$J = F_n - \omega_n n - \omega - H_n + (1-\lambda)\beta \mathbb{E} J', \tag{3.10}$$

where $F_n$ is the marginal productivity of labor and $\omega_n n$ captures the effect of employment on the cost of labor.

### 3.2.3 Workers

Workers are risk-neutral and discount future consumption of the aggregate good at the rate $\beta$. A worker earns a wage, $\omega$, if employed and receives income, $b$, if unemployed (this income is interpreted as unemployment benefits, home production or, more generally, as the income value of leisure). The change in employment status depends on job creation and job destruction. Each period, $\lambda n$ employed workers lose their job and $\theta\mu u$ of the unemployed are matched with a vacancy. When negotiating wages, workers take matching probabilities as given. Thus, denoting by $W$ the worker's net value of employment at the firm, the following non-arbitrage condition must hold,

$$W = \omega - b + \beta \mathbb{E}\left[(1-\lambda)W' - \theta\mu\hat{W}'\right], \tag{3.11}$$

where $\hat{W}'$ is the expected value of employment outside the firm in the following period. (From our assumption of identical firms it follows that $W' = \hat{W}'$ in equilibrium.)

### 3.2.4 Wage bargaining

A firm negotiates wages with each of its workers. The Nash-bargaining solution maximizes the weighted product of the worker's and the firm's value of employment. We use

$\gamma$ to denote the bargaining power of the worker. Formally, the wage is the solution to the following problem,

$$\omega = \arg max \left\{ W^{\gamma} J^{1-\gamma} \right\}. \tag{3.12}$$

The first-order condition to this maximization problem yields the standard sharing rule,

$$(1-\gamma) W = \gamma J. \tag{3.13}$$

Combining the equation above with (3.7), (3.10) and (3.11), and using the assumption of continuous wage renegotiation, we obtain

$$\omega(v,i,s,S) = \gamma \left[ F_n(z,k,n) - \omega_n(v,i,s,S)n - H_n(v,i,s,S) \right] + (1-\gamma) \left[ b + \theta\mu\beta\mathbb{E}\,\hat{W}' \right]. \tag{3.14}$$

Equation (3.14) is a differential equation in the unknown wage function $\omega(v,i,s,S)$. This equation embeds two important departures from the standard Mortensen-Pissarides model, where the production side is made up of employer-worker pairs (small firms) without capital. In our setting, the firm's flow value of the match is not solely pinned down by the marginal productivity of the worker. Here, the firm also takes into account the value of the worker's contribution to decreasing wages (the second term within the first brackets) as well as total adjustment costs (the third term within first brackets). Since new hires, $\mu v$, and new capital, $iq$, interact in the determination of total adjustment costs, the wage function also depends on the level of investment-specific technology $q$.

### 3.2.5 Equilibrium

**A recursive search equilibrium** with intra-firm bargaining can be loosely defined by decisions rules for vacancies and investment, a wage function $\omega(v,i,s,S)$, a vacancy matching rate $\mu(S)$, labor market tightness $\theta(S)$, value functions and laws of motion for aggregate state variables such that:

*i)* Decision rules for vacancies and investment solve the firm's maximization problem, given the wage function, the vacancy matching rate and the laws of motion for aggregate variables.

*ii)* The wage function is the solution to the Nash-bargaining problem (3.14).

*iii)* Matching rates are given by the matching function evaluated at $V = v$ and $N = n$.

*iv)* Laws of motion for the aggregate states are consistent with individual behavior.

*v)* Value functions solve the firms' and workers' maximization problems.


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### 3.2.6 The Wage Function in the Parameterized Economy

Functional forms for production, matching, adjustment costs and vacancy creation costs are now established. All of our functional forms are standard.

The production technology of the representative firm is represented by a Cobb-Douglas function with constant returns to scale in capital and labor,

$$F(z, k, n) = zAk^{\alpha}n^{1-\alpha}, \tag{3.15}$$

where $A > 0$ and $0 \leq \alpha \leq 1$ are parameters.

The matching technology is represented by a constant-returns-to-scale Cobb-Douglas function, which is the standard functional form in the literature of frictional labor markets,

$$\mathcal{M}(V, 1-N) = MV^{1-\eta}(1-N)^{\eta}, \tag{3.16}$$

where $M > 0$ is the matching-efficiency parameter and $0 \leq \eta \leq 1$ is the elasticitiy of matches with respect to unemployment.

The cost of adjusting labor and capital is represented by the following quadratic adjustment cost function,

$$H(\mu v, iq, n, k) = a_1(iq/k)^2 + a_2\frac{iq}{k}\frac{\mu v}{n} \qquad \text{for } \ n > 0 \ \text{ and } \ k > 0 \tag{3.17}$$

and

$$H(\mu v, iq, n, k) = 0 \qquad \text{for } \ n = 0 \ \text{ or } \ k = 0, \tag{3.18}$$

where $a_1 > 0$ and $a_2 > 0$ are parameters. This adjustment cost function is a particular case of one recently estimated by Merz and Yashiv (2007). As explained above, an important feature of this function is the interaction between employment and investment rates in the determination of total adjustment costs, which is captured by the last term in equation (3.17). Merz and Yashiv (2007) find that this interaction term is key in accounting for the market value of U.S. firms. Further support for this interaction can be found in the empirical literature on employment and capital adjustment decisions [see, i.e., Sakellaris (2004), Letterie, Pfann and Polder (2004) and Contreras (2006a, 2006b).] For example, Contreras (2006a) finds, using data from the Colombian Annual Census of Manufacturing, that it is more costly for the firm to adjust capital and employment at the same time rather than sequently. Indirect evidence can also be found in the work of Letterie, Pfann and Polder (2004) who analyze data on Dutch plants in the manufacturing sector and find that only 20% of the positive employment spikes occur in the same period as an investment spike.

We show in this paper that the interaction between labor and capital in the adjustment cost function is also key to generate volatility in labor market variables.


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Finally, the cost of opening vacancies is assumed to be linear in the number of vacancies, $C(v) = cv$, where $c > 0$ is a parameter.

For this parameterization, the wage function that solves the Nash-bargaining problem —differential equation (3.14)— can be found analytically. The next proposition presents the general solution to the differential equation.

