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Abstract

We analyze how different policy interventions may incentive the transition of workers from the informal to the formal sector. We use Italian data over the period 1998-2008 to evaluate ex post whether the 2003 Italian labor market reform was able to reach the objective to reduce the share of shadow employment. Based on our empirical results, we develop an ex ante evaluation based on a search and matching model, á la Mortensen and Pissarides to determine the right combination of policy interventions which may be effective in generating a significant reduction in undeclared work together with an expansion of the formal sector. We find that in an economy where permanent and temporary contracts coexist, the combination of lower payroll taxes for permanent jobs and higher probability of being audited generates a compression of the informal sector, leaving unemployment unchanged. A similar result can be obtained through a reduction of the firing cost associated with permanent jobs, even though this causes temporary contracts to increase relatively more than permanent contracts.

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JEL Classification: J38, J63, J64, H26.

1 Introduction

As Governments in Europe and in the U.S. struggle to manage the fiscal legacies of the global financial crisis and the prospect of a rapidly aging population, the circumstances that lead people to work and trade in the shadow economy have increased significantly (Packard *et al.* , 2012).[1] As noted by Boeri & Garibaldi (2002) and Schneider (2000), in recent years undeclared work has grown consistently in both developed and less developed countries.[2] This might not only imply the existence of some degrees of tolerance towards labor tax evasion, but it might also suggest that it is difficult to enforce deterrence. In the economic literature, there is still no consensus on which instruments are effective towards achieving this goal, despite tax evasion being a topic extensively studied. Increasing tax enforcement or augmenting the fines for this non compliant behavior are commonly considered the two most compelling policy interventions to reduce evasion. However, in both cases, the empirical literature shows contrasting evidence on the effect of these instruments on tax compliance (Alm *et al.* , 1992; Andreoni *et al.* , 1998; Di Porto, 2011; Garrido & Mittone, 2008). In addition, labor taxation and labor market regulations are also identified as major factors influencing the decision of individuals to work in the informal sector.[3] However, it is also controversial whether any of these two instruments are effective towards achieving compliance. For instance, labor taxes affect labor-leisure choices through a distortion effect caused by the overall tax burden. The greater the difference between total labor costs in the formal economy and after-tax earnings, the bigger the incentive to reduce the tax wedge and to work in the shadow economy. Since the tax wedge depends on the level of social security and the overall tax burden, these are key drivers for the persistence and growth of the shadow economy (Feld & Schneider, 2010). However, even when reforms carrying significant tax reductions are implemented, they do not necessarily lead to a reduction of the informal sector.[4] Moreover, high profits from irregular

[1] In several countries, (e.g., Italy, France, Germany), employers are responsible for paying a fraction of the social security contributions for the benefits of their workers. In Italy this fraction amounts to two third of the total contribution. Evading these payments is the same as declaring only some of the hours worked.

[2] Undeclared work plays a major role in several developing and developed countries. In a recent study Jutting & de Laiglesia (2009) show that out of a global working population of 3 billion workers, nearly two-thirds (1.8 billion) are undeclared or informal. Schneider (2011) estimates that in the European area the number of persons working in the unofficial economy doubled from 1978 to 1998. According to a report of the Pew Hispanic Center, the number of illegal immigrants living in the United States was 11.9 million in 2008, of which 8.3 million were part of the U.S. labor force (Passel & Cohn, 2009). According to the Canadian Encyclopedia, the police and immigration personnel estimated the number of illegal immigrants in Canada to range between 50,000 and 200,000. Similar percentages are reported for BRIC (Brazil, Russia, India and China) and Eastern European countries.

[3] The literature on tax evasion in recent years has shown that there are other factors that might be important to fight tax evasion such as social capital, stigma, tax morale, tax salience. These concepts are closely related to behavioral economics and therefore they are outside the scope of this paper.

[4] Wherever legal tax avoidance has been abolished and regulations have been unchanged, even a considerable cut on the direct tax burden did not reduce the size of labor tax evasion. On the contrary, for a not negligible group

activities (and associated investments in real and human capital) could generate disincentives for workers to transit from the informal to the formal sector (Schneider, 1994; Spiro, 1993).

Understanding the role of labor market regulations in achieving compliance in labor tax evasion is of great interest for economists.[5] From a pure theoretical point of view the reduction of monopsonistic powers is expected to lead towards a less segmented labor market and to a reduction of informality. Moreover, rigid employment protection legislations (EPL) are shown to have negative effects both on job creation and on job destruction, reducing the overall turnover. This might create incentives for firms to increase the utilization of temporary contracts or hire workers in the informal sector. Fialova & Schneider (2009) and Hazans (2011) show that a reduction of job protection has the potential to reduce informality; however, both analysis are carried out using aggregate measures of informality in EU countries, and therefore the results can be interpreted only as conditional means and not as causal effects. On the other hand, the effect of EPL on formal employment has been extensively studied in the literature. Bertola *et al.* (1999) and Blanchard & Portugal (2001) find that EPL reduction affects labor market flows, increasing both job creation and job destruction, with ambiguous results on total employment. Vindigni *et al.* (2013) show that the effect of EPL on employment is hump-shaped: first employment increases and then decreases as a function of the increased firing costs. In addition, in the literature there are no papers providing micro-econometric causal evidence on the effect of EPL on shadow activities.

In summary, the effect of deterrence, taxation and labor market regulations on labor tax compliance is still controversial. Our paper contributes to the literature by providing both theoretically and empirically an analysis of this issue based on recent Italian labor market reforms. We develop an ex post and ex ante social program evaluation on labor tax evasion in order to understand how to achieve labor tax compliance without raising unemployment. Specifically, our goal is to investigate whether combinations of policy instruments may be used to reduce labor tax evasion while boosting the flow of workers from the informal to the formal sector and to emphasize the role of temporary contracts in facilitating such transition. We call this process "emersion".[6] To understand why compliance and "emersion" can be thought as closely related, but different concepts, we provide a simple example:

Nations A and B feature both the following labor market outcomes in period 1: 10 percent

of taxpayers the actual tax and regulation burden remained unchanged.

[5]Other instruments can be taken in consideration while dealing with labor market legislation such as minimum wages, unemployment benefits.