**Proposition 3.1** *The general solution to the differential equation characterizing the symmetric Nash-bargaining problem is given by,*

$$\omega = \psi n^{-2} + \frac{1-\alpha}{2-\alpha} zAk^{\alpha} n^{-\alpha} + a_2 \frac{iq}{k} \frac{\mu v}{n} \frac{\ln(n)}{n} + \frac{1}{2}\left[b + \theta\mu\beta\mathbb{E}\,\hat{W}'\right], \tag{3.19}$$

*where $\psi$ is an arbitrary constant.*

**Proof.** See the Appendix. ■

We will impose $\psi = 0$ to focus our attention on the particular solution yielding a wage bill equal to zero at $n = 0$. Further, we will also make sure that the bargaining set is non-empty and wages are bounded along the equilibrium path of our baseline economy. The last term within brackets in equation (3.19) is the worker's value of unemployment which, in equilibrium, is given by $b+\theta[\omega_v n + C_v + H_v]$. It should be noted that all the derivatives of the wage function assume the worker's reservation value as given and independent of firm-level variables.

It is apparent from a simple inspection of the wage function in (3.19) that the levels of neutral and investment-specific technology affect wages differently. On one hand, neutral technology, $z$, has a positive, direct effect on wages, which leads to a perfect, positive correlation between labor productivity and wages. As discussed in Shimer (2005), it is the perfect correlation between productivity and wages generated by the Mortensen-Pissarides model that lies at the heart of its failure to account for the observed volatilities in labor market variables. On the other hand, investment-specific technology, $q$, enters with a negative sign in the wage function (notice that the firm's level of employment is bounded above by one, and, therefore, $\ln(n)$ is a negative number). Thus, investment-specific technology shocks are bound to reduce the contemporaneous correlation between labor productivity and wages and, as a consequence, to generate amplification in labor market fluctuations.

The concavity of the firm's maximization problem for the parameterized economy can now be assessed. Since the firm foresees the wage function (3.19) when choosing its hiring and investment policy, it is straightforward to show that the return function $F(z, k, n) - \omega(v, i, s, S)n - i - C(v) - H(v, i, s, S)$ is concave in the controls but not in the state variables. Indeed, the term $-\omega(v, i, s, S)n$ is convex in $n$. This class of dynamic maximization problems have been studied in Skiba (1978) and Ladrón-de-Guevara, Ortigueira and Santos (1999), and conditions for optimality have been established. In short, if parameter values are such that there exists a unique, interior, saddle-path stable, steady-state equilibrium with real roots, then first-order conditions are necessary and sufficient. This is the condition we will check in our baseline economy below.

### 3.2.7 Parameter Values

We now assign values to all parameters of the model in order to assess the quantitative effects of different sources of volatility on labor market variables. Parameter values are set so that the steady-state equilibrium of our baseline economy matches some key averages of the 1951-2003 U.S. economy.

A time period in our model is set to one month. Values of the constant in the production function, $A$, and of the bargaining power parameter, $\gamma$, are set arbitrarily. We normalize the value of $A$ to one, and set $\gamma$ equal to $1/2$. The assumption of symmetric bargaining is standard in the literature. The rate of job separation at the steady-state equilibrium is set equal to 0.034, which corresponds to the probability that a worker loses his job within an average month, as estimated by Abowd and Zelner (1985). The elasticity of matches with respect to unemployment is set at 0.6, which is the midpoint value of the range estimated by Petrongolo and Pissarides (2001). The value of the discount factor, $\beta$, is set to 0.995, which yields a monthly interest rate of 0.5 percent. The depreciation rate of capital, $\delta$, is 0.011 and the value of $\alpha$ in the production function is set at 0.3. The value chosen for $\delta$ yields a yearly rate of depreciation of the order of 13 percent, which is the value for the depreciation rate of equipment capital in the U.S. economy.

Income during unemployment $b$, the match-efficiency parameter $M$, the marginal cost of vacancy creation $c$, and the two parameters in the adjustment cost function $a_1$ and $a_2$ are set so that the steady-state equilibrium of the model yields: *i)* A vacancy-filling rate of 0.9 per month. *ii)* Income during unemployment represents 45 percent of employment income. This replacement rate is similar to the one chosen by Shimer (2005). *iii)* The total cost of adjusting capital and labor represents 2.4 percent of output. This is the value estimated by Merz and Yashiv (2007). *iv)* The sum of the marginal costs of adjusting capital and labor, i.e., $H_i k + H_v n$, amounts to 3.5 percent of output, also as estimated by Merz and Yashiv (2007). *v)* Vacancy creation costs represent one percent of output.

It must be noted that our baseline economy has been pinned down without targeting the unemployment rate and the workers' job-finding rate. Yet, the values implied by the baseline economy for these two variables are fairly close to U.S. average values. Thus, the

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steady-state equilibrium yields an unemployment rate of 6.2% and a job-finding rate of 0.5, whereas U.S. average values for the period 1951-2003 are 5.7% and 0.45, respectively.

Our baseline economy is presented in Table 1 below.

*Table 1:* Baseline Economy

| | | |
|---|---|---|
| Efficiency of matching | $M$ | 0.64 |
| Matching-unemployment elasticity | $\eta$ | 0.6 |
| Average job destruction rate | $\hat{\lambda}$ | 0.034 |
| Vacancy creation costs | $c$ | 0.9 |
| Parameter in adjustment cost function | $a_1$ | 180 |
| Parameter in adjustment cost function | $a_2$ | 99 |
| Workers' bargaining power | $\gamma$ | 0.5 |
| Elasticity of output w.r.t. capital | $\alpha$ | 0.30 |
| Depreciation rate of capital | $\delta$ | 0.011 |
| Discount factor | $\beta$ | 0.995 |
| Unemployment benefits | $b$ | 1 |

We close this section by confirming that our baseline economy satisfies the condition for optimality stated above. A log linearization around the unique, interior, steady-state equilibrium yields real eigenvalues, two of them lying outside the unit circle, which is the condition for saddle-path stability in our model economy.

## 3.3 Model Evaluation

In this section we review a number of labor market stylized facts and then assess the ability of our model to account for these facts. Tables 2 and 3 below present a selection of business cycle statistics which have guided most of the recent research in the macro labor literature. Standard deviations and correlations reported in these two tables are taken from Shimer (2005) and Horstein, Krusell and Violante (2007) and correspond to the cyclical components of logged variables detrended with a Hodrick-Prescott filter with smoothing parameter $10^5$. Data consist of quarterly observations for the U.S. economy from 1951 to 2003.