[6]Temporary employment contracts have been deployed rapidly across the rigid EU economies since the early 1990s. Featuring short (fixed) duration, lower costs, and more straightforward hiring procedures, they are designed to be an agile instrument to increase labor market flexibility and, in turn, to reduce unemployment. In Italy, there are two additional reasons which motivated the implementation of the reforms introducing temporary contracts. First, temporary contracts might have helped increase labor force participation, which is particularly low among women. Second, they might have contributed significantly to reduce the share of undeclared work, and therefore labor tax evasion, which is estimated to account for 17% of the Italian GDP. In order to achieve the last objective, the Italian Government approved a number of reforms, which introduced several types of short-term contracts to target specific situations, in which undeclared work might have prevailed. As of today, in Italy the workers unions count up to 46 different types of employment contracts. Moreover, the Italian share of short-term employment jumped from 5% in 1990 to approximately 13% in 2010. The objective of this paper is, firstly, to test empirically whether these reforms have been successful in reducing the share of undeclared work (through the "emersion" channel).

unemployment, 55 percent formal employment and 5 percent informal employment. At the end of period 1 each nation implements a labor market reform. In period 2, the new labor market outcomes are as follows: nation A features 15 percent unemployment, 55 percent formal employment and 0 informal employment; nation B is characterized by 10 percent unemployment, 58 percent formal employment and 2 percent informal employment. Nation A was able to achieve full compliance in period 2: tax evasion has been eradicated, formal employment is unchanged and unemployment has increased. In nation B, tax evasion is lower, but still present, unemployment is stable and formal employment has increased. Therefore, we observe in nation B a flow of workers moving from the informal to the formal sector, without transiting into unemployment: this is what we refer to as the "emersion effect". We believe that in period 2 the labor market outcome achieved by nation B is much more desirable, equal and socially stable than the outcome achieved by nation A, even though the level of compliance is lower.

From our ex post social program analysis, we find that the reform approved in Italy in 2003, which introduced new types of temporary contracts and modified the legislation in relation to the apprenticeship contract did not reduce informal work.[7] In particular, not only the share of informal workers did not decline as a consequence of the reform (extensive margin), but also the hours worked in the informal sector were unaffected (intensive margin). Therefore, our evidence seems to suggest that temporary contracts per se may not be an efficient instrument to reduce informal work. In order to understand the causes for this negligible effect and to propose alternatives policy interventions, we develop an ex ante evaluation using the ex post finding as a background to design a theoretical model, which is essential to investigate the phenomenon of emersion and to identify potential instruments to achieve it. Intuitively, since temporary jobs doesn't seem to be a relaible intrument for emersion (as evident from ex post social program evaluation) we construct through a structural model an ex ante social program evaluation aimed to simulate different policies intervention and we (ex ante) evaluate the best possible alternative paths to emersion. This approach that pose a bridge between structural (ex ante) and reduced form (ex post) policy evaluation seems a very suitable way to provide policy suggestions, in this we follow the line of resonament enlighten in Heckman 2010[8]. The choice of a search theoretical framework in the spirit of Diamond (1981) and Mortensen & Pissarides (1994) is a suitable choice for our ex ante evaluation moreover it is justified by its adaptability and flexibility in modeling transitions of workers across markets and inefficiencies due to labor market frictions (Boeri & Garibaldi, 2002; Bosch & Esteban-Pretel, 2012; Meghir *et al.* , 2012). In the model we account for workers' heterogeneity, social security contributions, and we allow for differentiated contracts, as in Tealdi (2011). In addition, for the first time in the literature, we introduce the informal sector side by side with the formal sector, where different types of contracts are available. Therefore, we bring in flexibility by allowing firms to hire workers formally, choosing whether to offer them a temporary

[7]Please refer to section 3.1 below for further details.

[8]In particular following this approach we are able to solve the policy evaluation problems P1("Evaluating the Impacts of Implemented Interventions on Outcomes Including Their Impacts on the Well-Being of the Treated and Society at Large". and P3 ("Forecasting the Impacts of Interventions, Constructing Counterfactual States Associated with Interventions Never Historically Experienced, including Their Impacts on Well-Being") as described by Heckman 2010

or a permanent contract, or informally. This menu of options enriches the analysis and expands the set of policy tools that can be tested as potentially valid instruments to achieve "emersion".

An important feature of the model is that the decision of firms to hire in the formal or informal sector when they open a vacancy is endogenous. We assume that firms post generic vacancies and when they extend an offer to the worker, they choose the sector (formal vs informal) and the type of contract (short-term or permanent). If a worker is hired in the formal sector, the firm pays social security contributions to the tax authority. If the worker is hired in the informal sector, no social security contribution is paid, but the firm may be caught by the tax enforcement authority and be subject to the payment of a penalty fee. The type of contract and the sector (formal or informal) are chosen by the firm according to several parameters, such as the worker's productivity, the quality of the match, the social security fee, the probability to be caught, if operating in the informal sector. In the model, we also allow for endogenous transitions of workers from the formal to the informal sector and vice versa. When we calibrate the model according to the Italian regulations and institutions, we test the effects of several policy interventions, such as the increase of the monitoring rate of the informal sector, the increase of the penalty fee, the reduction of the social security fees. We conclude that "emersion" is possible just with a well designed combination of policies. In particular we focus on two different policy combinations:

1. policy (a): lower payroll taxes for permanent positions and an higher penalty fee for firms operating in the informal sector;

2. policy (b): lower firing costs for permanent positions and an higher penalty fee for firms operating in the informal sector.

While the former generates "emersion" through an expansion of permanent positions, the latter generates "emersion" through an expansion of temporary positions, which may worsen the well-known problem of duality in the formal sector.[9]

The paper is organized as follows. Section 2 reviews the literature on the topic. The ex post evaluation, the econometric strategy, the details of the reform approved in Italy in 2003, the data used and the estimation results are presented in Sections 3. Section 4 introduces the theoretical model, explains the calibration procedure and describes the ex ante policy analysis. Section 5 concludes the paper and discusses future research.

2 Literature review

There are several strands of literature related to this paper. First, this paper is related to the literature on shadow economy, tax evasion and undeclared work. Tax evasion has been widely reported since antiquity, and one which has always been difficult to examine on both theoretical and empirical grounds. On the one hand, theoretical economic models based on taxpayer rationality are unable to comprehensively describe the behavior of agents involved in the tax evasion setting. If one applies a standard game theory, or any rational choice approach to the problem of tax compliance, the level of penalties and enforcement that we observe would appear to be insufficient

[9]Please refer to Saint-Paul (1997) for further details.

to explain the degree of compliance with tax laws. In the last 15 years, economists have attempted to address the behavioral and experimental aspects of tax evasion, by analyzing the variety of psychological reasons affecting the motivations for paying taxes such as honesty, fear, sense of group membership (Alm *et al.* , 1992; Chorvat & Knoll, 2002).