The most salient features of fluctuations in U.S. labor market variables are the large volatilities of unemployment ($u$), vacancies ($v$), tightness ($v/u$) and the workers' job-finding rate ($\theta\mu$), relative to the volatility of labor productivity ($y/n$). As shown in the second row of Table 2, unemployment fluctuates 9.5 times more than labor productivity, vacancies fluctuate 10 times more; fluctuations in labor market tightness are almost 20 times larger

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than those in productivity and the job-finding rate fluctuates almost 12 times more than productivity. On the contrary, the volatility of wages is close to the volatility in labor productivity. Another important feature of these data is the low-to-moderate correlation between fluctuations in labor market variables and fluctuations in labor productivity (see fourth row of Table 2). Unemployment is counter-cyclical with a correlation coefficient of $-0.408$. Vacancies, tightness and the job-finding rate are pro-cyclical, with a coefficient of correlation of about 0.4. Wages are also pro-cyclical with a correlation of 0.65. In terms of autocorrelation, all variables except wages have an autocorrelation coefficient of about 0.9. Wages have a first-order autocorrelation coefficient of 0.78.

*Table 2.* 1951-2003 Quarterly U.S. Labor Market

| | $u$ | $v$ | $v/u$ | $\theta\mu$ | $\omega$ | $y/n$ |
|---|---|---|---|---|---|---|
| Standard Deviation(%) | 19.00 | 20.20 | 38.20 | 11.80 | 2.200 | 2.000 |
| Std. Dev. relative to $y/n$ | 9.500 | 10.10 | 19.10 | 5.900 | 1.100 | 1 |
| Auto-Correlation | 0.936 | 0.940 | 0.941 | 0.908 | 0.781 | 0.878 |
| Correlation with $y/n$ | $-0.408$ | 0.364 | 0.396 | 0.396 | 0.655 | 1 |

*Notes.* Standard Deviations and correlations in this table correspond to quarterly series, detrended using a Hodrick-Prescott filter with smoothing parameter $10^5$, as calculated by Shimer (2005).

Cross correlations in fluctuations of labor market variables are presented in Table 3 below. It is worth noting the strong negative correlation between fluctuations in unemployment and vacancies of $-0.89$. This is the slope of the Beveridge curve.

*Table 3.* 1951-2003 Quarterly U.S. Labor Market

| | $u$ | $v$ | $v/u$ | $\theta\mu$ | $y/n$ |
|---|---|---|---|---|---|
| $u$ | 1 | $-0.894$ | $-0.971$ | $-0.949$ | $-0.408$ |
| $v$ | - | 1 | 0.975 | 0.897 | 0.364 |
| $v/n$ | - | - | 1 | 0.948 | 0.396 |
| $\theta\mu$ | - | - | - | 1 | 0.396 |
| $y/n$ | - | - | - | - | 1 |

*Notes.* Cross Correlations of detrended U.S. labor market variables.

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### 3.3.1 Labor Market Volatility in the Baseline Economy

In order to assess the ability of the model to amplify and propagate shocks, we adopt a step-by-step strategy and introduce each of the shocks separately. We first consider neutral technology shocks, i.e. shocks that affect the production of the consumption and investment good equally. Secondly, we study the response of labor market variables to investment-specific shocks, i.e. to shocks that affect only the production of the capital good. Finally, we combine these two shocks along with shocks to the rate of job destruction.

#### 3.3.1.1 Neutral Technology Shocks

The standard approach used to assess the volatility properties of the Mortensen-Pissarides model consists in assuming a reduced-form, stochastic, exogenous process for labor productivity and then deriving the implied fluctuations in unemployment, vacancies, tightness, the job-finding rate and wages. In our extended version of the model, however, labor productivity is endogenous to the firm's investment and hiring policies. Therefore, the obvious counterpart for our model of the above approach is to shock labor productivity —defined as output (net of adjustment and vacancy costs) per worker— by introducing neutral technology shocks, i.e., shocks to the technology to produce the aggregate good. In this section, we carry out this exercise and calibrate the neutral technology process by following the traditional approach of the business cycle literature. As specified in equation (3.3), neutral technology, $z$, follows the law of motion,

$$\ln z' = \rho_z \ln z + \epsilon_z, \tag{3.20}$$

where $\epsilon_z \sim N(0, \sigma_{\epsilon_z})$. We set $\sigma_{\epsilon_z}$ equal to 0.0078 in order to match the quarterly standard deviation of U.S. labor productivity of 2%. The persistence parameter, $\rho_z$, is set equal to 0.95. In this section, the level of investment-specific technology and the rate of job separation are assumed to remain constant at their average values.

Our results, presented in Tables 4 and 5 below, are in accordance with those found by Shimer (2005) within the standard Mortensen-Pissarides model with small firms (employer-worker pairs) and no capital. Shocks to the level of technology in the production of the aggregate good fail to generate enough amplification in labor market variables. Neutral technology shocks that generate the observed volatility in labor productivity of 2% account for only 6% percent of the observed volatility in unemployment; for less than 12% percent of the volatility in vacancies and for 9% of the volatility in tightness. The second row of Table 4 shows the generated volatilities in labor market variables relative to the volatility of labor productivity. (Relative volatilities are the standard statistic reported in this literature to

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assess amplification.) Unemployment and the job-finding rate fluctuate relatively less than productivity. Vacancies and labor market tightness fluctuate only 1.23 and 1.81 times more than productivity, respectively. On the other hand, the relative volatility of wages is slightly below that observed in U.S. data.

Shocks to neutral technology also fail to account for the moderate contemporaneous correlation of labor market variables with labor productivity. In particular, labor market tightness in the model is almost perfectly correlated with productivity, while this correlation is only 0.4 in the data. The model has no propagation of neutral technology shocks.

The explanation for the model's limited amplification of neutral technology shocks is to be found, as in the framework of Shimer (2005), in the high sensitivity of wages to these shocks. In our baseline economy, the contemporaneous correlation between labor productivity and wages is 0.998 (see fourth row of Table 4). As formulated by Shimer (2005), the increase in wages after a positive technology shock absorbs most of the productivity increase and therefore reduces the incentive for vacancy creation. Hence, equilibrium unemployment, vacancies and the job-finding rate do no respond much to neutral technology shocks.