Considering the empirical grounds, the lack of reliable data on tax evasion raises concerns about the validity of the empirical results. Conventional data on evasion are obtained from administrative audit databases which are usually selected data. Moreover, we seldom have sufficient information to deal with such a selection. This happens mainly because audit authorities try to maintain secrecy on their audit strategies. Recently, some advances in this field have been made using randomized experiments (Kleven *et al.* , 2011), and by relying on individual audit data, where the information provided is detailed enough to allow for the adoption of a proper selection model (Di Porto, 2011; Di Porto *et al.* , 2013).

Second, this study is linked to the extensive empirical literature on short-term employment contracts and their impact on European labor markets. Studies such as Gagliarducci (2005); Güell (2003); Tealdi (2010) investigate the way short-term contracts have changed the pattern dynamics across states and contracts. Specifically, their objective is to identify the role of short-term contracts as screening device or as an instrument for firms to reduce costs. Their results show that both in Italy and in Spain short-term contracts are used for both purposes. In addition, Pfeifer (2009) shows that in Germany short-term contracts are utilized by firms to adjust the workforce according to business cycle fluctuations. A parallel strand of the literature studies the effects of short-term contracts on labor market aggregates, such as employment and unemployment. In this context, findings are controversial. By investigating whether short-term contracts have been effective in reducing the high rate of long-term unemployment in Italy, Berton (2008) concludes that the objective was not achieved. Giannelli *et al.* (2012) show that in Italy short-term contracts did not help increase the length of the first employment spell. In addition, the authors show that in Italy short-term contracts are associated with higher uncertainty. On the positive side, for the case of Spain, Aguirregabiria & Alonso-Borrego (2009) find that short-term contracts had a positive effect on employment and job turnover and Güell & Petrongolo (2007) show that the rate at which workers leave unemployment is higher after the reforms. This paper complements the existing literature, by testing for the first time whether the introduction of short-term contracts has been effective in reducing the share of undeclared work in Italy.

This paper relates also to the search model of dynamic labor demand of Mortensen & Pissarides (1994). We extend their framework, by allowing firms to hire workers in different sectors (formal or informal). Moreover, as in Tealdi (2011), firms are allowed to offer different types of contracts (permanent or short-term) to the workers and are bound to pay social security fees whenever they hire a worker in the formal sector. Within this literature, this model specifically relates to studies which use the search theory to address the issue of undeclared work (Albrecht *et al.* , 2009; Boeri & Garibaldi, 2002; Bouev, 2005; Fugazza & Jacques, 2004; Kolm & Larsen, 2003). However, for the first time in the literature, our paper addresses the problem of informality in an economy where permanent and temporary contracts coexist. The paper which most closely resembles our work is the one by Bosch & Esteban-Pretel (2012), in which direct transitions from the formal to the informal sector (and vice versa) are allowed and endogenously modeled. While they use this set up to analyze the undeclared work phenomenon in developing countries, it serves our purpose to

test the effects of the reforms implemented in Italy to increase labor market flexibility.

Finally, this paper is related to the growing literature on program evaluations (Behrman *et al.* , 2012; Todd & Wolpin, 2006) based on the combination of the structural approach to economic policy analysis with the program evaluation approach, as suggested by Heckman (2010). This third way to do policy analysis integrates the best features of both approaches and extends the interpretability and range of policy questions which can be addressed in social sciences.

3 Ex post evaluation: Empirical Strategy and Estimation Results

In this section we describe the empirical strategy adopted to estimate the impact of the apprenticeship reform approved in Italy in 2003 (law no. 30/2003, known as "Biagi Law") on the probability of being employed in the undeclared sector and on the hours worked by undeclared workers, our ex post evaluation. For this purpose, we use the difference-in-differences (DiD) and the triple difference (DDD) models. Before presenting the details of the estimation procedure, in the next section we outline the main characteristics of the apprenticeship contract and the changes introduced by the reform.

3.1 The apprenticeship reform

The apprenticeship is a type of temporary employment contract which targets young workers (below the age of 25). With this contract the employer is required to provide to the apprentice the vocational training necessary to perform an activity (trade, art, or business). The training must be performed during the working hours by local authorities or accredited training institutions. The qualifications gained during these training activities are acknowledged by a formal certification. The labor costs associated with the apprenticeship are lower compared to regular contracts to compensate for the training costs incurred by the firms. Specifically, social security contributions amount to one third compared to permanent and other forms of temporary contracts (fixed-term and temporary help agency contracts) and to one half compared to collaboration contracts.[10]

The "Biagi Law" amended some regulations to the apprenticeship to make it more appealing for employers. The first modification concerned the age restrictions: the limit for eligibility was raised from 25 to 30 years old. In addition, since local authorities were often unable to provide training because of lack of public funding and infrastructures, the new law introduced the option for firms to provide training at the workplace. Since the provision of training at the workplace makes it hard to monitor compliance, the new apprenticeship could represent a viable instrument for firms to lower labor costs and to encourage "emersion".

In order for the new apprenticeship to become effective, regional rules for implementation were needed. These rules have been carried out in a staggered manner. Since 2003 to the end of 2010, only 11 out of 20 regions adopted the guidelines regarding the training content of the

[10]Workers hired on a collaborator contract are not employees of the firm; they provide their services as independent consultants.

new apprenticeship.[11] In case of no regional legislation, industry-specific collective agreements could rule on behalf of the regions.[12] In this paper, we take advantage of these time and regional (industry) variations to identify the casual effect of the new regulations on apprenticeship on the share of undeclared work within a DiD framework, as in Cappellari *et al.* (2012).

3.2 Empirical Models

We estimate the causal effect of the apprenticeship reform on (i) the probability of working in the undeclared sector and (ii) hours worked, by using a DiD research design. By exploiting regional, sector, and time variations, we assess the causal impact of the policy by comparing the probability of being undeclared in adopting and non-adopting clusters.[13] The model is specified as follow:

$$P(\text{Undeclared} = 1|X)_{i,r,s,t} = c + \gamma(D_{Reform})_{r,s,t} + \beta X_{i,r,s,t} + \delta_r + \mu_s + \zeta_t + \epsilon_{i,r,s,t} \qquad (1)$$

where i identifies the individual, r the region, s the sector and t the time. D_{Reform} is the dummy variable which takes on the value of one for the years, regions and sectors affected by the policy. All estimates include a vector of region dummies, δ_r, that controls for mean differences in the probability of working in the black sector across regions, of sector dummies, μ_s, that takes into account mean differences across sectors, and year dummies, ζ_t, that controls for shift in the dependent variable common to all regions and sectors. The matrix $X_{i,r,t}$ includes a series of individual characteristics such as age and its square, a dummy for women, a dummy for fixed-term contract, a dummy for part-time work schedule, years of potential work experience and its square, two dummies for education, the interactions between three experience dummies and two education dummies, 14 occupations dummies, a dummy for migrants and a dummy selecting workers living in urban areas. Some models also allow for region-specific linear trend. We run this equation by using ordinary least squares, so the estimated coefficients are readily interpretable as marginal effects.

If both employer and employee agree on declaring only part of the hours worked and leaving the rest in the shadow, we could also expect an effect of the reformed apprenticeship contract on informal hours worked. To tackle this issue, we specify and estimate models of the form:

$$\log h_{i,r,s,t} = c+\gamma(D_{Reform})_{r,s,t}+\phi B_{i,r,s,t}+\varphi\Big[(D_{Reform})_{r,s,t}\times B_{i,r,s,t}\Big]+\beta X_{i,r,s,t}+\delta_r+\mu_s+\zeta_t+\epsilon_{i,r,s,t} \quad (2)$$

[11] Among the regions which first implemented the new rules Emilia-Romagna, Toscana, Friuli Venezia Giulia and Marche acted in 2005; Puglia, Sardegna and the province of Bolzano in 2006; Lazio in 2007 and Piemonte, the province of Trento and Umbria in 2008.

[12] According to law no. 80/2005 industry-specific collective agreements may define the rules for training whenever the regional legislation is lacking. Collective agreements were signed in several sectors: Banking, Chemicals, Construction, Energy, Food Products, Metals, Retail Trade, Textile, Transportation, Wood products, Telecommunication.

[13] The formulation used in this paper is the benchmark regression DiD, where the customary DiD is extended by controlling for a set of individual covariates.

where the dependent variable is log hours worked by individuals i in region r, sector s and time t. $(D_{Reform})_{r,s,t}$ is the dummy for adoption of the new apprenticeship contract, $B_{i,r,s,t}$ is the dummy that indicates whether the worker is undeclared. The matrix $X_{i,r,s,t}$ comprises individual characteristics as in model 1. δ_r, μ_s, ζ_t are respectively region, industry and time fixed effects. Some models also allow for region-specific linear trend. The coefficient of interest in equation 2 is φ. It gauges the time difference in informal hours worked in the aftermath of the policy. Standard errors in both models are clustered at the region level, therefore they are robust to arbitrary forms of error correlation within a region.[14]

As mentioned above, the apprenticeship contract is a fixed-term labor contract targeted to workers up to 30-year-old. This aspect gives the opportunity to carry out an additional exercise, namely implementing a triple difference research design (DDD). In so doing, the treatment group is refined such as to include workers under-30 in the adopting regions (sectors) that are most likely to be affected by the reform; whereas the control group is made up of individuals under-35 but over-30 years old in the adopting regions (sectors). As an additional control we use the under-30 population from the non adopting regions (sectors). This approach enables us to clear out any difference between young populations across treated and nontreated regions (sectors) not arising from the adoption of the new regulations. We specify models for the probability of working in the undeclared sector and hours worked as follows:

$$\begin{aligned} P(\text{Undeclared}=1|X)_{i,r,s,t} &= c+\gamma\Big[(D_{Reform})_{r,s,t}\times dY_{i,r,s,t,}\Big]+\psi(D_{Reform})_{r,s,t}+\lambda dY_{i,r,s,t} \quad (3)\\ &+ \Big[\pi dY_{i,r,s,t}\times\sum_t\zeta_t\Big]+\delta_r+\mu_s+\zeta_t+\epsilon_{i,r,s,t}\\ \log h_{i,r,s,t} &= c+\gamma\Big[(D_{Reform})_{r,s,t}\times dY_{i,r,s,t,}\Big]+\phi\Big[B_{i,r,s,t}\times dY_{i,r,s,t,}\Big] \quad (4)\\ &+ \varphi\Big[(D_{Reform})_{r,s,t}\times B_{i,r,s,t}\times dY_{i,r,s,t,}\Big]+\pi\Big[dY_{i,r,s,t}\times\sum_t\zeta_t\Big]\\ &+ \gamma(D_{Reform})_{r,s,t}+\phi B_{i,r,s,t}+\varphi\Big[(D_{Reform})_{r,s,t}\times B_{i,r,s,t}\Big]\\ &+ \beta X_{i,r,s,t}+\delta_r+\mu_s+\zeta_t+\epsilon_{i,r,s,t} \end{aligned}$$

where dY is the dummy variable for the under-30 population. All other variables are defined as in equation 1 and 2. The parameters of interest are γ and φ in model 3 and 4 respectively. They inform us about the causal effect of the reform on the probability of working in the informal sector and the hours worked in the shadow by the under-30 population.

This DiD analysis assumes that the evolution of the outcomes of interest for the adopting and nonadopting regions (sectors) would not be systematically different in the absence of intervention. Although there is no formal procedure of testing the validity of this assumption, we provide some encouraging evidence that supports it. First, we compare how the share of undeclared work over

[14]Since the identifying assumption of the estimated DiD models relies on the staggered policy implementation across regions and sectors, serial correlation can also be found within sector-region clusters. Therefore, a viable solution would be to cluster standard errors at the region-sector level. We found that this clustering correction produces slightly smaller standard errors than the ones reported in this paper, without however affecting our main conclusions.

total employment and informal hours worked evolve in treated and control regions.[15] We report this check in Figure 1. The top panel of Figure 1 depicts the evolution of the share of informal work, while the bottom panel presents the time series of the hours worked in adopting and non-adopting regions. The Figure reveals a striking similarity in the movements of the two series no matter what the outcomes is, reassuring on the validity of the DiD identifying assumption. Second, we carry out a falsification test based on placebo regressions. We re-estimate models 1-4 using a false implementation date one year earlier. Results are shown in tables A-2-A-3 in the appendix. For both outcomes, hours worked and the likelihood of being undeclared, this check rules out the presence of heterogenous trends between adopting and nonadopting regions (sectors). It therefore appears that adoption of the new apprenticeship contract is an independent random event.

3.3 Data

The empirical exercise uses individual data drawn from the Bank of Italy - Survey on Household Income and Wealth (SHIW). The survey is carried out every two years with the aim of collecting detailed information on household composition, age, education, labour market variables, incomes, savings and consumption. To the scope of the present paper we consider the waves from 1995 to 2010. Individuals working in the undeclared sector are identified by matching two information: wage and payment of social security contributions. We define as undeclared workers those individuals reporting a positive wage without receiving paid the social security contributions. The latter information is obtained by means of a specific question in the SHIW questionnaire asking whether the interviewee had ever received paid social security contributions throughout his working career. The question reads: *Considering the employment history of... (name), did he/she ever pay, or his/her employer pay, the social security contributions even for a short period?* A negative reply to this question, along with a positive wage, is thus the evidence that the individual worked in the undeclared sector.[16] The pooled sample consists of employed people aged 16 to 64 and amounts to 48700 individuals, evenly distributed across the 8 waves. Descriptive statistics are presented in table A-1 in the appendix.