*Table 4.* Baseline Economy with Neutral Technology Shocks

| | $u$ | $v$ | $v/u$ | $\theta\mu$ | $\omega$ | $y/n$ |
|---|---|---|---|---|---|---|
| Standard Deviation(%) | 1.307 | 2.478 | 3.634 | 1.450 | 1.929 | 2.000 |
| Std. Dev. relative to $y/n$ | 0.653 | 1.239 | 1.815 | 0.725 | 0.964 | 1 |
| Auto-Correlation | 0.886 | 0.641 | 0.803 | 0.803 | 0.848 | 0.857 |
| Correlation with $y/n$ | −0.940 | 0.899 | 0.952 | 0.952 | 0.998 | 1 |

*Notes.* Baseline economy with neutral technology shocks: Standard deviations and correlations in this table correspond to detrended quarterly averages of the monthly generated series. A H-P filter with smoothing parameter $10^5$ has been used to obtain the trend.

As for cross correlations, the baseline economy succeeds at generating the strong correlations between unemployment, vacancies, tightness and the job-finding rate observed in the U.S. economy.

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*Table 5.* Baseline Economy with Neutral Technology Shocks

| | $u$ | $v$ | $v/u$ | $\theta\mu$ | $y/n$ |
|---|---|---|---|---|---|
| $u$ | 1 | $-0.821$ | $-0.920$ | $-0.920$ | $-0.940$ |
| $v$ | - | 1 | 0.978 | 0.978 | 0.899 |
| $v/n$ | - | - | 1 | 0.999 | 0.952 |
| $\theta\mu$ | - | - | - | 1 | 0.952 |
| $y/n$ | - | - | - | - | 1 |

*Notes.* Neutral Technology Shocks: Cross correlations of simulated variables.

We find it convenient to close this section by taking a further look at the high sensitivity of wages to neutral technology shocks from the dynamics of the firm's flow value of employment [the first expression within the brackets of equation (3.14)] and of the worker's value of unemployment [the second expression within the brackets of equation (3.14)]. Under symmetric Nash-bargaining the wage is the average of these two values. Figure 1 below shows the gross flow value of the match for the firm (upper series) and the worker's value of unemployment (lower series) when the model is run for one thousand months. Cyclical components of these values are not only strongly correlated (the correlation coefficient is 0.9944) but show also a strong correlation with the level of neutral technology (the correlation coefficient between the firm's flow value of a match and $z$ is 0.9902, and the coefficient for the workers' value of unemployment and $z$ is 0.9982.)

#### 3.3.1.2 Investment-specific Technology Shocks

We now study business cycle fluctuations in labor market variables in the economy with investment-specific technology shocks and assess the ability of the model to generate amplification. In this section, we shut down shocks to neutral technology and leave shocks to investment-specific technology as the only source of volatility. As explained above, the volatility and persistence of the investment-specific technology process can be estimated from the capital price series (see Greenwood, Hercowitz and Krusell (2000) and Fisher (2006) for details). Thus, unlike neutral technology, whose volatility was set to match the observed volatility in labor productivity, the calibration of investment-specific technology is guided by observed capital price series. Consequently, the question addressed in this section is twofold. First, how much of the observed volatility in labor productivity can be explained by shocks to investment-specific technology? Second, do shocks to investment-specific technology generate the observed amplification in labor market variables? That is, does the model generate relative volatilities in unemployment, vacancies, tightness and the job-finding rate as those observed in the U.S. economy?

The two parameters to be calibrated in the investment-specific technology process,

$$\ln q' = \rho_q \ln q + \epsilon_q, \tag{3.21}$$

are the volatility of $\epsilon_q$ and the persistence parameter $\rho_q$. The volatility of shocks to investment-specific technology, $\sigma_{\epsilon_q}$, is set at 0.0095 in order to match the 2.6% quarterly standard deviation of detrended capital prices of the U.S. economy. The baseline value for the persistence parameter is set at 0.98. Capital prices show high persistence and we have carried out a sensitivity analysis with respect to this parameter. Our results are robust to changes in this parameter.

The results of our exercise are shown in Tables 6 and 7 below. The answer to our first question is in the first row of Table 6: investment-specific technology shocks yield a volatility in labor productivity of 0.8%, thus accounting for 40% of its empirical value. This number agrees with the estimated contribution of investment-specific shocks to output volatility found by Greenwood, Hercowitz and Krusell (2000) and Fisher (2006). These authors use a standard neoclassical model with a Walrasian labor market and find that shocks to investment-specific technology explain about one third of U.S. output volatility.

Our question concerning the extent of labor market volatility generated by shocks to investment-specific technology is also addressed in Table 6. The volatility of unemployment is 4.15%, which amounts to 22% of the volatility observed in the U.S. economy. The volatility of vacancies is 8.09%, which is 40% of its observed value. As for labor market tightness and the job-finding rate, generated volatilities represent 30% and 40% of the observed values, respectively. The second row of Table 6 presents volatilities relative to the volatility of labor productivity. Relative volatilities are close to the ones observed in U.S. data. For instance, vacancies in our model economy fluctuate 10.05 times more than labor productivity and the job-finding rate fluctuates 5.79 times more. In the U.S. economy these two numbers are 10.1 and 5.9, respectively. Unemployment in the model fluctuates 5.15 times more than productivity, while this number is 9.5 in the U.S. economy. The relative volatility of labor market tightness is 14.4, against 19.1 in the data. Finally, the model matches the observed relative volatility of wages of 1.1.

Correlations of unemployment, vacancies, tightness and the job-finding rate with labor productivity are also in line with the ones observed in U.S. data. In the model, the contemporaneous correlation coefficient between unemployment and labor productivity is $-0.42$, against a $-0.4$ in the data. For the other three variables, the model yields coefficients of around 0.48, against correlations of around 0.4 in the data.