3.4 Estimation Results

Estimates of equation 1 are found in table 1. Each column represents a regression of the indicator variable, which is unity if the individual works in the undeclared sector (to have not receive paid or have paid the SSCs) and zero otherwise, on region, sector and year dummies and the reform variable, which is equal one in adopting regions (sectors) and zero otherwise. Columns (ii)-(iii) control for a set of individual characteristics and column (iii) adds region linear time trends. To

[15] This check ignores the sector variation in the implementation of the policy, but it differentiates only between adopting and nonadopting regions. Both regions and sectors are considered in the following test.

[16] In addition, for those people answering affirmatively, SHIW reports the cumulative number of years of social security contributions paid by the employer to the worker. To test the robustness of our undeclared labor proxy, we exploited such information too. In particular, we also treated as undeclared workers people whose number of years of social security contributions lay below the 10th, the 5th and the 3rd percentile of the distribution of the following ratio *# of years of social contributions/# of years of potential work experience*. Results not reported in the present paper but available upon request are not affected by the choice of the undeclared labor proxy.

purge the likely heterogeneity coming from the differential impact of the reform on population groups or different labor market attachment across gender, the last two column, labelled $Young$ and Men, focus only on the under-30 and male populations. By lurking behind table 1 it seems that no statistically different from zero effect of the apprenticeship reform in reducing the probability of being employed in the informal sector is detected.

Estimated coefficients of the model for hours worked are reported in table 2. Each column denotes different specifications of the linear regression of log hours worked by declared and undeclared workers and is arranged as in table 1. The first row of table 2 shows the estimates of the impact of the apprenticeship reform on the undeclared hours worked. The coefficients are not statistically different from zero in all cases, suggesting that the reform did not affect the distribution of hours worked across workers.

In line with our discussion above, table 3 reports the DDD estimates, where the under-30 population in nonadopting regions (sectors) is used as an additional control group. In table 3 we show only the coefficients of the triple interaction term, $(D_{Reform})_{r,s,t} \times dY_{i,r,s,t}$, in columns (i)-(iii) and $(D_{Reform})_{r,s,t} \times B_{i,r,s,t} \times dY_{i,r,s,t}$, in columns (iv)-(vi). Different specifications are also presented and the number and type of controls are depicted at the bottom of the table. The DDD approach does not provide any improvement in terms of statistical significance of the effect of the apprenticeship reform. These results corroborate the fact that the apprenticeship reform did not have an impact on neither the chances of being employed in the shadow economy nor hours devoted to undeclared work. Taken all together, these findings provide encouraging support to the idea that easing restrictions on the use of temporary contracts does not help tackling undeclared work.

4 A search and matching model

The model is a continuous time search and matching model à la Mortensen and Pissarides (1994) with several innovative features. First, in order to account for the coexistence of formal and informal markets we allow employers to hire the workers with a formal or an informal contract. Second, to evaluate (ex ante) the effect of the introduction of temporary contracts on the informal economy, we model the labour market before the reforms, when only permanent contracts are available and we compare it with the market post-reforms, when temporary contracts represent an additional option for firms. Third, we allow for endogenous transitions between formal and informal and between permanent and temporary jobs. Finally, we model job separations as a result of an endogenous process. In line with the standard search and matching model, we assume that workers and firms meet in the labour market and the outcome of their match is a non negative surplus. Matches occur randomly and according to a matching function $m(u, v)$, which depends on the total number of unemployed individuals u and the total number of vacancies v. The matching function is increasing in both arguments, concave, and homogeneous of degree one. When the firm opens a vacancy, it meets an unemployed worker according to a Poisson process with arrival rate $\lambda(\theta) = m(u, v)/v$, where $\theta = u/v$ is defined as the market tightness. The arrival rate of a job offer for unemployed workers is $\gamma(\theta) = m(u, v)/u \equiv \theta\lambda(\theta)$.

Workers are ex ante homogeneous. However, when the match worker-firm is formed the produc-

tivity is revealed and heterogeneity emerges. The productivity of the match has two components: an aggregate component p, which is common among all pairs worker-firm and an idiosyncratic component ϵ, which is match-specific. The random component is drawn from the random distribution G with support $[\underline{\epsilon}^G, \overline{\epsilon}^G]$. Depending on the productivity level of the match, the firm decides which type of contract to offer to the worker.

4.1 The model pre-reforms

Firms can decide to offer a formal (permanent) contract or an informal contract to the unemployed worker they meet, according to the productivity level of the match. If a formal contract is offered, the firm is required to pay payroll taxes, whose marginal rate is τ^F, for the entire length of the contract, and firing costs F, when the formal employee is dismissed. If an informal contract is offered, the firm is not required to pay payroll taxes to fund the benefits of the worker. However, imperfect monitoring is enforced by Government authorities: when the firm is caught, at rate ϕ, the employment relationship is terminated and the firm incurs into a penalty fee σ. All the costs are paid to the Government and used in activities external to the model. In this framework, we allow informal workers to search on the job for better formal opportunities. Since it is assumed that the search efficiency of an employed worker is lower compared to the search efficiency of an unemployed worker, the rate at which an informal worker finds a formal job is $\chi\gamma$, where $\chi < 1$.

After the match worker-firm is formed, at rate α a productivity shock may hit the work relationship and a new ϵ is drawn from a sector specific distribution $H^j : [\underline{\epsilon}^j, \overline{\epsilon}^j] \to [0, 1]$, where $j = \{F, I\}$ (formal, informal). The new productivity levels are i.i.d. across workers and time. The future of the worker-firm relationship depends on the new productivity level of the match: firms might decide to change sector (formal vs informal), to continue the ongoing match, or to dismiss the worker.

In this model, low productivity matches tend to be framed within the informal sector, since it is optimal for firms to bypass formal regulations. This happens even though these matches are subject to higher turnover due to the Government monitoring and the searching for better opportunities in the formal sector by informal workers.

In order to understand the labour market dynamics in detail, we will analyze in the next paragraph the firm's and worker's problems.