*Table 6.* Baseline Economy with Investment-specific Technology Shocks

| | $u$ | $v$ | $v/u$ | $\theta\mu$ | $\omega$ | $y/n$ |
|---|---|---|---|---|---|---|
| Standard Deviation(%) | 4.150 | 8.095 | 11.61 | 4.668 | 0.947 | 0.805 |
| Std. Dev. relative to $y/n$ | 5.155 | 10.05 | 14.42 | 5.798 | 1.176 | 1 |
| Auto-Correlation | 0.854 | 0.564 | 0.754 | 0.753 | 0.767 | 0.978 |
| Correlation with $y/n$ | −0.423 | 0.472 | 0.481 | 0.481 | 0.901 | 1 |

*Notes.* Baseline economy with investment-specific technology shocks: Standard deviations and correlations in this table correspond to detrended quarterly averages of the monthly generated series. A H-P filter with smoothing parameter $10^5$ has been used to obtain the trend.

The explanation as to why investment-specific technology shocks amplify the volatility of labor market variables stems from adjustment costs and their impact on wages. We will make use of the impulse-responses to a positive investment-specific shock, shown in Figure 2, to explain our results. Unlike shocks to neutral technology, investment-specific shocks introduce a bias in favor of capital by lowering its price. Hence, an increase in $q$ yields an immediate increase in investment with a consequent increase in adjustment costs. In order to spread out these (convex) costs over time, the firm's optimal policy calls for a delay in the increase of hiring after the increase in $q$. That is, the firm first builds up the capital stock, taking advantage of its lower price, and then increases employment. Indeed, both labor productivity and vacancies are hump-shaped after an initial drop. [The drop in vacancies on impact to the increase in technology is consistent with some empirical evidence using aggregate data on hours worked. For recent work on the short-run effect of technology improvements on hours worked see, i.e., Fisher (2006) and Basu, Fernald and Kimball (2006).][7]

These two variables –productivity and vacancies– show, after the initial drop, a prolonged increase before they start decreasing to their steady-state values (see Figure 2). The delayed increase in hiring is fostered by the dampening effect of $q$ on wages. Intra-firm wage bargaining implies that the firm shares adjustment costs with the workers and thus,

[7] It is also worth noting that the initial jump in investment and the drop in productivity at the time of the increase in investment-specific technology are consistent with both plant level and aggregate observations. For instance, Sakellaris (1994) uses data on U.S. manufacturing plants from the Annual Survey of Manufactures and studies plant productivity after factor adjustments. He finds that Total Factor Productivity falls in periods of investment spikes. His hypothesis for this fall is that the investment spike involves the introduction in the plant of new technology embodied in the installed equipment, which may be operated inefficiently in the short run. In our model, the fall in productivity is due to the increased costs of adjusting the new equipment. On the other hand, Hornstein and Krusell (1996) and Greenwood and Yorukoglu (1997) argue that the mid-70's productivity slowdown was caused by the increase in investment-specific technology of the mid 70's. They point to adoption and learning as the main mechanisms for the productivity slowdown.

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investment-specific technology shocks do not create a perfect correlation between labor productivity and wages (see fourth row of Table 6). Even though this correlation coefficient is higher than its empirical value, 0.9 against 0.65, it represents a substantial decrease in the sensitivity of wages to labor productivity, as compared to the case of neutral technology shocks. Therefore, unemployment and vacancies respond relatively more to investment-specific shocks than they do to neutral shocks.

Furthermore, the model also does fairly well in accounting for the observed cross correlations between labor market variables. The slope of the Beveridge curve is slightly below the U.S. value. The model yields a contemporaneous correlation coefficient between unemployment and vacancies of $-0.77$, against a $-0.89$ in the data.

*Table 7.* Baseline Economy with Investment-specific Technology Shocks

| | $u$ | $v$ | $v/u$ | $\theta\mu$ | $y/n$ |
|---|---|---|---|---|---|
| $u$ | 1 | $-0.772$ | $-0.896$ | $-0.895$ | $-0.423$ |
| $v$ | - | 1 | 0.974 | 0.974 | 0.472 |
| $v/n$ | - | - | 1 | 0.999 | 0.481 |
| $\theta\mu$ | - | - | - | 1 | 0.481 |
| $y/n$ | - | - | - | - | 1 |

*Notes.* Investment-specific technology shocks: Cross correlations of simulated variables.

We close this section by showing the dynamics of the firm's and workers' values determining the wage (see Figure 3 below). Unlike the case of neutral technology shocks, the cyclical components of these two values are not perfectly correlated (the correlation coefficient is 0.6375). Moreover, the correlation of the cyclical component of each of these values with the level of investment-specific technology is also substantially lower than under neutral-technology shocks. Thus, the correlation coefficient between the firm's flow value of a match and $q$ is 0.4696 and between the worker's value of unemployment and $q$ is only $-0.1727$. This latter value implies a low feedback from the value of unemployment to the current wage, contrary to what we observe in the economy with neutral-technology shocks.

#### 3.3.1.3 Shocks to Neutral, Investment-specific Technology and Job Separation

In this section we study labor market dynamics in the economy with three sources of volatility: two technology shocks —neutral and investment-specific— and shocks to the rate of job separation, $\lambda$. Fluctuations in job separation in the U.S. economy are large and

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their contribution to labor market volatility has been widely acknowledged in the literature. Fujita and Ramey (2008) estimate that contemporaneous fluctuations in the separation rate explain an important fraction of fluctuations in U.S. unemployment.

The exercise we carry out in this section proceeds as follows. The exogenous process for job separation, which we rewrite here for convenience, is,

$$\ln \lambda' = (1 - \rho_\lambda) \ln \hat{\lambda} + \rho_\lambda \ln \lambda + \epsilon_\lambda, \tag{3.22}$$

where $\epsilon_\lambda \sim N(0, \sigma_{\epsilon_\lambda})$. This is the process used by Ramey (2008) in Section 2.2 of his paper. First, we calibrate the two parameters $\rho_\lambda$ and $\sigma_{\epsilon_\lambda}$ in the job separation process so that we match the persistence and volatility of job separation in the 1951-2003 U.S. economy. For this period, the cyclical component of job separation yields a first-order autocorrelation coefficient of 0.733, and a volatility of 7.5% [see Shimer (2005)]. As for the investment-specific technology process we use the same calibration as in the previous subsection. Finally, we recalibrate the volatility of the neutral technology shock so that the standard deviation of labor productivity equals 2% in the model economy. That is, while the volatilities of the innovations to $\lambda$ and $q$ are set to match the observed volatilities in job separation and in capital prices, respectively, the volatility of innovations to $z$ is chosen as the residual to match the volatility of U.S. labor productivity. Following this procedure, the values obtained for $\rho_\lambda$, $\sigma_{\epsilon_\lambda}$ and $\sigma_{\epsilon_z}$ are 0.85, 0.043 and 0.007, respectively.

Tables 8 and 9 present volatilities and correlations of labor market variables in our baseline economy with two technology shocks and a job separation shock. As shown in the first row of Table 8, the model explains a substantial fraction of observed labor market volatility. In particular, the model accounts for 43% of the observed volatility in unemployment, 78% of the volatility in vacancies, 45% of the volatility in tightness and 61% of the volatility in the job-finding rate. The volatility of wages in the model is 97% of its empirical value. The model also accounts for the mild correlation between labor productivity and unemployment, vacancies, tightness and the job-finding rate.

*Table 8.* Baseline Economy with Three Sources of Volatility

| | $u$ | $v$ | $v/u$ | $\theta\mu$ | $\omega$ | $y/n$ |
|---|---|---|---|---|---|---|
| Standard Deviation(%) | 8.100 | 15.795 | 16.912 | 7.281 | 2.136 | 2.000 |
| Std. Dev. relative to $y/n$ | 4.050 | 7.897 | 8.456 | 3.640 | 1.068 | 1 |
| Auto-Correlation | 0.764 | 0.346 | 0.536 | 0.519 | 0.654 | 0.874 |
| Correlation with $y/n$ | −0.302 | 0.284 | 0.401 | 0.391 | 0.890 | 1 |

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*Notes.* Baseline economy with two technology shocks and a job separation shock: Standard deviations and correlations in this table correspond to detrended quarterly averages of the monthly generated series. A H-P filter with smoothing parameter $10^5$ has been used to obtain the trend.

Cross correlations are presented in Table 9. As already shown by many authors —e.g. Cole and Rogerson (1999), Shimer (2005) and Ramey (2008)— shocks to the exogenous rate of job separation generate a counterfactual upward-sloping Beveridge curve. In our model economy this slope is 0.172. It should be noted that the positive unemployment-vacancy correlation is not a result specific to our model nor to the assumption of exogenous separation. Ramey (2008) solves a version of the search-and-matching model with small firms and shocks to the exogenous rate of job separation and obtains a correlation between unemployment and vacancies of 0.75. In a specification of his model with endogenous separation the value for this correlation is as high as 0.92.

*Table 9.* Baseline Economy with Three Sources of Volatility

| | $u$ | $v$ | $v/u$ | $\theta\mu$ | $y/n$ |
|---|---|---|---|---|---|
| $u$ | 1 | 0.172 | $-0.332$ | $-0.304$ | $-0.302$ |
| $v$ | - | 1 | 0.879 | 0.880 | 0.284 |
| $v/n$ | - | - | 1 | 0.991 | 0.401 |
| $\theta\mu$ | - | - | - | 1 | 0.391 |
| $y/n$ | - | - | - | - | 1 |

*Notes.* Baseline economy with two technology shocks and a job separation shock: Cross correlations of simulated variables.

In light of the results in this paper and in some recent papers in this literature, it may be said that the puzzle on labor market fluctuations is more about correlations than about volatilities. In other words, the question is not so much whether the search-and-matching model generates amplification in labor market variables as whether it generates amplification with the right correlations. A better understanding of the flow into unemployment seems to be crucial to answer this latter question.

### 3.3.2 The Response of Unemployment to Labor Market Policy

We now turn to the sensitivity of unemployment with respect to unemployment benefits. As pointed out recently by Costain and Reiter (2008), the unemployment puzzle is not only

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about volatilities but also about the sensitivity of unemployment to policy, particularly to unemployment benefits. Besides citing a large body of empirical studies aimed at estimating this sensitivity, these authors also conduct their own estimation using low-frequency cross-country data from 1960 to 1999. They find that the long-run semi-elasticity of unemployment with respect to benefits ranges from 1.33 to 2.45, depending upon whether controls for country or time effects are included or not.

In our benchmark economy, the long-run semi-elasticity of unemployment with respect to the replacement rate, $\frac{\triangle u}{\triangle b}\frac{1}{u}$, is equal to 1.1. This number is in the lower bound of empirical estimates, implying that in our calibration there is still room to increase unemployment benefits, which will allow us to generate even more volatility in labor market variables with investment-specific technology shocks, without creating an excessive sensitivity of unemployment to benefits.

## 3.4 Conclusions

In the vast majority of the literature on search-and-matching models of the labor market, production takes place in small firms (employer-worker pairs) —the Mortensen-Pissarides model[8]. The productivity of the worker is assumed to follow an exogenous process and capital is typically left out of the analysis. We depart from this framework by assuming large firms, which invest in capital, create vacancies to hire new workers and pay adjustment costs. We assume that wages are the outcome of a Nash-bargaining problem between the firm and the workers. Our main focus is on the business-cycle fluctuations of labor market variables. To this aim, we assume that the levels of neutral and investment-specific technologies are subject to shocks. A key feature of our model is that investment and hiring rates interact in the determination of total adjustment costs. Empirical support for this interaction has been recently offered by Merz and Yashiv (2007) using U.S. data.

While neutral technology shocks have only a small impact on labor market variables, shocks to investment-specific technology generate sizable fluctuations in unemployment, vacancies, labor market tightness and the worker's job finding rate. In our economy, fluctuations in labor market variables are not associated with an implausible elasticity of unemployment to unemployment benefits.

By bringing the neoclassical firm to the center stage of the search-and-matching model, we show that volatility in labor market variables can be amplified without abandoning the assumption of continuous Nash-wage bargaining. Even though the model we explored in this paper is rather stylized, it allows us to gain new insights on the effect of investment-

[8]See Mortensen and Pissarides (1994) and Pissarides (2000).

specific technology shocks on labor market volatility. There are, however, many dimensions along which the model can be extended and improved. The model, like many others in the literature, fails to account for the strong, negative correlation between unemployment and vacancies over the business cycle when job separation is non-constant.

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## 3.5 Appendix A:

**Proof of the Proposition:** Equation (3.14) is a linear, first-order differential equation and its solution can be found analytically. Since the worker's outside value is independent of the firm's level of employment, $n$, it follows that if $\hat{\omega}$ is the general solution to,

$$\omega(v,i,s,S) = \frac{1}{2}\left[F_n - \omega_n(v,i,s,S)n - H_n(v,i,s,S)\right], \tag{3.23}$$

then, $\omega = \hat{\omega} + \frac{1}{2}\left[b + \theta\mu\beta E\hat{W}'\right]$ is the general solution to (3.14).