4.1.1 The firm's problem

Let V be the present discounted value of opening a vacancy for a firm. In addition, let J^j, where $j = \{F, I\}$, be the present discounted value for a firm of a filled position respectively in the formal (F) or informal (I) sector. Therefore, the value of posting a vacancy is:

$$rV = -c + \lambda(\theta) \int_{\underline{\epsilon}^G}^{\overline{\epsilon}^G} \max[J^F(\epsilon'), J^I(\epsilon'), V] dG(\epsilon') - \lambda(\theta)V. \tag{5}$$

The firm has to pay a cost c for the time the vacancy being open. At rate $\lambda(\theta)$ the firm meets an unemployed worker, the idiosyncratic productivity level of the match (ϵ) is revealed and the firm

decides whether to offer a formal job, $J^F(\epsilon)$, an informal job, $J^I(\epsilon)$, or to keep the vacancy open V.

If the firm decides to hire the worker in the formal sector, the value function for the firm for a filled position with idiosyncratic productivity ϵ is:

$$\begin{aligned} rJ^F(\epsilon) &= p+\epsilon-(1+\tau^F)\omega^F(\epsilon)+\alpha^F\int_{\underline{\epsilon}^F}^{\bar{\epsilon}^F}\max[J^F(\epsilon'),J^I(\epsilon')-F,V-F]dH^F(\epsilon') \\ &- \alpha^F J^F(\epsilon) \end{aligned} \tag{6}$$

The match generates a productivity flow equal to $p+\epsilon$. In addition, the firm pays to the worker a salary $\omega^F(\epsilon)$ and to the Government payroll taxes, whose marginal rate is equal to τ^F. At rate α^F a productivity shock may hit the match and a new productivity level ϵ is drawn from the distribution H^F. Together, workers and firms decide whether to keep the relation formal, to turn it into an informal one, or whether to terminate it. In the latter two cases, the firm is required to pay a firing cost F.

If the firm decides to hire the worker in the informal sector, the value function for the firm for a filled position with idiosyncratic productivity ϵ is:

$$\begin{aligned} rJ^I(\epsilon) &= p+\epsilon-\omega^I(\epsilon)+\alpha^I\int_{\underline{\epsilon}^I}^{\bar{\epsilon}^I}\max[J^F(\epsilon'),J^I(\epsilon'),V]dH^I(\epsilon')-\alpha^I J^I(\epsilon) \\ &+ \phi(V-J^I(\epsilon))-\phi\sigma+\eta(V-J^I(\epsilon)) \end{aligned} \tag{7}$$

The match generates the productivity flow $p+\epsilon$ and the firm pays the worker a salary $\omega^I(\epsilon)$. However, the firm does not pay payroll taxes to the Government. At rate α^I the match is hit by a productivity shock and as a result the relation may stay unchanged, may be turned into a formal one, or may be terminated, depending on the new productivity level. In addition, at rate ϕ, Government authorities may discover the illegal activity of the firm, dissolve the worker-firm match, and charge the firm with a penalty fee σ. Finally, we allow informal workers to look for better (formal) jobs. The event that an informal worker transits from an informal to a formal job happens at rate η.

4.1.2 The worker's problem

Let the present discounted value of an unemployed worker be U. In addition, let the present discounted value of an employed worker be W^j, where $j=\{F,I\}$, respectively in the formal (F) of informal (I) sector. Therefore, the value function for an unemployed worker is:

$$rU = b+\gamma(\theta)\int_{\underline{\epsilon}^G}^{\bar{\epsilon}^G}\max[W^F(\epsilon'),W^I(\epsilon'),U]dG(\epsilon')-\gamma(\theta)U \tag{8}$$

The worker receives unemployment benefits b until he is unemployed. At rate $\gamma(\theta)$ the worker meets a firm and the idyosincratic productivity level of the match is revealed. The worker may receive a formal contract ($W^F(\epsilon)$), an informal contract ($W^I(\epsilon)$), or no offer and continue to be unemployed. If it receives an offer, it might be formal or informal and the corresponding value functions for the worker are:

$$\begin{aligned} rW^F(\epsilon) &= \omega^F(\epsilon) + \alpha^F \int_{\underline{\epsilon}^F}^{\bar{\epsilon}^F} \max[W^F(\epsilon'), W^I(\epsilon'), U] dH^F(\epsilon') \\ &- \alpha^F W^F(\epsilon) \end{aligned} \tag{9}$$

$$\begin{aligned} rW^I(\epsilon) &= \omega^I(\epsilon) + \alpha^I \int_{\underline{\epsilon}^I}^{\bar{\epsilon}^I} \max[W^F(\epsilon'), W^I(\epsilon'), U] dH^I(\epsilon') - \alpha^I W^I(\epsilon) \\ &+ \phi(U - W^I(\epsilon)) + \chi\gamma \int_{\underline{\epsilon}^G}^{\bar{\epsilon}^G} \max[W^F(\epsilon'), W^I(\epsilon'), U] dG(\epsilon') - \chi\gamma W^I(\epsilon) \end{aligned} \tag{10}$$

The formal worker receive a salary $\omega^F(\epsilon)$ and at rate α^F its employment relation may be unchanged or may change by becoming informal or by being terminated, according to the newly drawn productivity level. If the worker is offered an informal job, the worker receives a salary $\omega^I(\epsilon)$ and at rate α^I, his productivity level may change. Therefore, its employment relation may become informal, terminate, or it may be unchanged. Moreover, at rate ϕ the worker may lose its job if the illegal working relationship has been discovered by the authorities. Finally, informal workers may also look for better jobs while working and find a new position at rate $\chi\gamma$, where χ is the search efficiency. Since the effort spent in looking for jobs while employed is lower than while unemployed, the probability for employed workers to find a job is lower compared to unemployed workers; therefore $\chi < 1$.

4.1.3 Surplus and wage bargaining

A non-negative surplus is generated every time a pair worker-firm meets and it is match-specific. The surplus changes according to the productivity level of the match and according to the type of contract the worker is hired on. If the contract signed between firm and worker is formal, the firing cost which the firm has to pay at termination enters in the surplus equation and affects the wage bargaining. In addition, the marginal payroll tax rate is accounted for in the wage negotiations. If the contract signed between firm and worker is informal, neither the firing cost nor the payroll tax affect the wage bargaining. The Nash bargaining mechanism is used to compute the wage, where $\beta^j, j = \{F, I\}$ represents the bargaining power of the worker respectively in the formal and informal sector. We believe that the bargaining power of the worker in the informal sector is lower than in the formal sector. For simplicity reasons, we assume that

$$\frac{\beta^F}{(1-\beta^F)(1+\tau)} = \frac{\beta^I}{(1-\beta^I)}, \tag{11}$$

which satisfies the above mentioned belief that $\beta^I < \beta^F$. Workers and firms always agree on the decision to terminate the contract, thus there is no room in this model for involuntary unemployment.

$$S^F(\epsilon) = J^F(\epsilon) + W^F(\epsilon) - (V - F) - U. \tag{12}$$
$$\beta^F[J^F(\epsilon) - (V - F)] = (1 - \beta^F)(1 + \tau)[W^F(\epsilon) - U]. \tag{13}$$

$$S^I(\epsilon) = J^I(\epsilon) + W^I(\epsilon) - V - U. \tag{14}$$
$$\beta^I[J^I(\epsilon) - V] = (1 - \beta^I)[W^I(\epsilon) - U]. \tag{15}$$

As a result of the Nash bargaining, according to the sector, the following wage equations for formal an informal workers respectively are derived:

$$\omega^F(\epsilon) = \frac{\beta^F}{(1 + \tau)}(p + \epsilon + c\theta + rF) + (1 - \beta^F)b. \tag{16}$$

$$\omega^I(\epsilon) = \beta^I(p + \epsilon - \phi\sigma + (1 - \chi)c\theta) + (1 - \beta^I)b. \tag{17}$$

4.1.4 Steady State

In order to compute the steady state of the model, we solve five equations in five unknowns. We recognize four productivity thresholds and the market tightness as the parameters which identify the equilibrium. The five equations summarize the job creation and job destruction conditions as well as the free market condition $V = 0$.

When the firm hires an unemployed worker or an informal worker and the productivity level is equal to ϵ_R the firm is indifferent whether to offer a formal or an informal job.

$$J^F(\epsilon_R) = J^I(\epsilon_R). \tag{18}$$

This equation defines the flows of workers from unemployment to formal and informal employment. When the firm transforms a formal job into an informal job the threshold productivity level is equal to ϵ_T. This threshold differs from the one described above, because when transforming a formal job into an informal one the firm is subject to the payment of a firing cost.

$$J^F(\epsilon_T) + F = J^I(\epsilon_T). \tag{19}$$

Therefore, this equation defines the flow of workers from formal to informal jobs. Finally, the two job destruction conditions from a formal or an informal job are defined by:

$$J^F(\epsilon_F) + F = 0. \tag{20}$$
$$J^I(\epsilon_I) = 0. \tag{21}$$

From equation 19 by plugging in the expression for the wage for formal workers $\omega^F(\epsilon)$ as in 16 we obtain:

$$J^F(\epsilon) + F = \frac{(1-\beta^F)(\epsilon - \epsilon_F)}{r + \alpha^F}. \tag{22}$$

From equation 18 by plugging in the expression for the wage for formal workers $\omega^I(\epsilon)$ as in 17 we obtain:

$$J^I(\epsilon) + F = \frac{(1-\beta^I)(\epsilon - \epsilon_I)}{r + \phi + \eta + \alpha^I}. \tag{23}$$

The set of equations which define the equilibrium of the model is presented in the appendix. We can prove that the equilibrium exist and is unique.

We can retrieve the steady state value of unemployment and formal and informal employment, by looking at the workers flows. Normalizing the labor force to unity, we get:

$$n^I = 1 - n^F - u \tag{24}$$

$$u = \frac{\alpha^F H^F(\epsilon_F) n^F + (\alpha_I H^I(\epsilon_I) + \phi) n^I}{\gamma(\theta)} \tag{25}$$

$$n^F = \frac{[\alpha^I(1 - H^I(\epsilon_R)) + \chi\gamma(\theta)(1 - G(\epsilon_R))]n^I + \gamma(1 - G(\epsilon_R))u}{\alpha^F H^F(\epsilon_T)} \tag{26}$$

We can also compute the flows of workers transiting across states. In particular, the transition from unemployment to employment is given by the sum of the transition to a formal or an informal job, which are described by the following equations:

$$J_{UI} = \gamma(\theta) G(\epsilon_R) \tag{27}$$

$$J_{UF} = \gamma(\theta)(1 - G(\epsilon_R)) \tag{28}$$

The flows of workers transiting from a formal to an informal position and viceversa are given by:

$$J_{FI} = \alpha^F (H^F(\epsilon_T) - H^F(\epsilon_F)) \tag{29}$$

$$J_{IF} = \alpha^I (1 - H^I(\epsilon_R)) + \chi\gamma(\theta)(1 - G(\epsilon_R)) \tag{30}$$

Finally, the flows into unemployment are given by the flow of workers fired while in a formal job and those who are fired while in an informal job:

$$J_{FU} = \alpha^F H^F(\epsilon_F) \tag{31}$$

$$J_{IU} = \alpha^I H^I(\epsilon_I) + \phi \tag{32}$$

4.2 The model post-reforms

We now extend the previous model by including the possibility for firms to hire workers in the formal sector for a fixed period of time (temporary contracts). Three are the main distinct features characterizing this model. First, temporary contracts are modeled to be more flexible than permanent contracts, since at expiration the firm may dismiss the worker without incurring in any firing cost. Second, the marginal payroll tax rate associated with temporary contracts is lower compared to the rate associated with permanent contracts. Finally, workers are allowed to search for better jobs while employed, hence the firm may lose the worker at rate $\xi\gamma$, where $\xi < 1$.[17] In the next section we will describe the firm's and worker's problems in detail.

4.2.1 The firm's problem

Whenever a firm opens a vacancy it incurs in a cost c. At rate $\lambda(\theta)$ the firm meets a worker, the productivity of the match is revealed, and the two parities agree on the future of the relationship. If the productivity is very high, it is optimal for the firm to offer the worker a permanent contract. If the productivity is very low, the firm keeps the vacancy opened. In the intermediate situation, the firm may either offer a temporary contract or hire the worker in the informal market.

$$rV = -c + \lambda(\theta) \int_{\underline{\epsilon}}^{\overline{\epsilon}} \max[J^P(\epsilon'), J^T(\epsilon'), J^I(\epsilon'), V] dG(\epsilon') - \lambda V \tag{33}$$

Whenever the worker is employed, the firm receives a productivity flow equal to $p + \epsilon$. According to the type of contract and the sector the worker is hired on, it receives salary $\omega^P(\epsilon)$, if permanent, $\omega^T(\epsilon)$, if temporary or $\omega^I(\epsilon)$, if informal. If the worker is hired in the formal sector, the firm in addition is required to pay to the Government payroll taxes proportional to the wage, corresponding to a marginal rate τ^P, if the worker is permanent or τ^T, if the worker is temporary, where $\tau^T < \tau^P$.[18] At rate α^j, where $j = \{P, T, I\}$ (permanent, temporary, informal), the match is hit by a productivity shock and the relationship may change according to the new productivity level. In addition, if the worker is hired on a temporary job, the worker is allowed to look for better job opportunities. Therefore, at rate δ it may find a better job and quit his current position, leaving the firm with an open vacancy (Equation 35). If the worker is hired in the informal market, at rate ϕ the firm may be caught by the Government authorities, be subject to the payment of a penalty fee σ, and be forced to open a new vacancy. Finally, at rate η the worker may find a better job

[17] As in the benchmark model, we assume that searching while employed is less efficient than searching while unemployed.