To solve equation (3.23), we re-arrange terms and write it as,

$$\omega_n = -\frac{2}{n}\,\omega + \frac{F_n}{n} - \frac{H_n}{n}. \tag{3.24}$$


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Therefore, $\hat{\omega}$ is the solution to (3.24) if and only if,

$$\hat{\omega}_n e^{\int (2/n)dn} + (2/n)\hat{\omega} e^{\int (2/n)dn} = \left(\frac{F_n}{n} - \frac{H_n}{n}\right) e^{\int (2/n)dn} \tag{3.25}$$

that is, if and only if,

$$\frac{d}{dn}\left(\hat{\omega} e^{\int (2/n)dn}\right) = \left(\frac{F_n}{n} - \frac{H_n}{n}\right) e^{\int (2/n)dn}.$$

Multiplying through by $dn$ and integrating, we get,

$$\hat{\omega} = \psi e^{-\int (2/n)dn} + e^{-\int (2/n)dn} \int \left(\frac{F_n}{n} - \frac{H_n}{n}\right) e^{\int (2/n)dn} dn, \tag{3.26}$$

where $\psi$ is a constant of integration. For our parameterized economy, the integral in the last term of (3.26) can be solved. First, $e^{\int (2/n)dn} = e^{2\ln(n)} = n^2$. Then, using the functional forms specified in Section 2.6 we have that,

$$e^{-\int (2/n)dn} \int \frac{F_n}{n} e^{\int (2/n)dn} dn = n^{-2} \int (1-\alpha) z A k^{\alpha} n^{1-\alpha} dn = \frac{1-\alpha}{2-\alpha} z A k^{\alpha} n^{-\alpha} \tag{3.27}$$

and

$$-e^{-\int (2/n)dn} \int \frac{H_n}{n} e^{\int (2/n)dn} dn = n^{-2} \int a_2 \frac{iq}{k} \frac{\mu v}{n} dn = a_2 \frac{iq}{k} \frac{\mu v}{n} \frac{\ln(n)}{n}. \tag{3.28}$$

After plugging the last two expressions back into (3.26) we obtain $\hat{\omega}$. Finally, adding the worker's reservation wage to this solution we obtain the wage function shown in Proposition 1 in the text.

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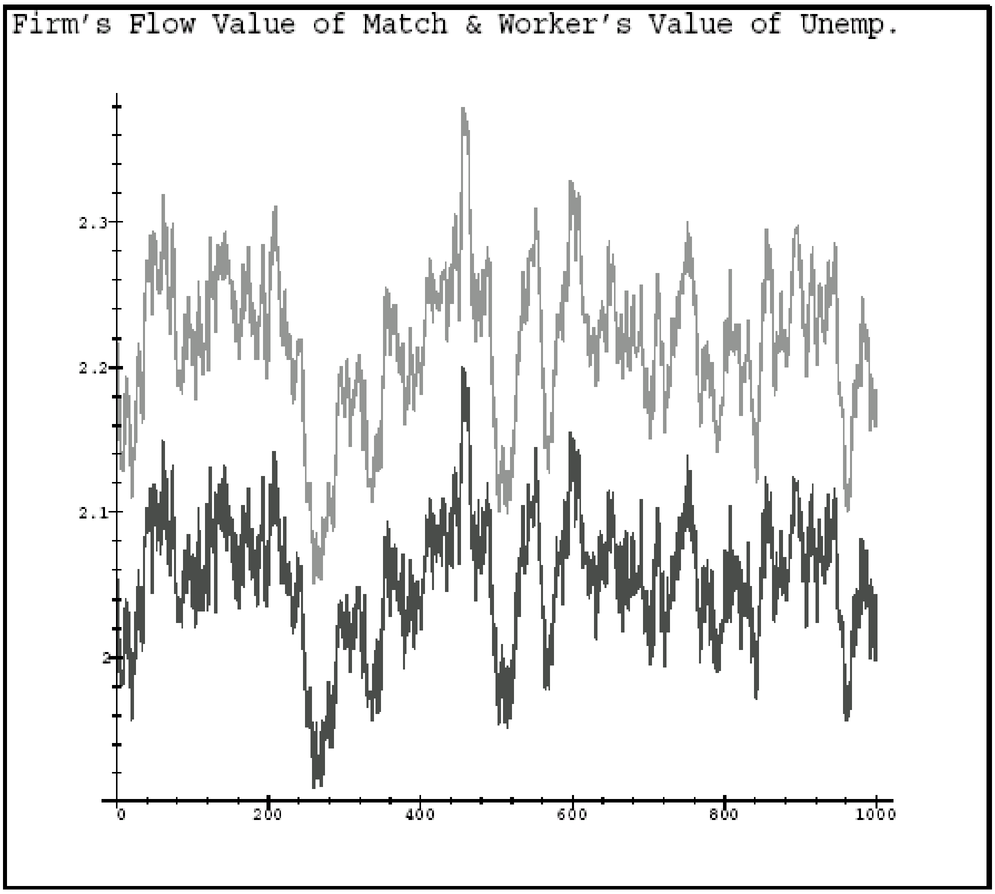


*Figure 1*: Firm's flow value of a match (upper series) and worker's value of unemployment in our baseline economy under neutral technology shocks.

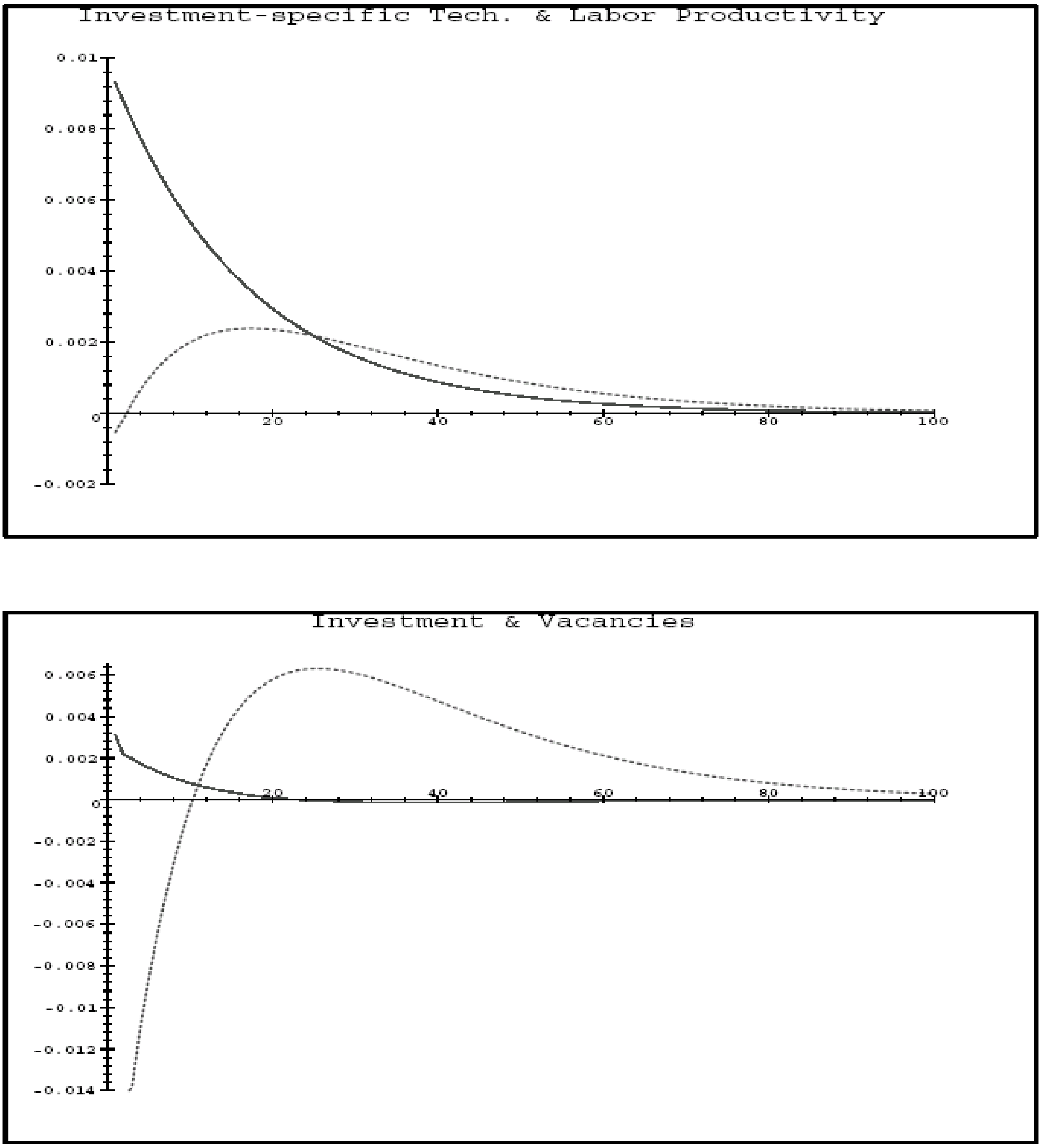


*Figure 2*: Top chart plots the response of labor productivity (broken line) to a positive shock to investment-specific technology (solid line). Bottom chart plots the response of investment (solid line) and vacancies (broken line).

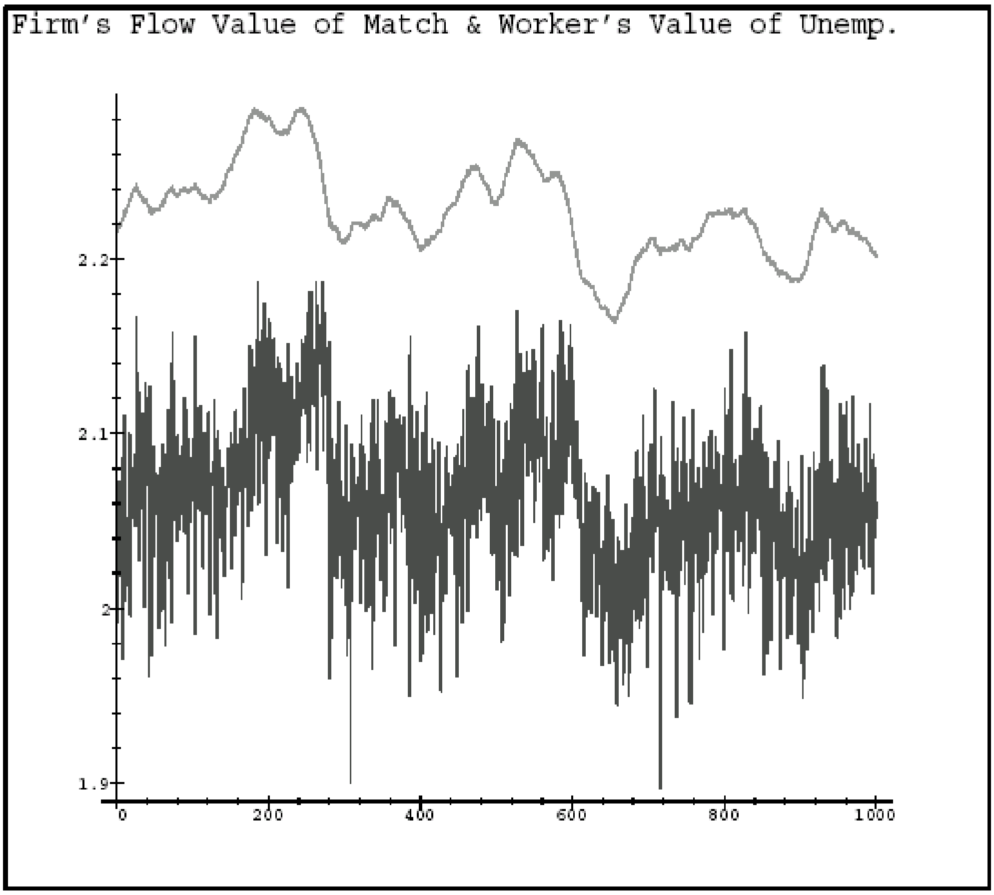


*Figure 3*: Firm's flow value of a match (upper series) and worker's value of unemployment in our baseline economy under investment-specific technology shocks.

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