[18] The payroll taxes associated with temporary contracts are lower compared to the payroll taxes associated with permanent contracts.

and quit his current position, leaving the firm with an open vacancy (Equation 36).

$$
\begin{aligned}
rJ^P(\epsilon) &= p+\epsilon-(1+\tau^P)\omega^P(\epsilon) \qquad (34)\\
&+ \alpha^P\int_{\underline{\epsilon}^P}^{\bar{\epsilon}^P}\max[J^P(\epsilon'),J^T(\epsilon')-F,J^I(\epsilon')-F,V-F]dH^P(\epsilon')-\alpha^P J^P(\epsilon)\\
rJ^T(\epsilon) &= p+\epsilon-(1+\tau^T)\omega^T(\epsilon) \qquad (35)\\
&+ \alpha^T\int_{\underline{\epsilon}^T}^{\bar{\epsilon}^T}\max[J^P(\epsilon'),J^T(\epsilon'),J^I(\epsilon'),V]dH^T(\epsilon')-\alpha^T J^T(\epsilon)\\
&+ \delta(V-J^T(\epsilon))\\
rJ^I(\epsilon) &= p+\epsilon-\omega^I(\epsilon)+\alpha^I\int_{\underline{\epsilon}^I}^{\bar{\epsilon}^I}\max[J^P(\epsilon'),J^T(\epsilon'),J^I(\epsilon'),V]dH^I(\epsilon')-\alpha^I J^I(\epsilon) \qquad (36)\\
&+ \phi(V-J^I(\epsilon))-\phi\sigma+\eta(V-J^I(\epsilon))
\end{aligned}
$$

4.2.2 The worker's problem

When the worker is unemployed it receives unemployment benefits b and meets a firm at rate $\gamma(\theta)$. According to the productivity level of the match, the worker may receive a permanent, temporary or informal contract (Eq. 38). When employed, the worker receives a salary $\omega^j(\epsilon)$ and at rate α^j,where $j=\{P,T,I\}$, the productivity level of the match may change and therefore also the worker's employment status. The worker might keep its current contract or may switch to any of the other available contracts.

$$
\begin{aligned}
rU &= b+\gamma(\theta)\int_{\underline{\epsilon}}^{\bar{\epsilon}}\max[W^P(\epsilon'),W^T(\epsilon'),W^I(\epsilon'),U]dG(\epsilon')-\gamma(\theta)U \qquad (37)\\
rW^P(\epsilon) &= \omega^P(\epsilon)+\alpha^P\int_{\underline{\epsilon}^P}^{\bar{\epsilon}^P}\max[W^P(\epsilon'),W^T(\epsilon'),W^I(\epsilon'),U]dH^P(\epsilon') \qquad (38)\\
&- \alpha^P W^P(\epsilon)
\end{aligned}
$$

If the worker is hired on a temporary basis (Eq. 39), in addition at rate $\xi\gamma$, where $\xi<1$, it may find a better job. Finally, if the worker is hired in the informal sector at rate ϕ it may lose his job because of the Government authorities intervention. Finally, at rate $\chi\gamma$,$\chi<1$, it may find

a better job opportunity (Eq. 40).

$$
\begin{aligned}
rW^T(\epsilon) &= \omega^T(\epsilon) + \alpha^T \int_{\underline{\epsilon}^T}^{\bar{\epsilon}^T} \max[W^P(\epsilon'), W^T(\epsilon'), W^I(\epsilon'), U] dH^T(\epsilon') \qquad (39)\\
&- \alpha^T W^T(\epsilon) + \xi\gamma(\theta) \int_{\underline{\epsilon}}^{\bar{\epsilon}} \max[W^P(\epsilon'), W^T(\epsilon'), W^I(\epsilon'), U] dG(\epsilon')\\
&- \xi\gamma(\theta) W^T(\epsilon)\\
rW^I(\epsilon) &= \omega^I(\epsilon) + \alpha^I \int_{\underline{\epsilon}^I}^{\bar{\epsilon}^I} \max[W^P(\epsilon'), W^T(\epsilon'), W^I(\epsilon'), U] dH^I(\epsilon') - \alpha^I W^I(\epsilon) \qquad (40)\\
&+ \phi(U - W^I(\epsilon)) + \chi\gamma(\theta) \int_{\underline{\epsilon}}^{\bar{\epsilon}} \max[W^P(\epsilon'), W^T(\epsilon'), W^I(\epsilon'), U] dG(\epsilon')\\
&- \chi\gamma(\theta) W^I(\epsilon)
\end{aligned}
$$

4.2.3 Surplus and wage bargaining

The surplus, which is generated whenever a match is formed, is a function of the sector as well as the type of contract the worker is hired on. The existence of firing costs F associated with permanent contracts and the payroll taxes τ associated with any formal contract generates a difference in the equilibrium wages, which is reflected in different surpluses. Therefore, three levels of surpluses are computed: the surplus of a permanent contract, the surplus of a temporary contract, and the surplus of an informal contract. As in the benchmark model, we assume that wages are bargained via the standard Nash bargaining mechanism, where β^j, $j = \{P, T, I\}$, is the bargaining power of the permanent versus temporary versus informal worker. As a result, firms and workers always agree on the sector as well as on the type of contract and involuntary unemployment is not contemplated.

Due to the existence of payroll taxes for formal contracts, the sharing rules differ from the standard one. Indeed, for certain productivity values, both workers and firms may agree upon an informal contract to avoid paying taxes.

$$S^P(\epsilon) = J^P(\epsilon) + W^P(\epsilon) - (V - F) - U \qquad (41)$$
$$\beta^P[J^P(\epsilon) - (V - F)] = (1 - \beta^P)(1 + \tau^P)[W^P(\epsilon) - U] \qquad (42)$$

$$S^T(\epsilon) = J^T(\epsilon) + W^T(\epsilon) - V - U \qquad (43)$$
$$\beta^T[J^T(\epsilon) - V)] = (1 - \beta^T)(1 + \tau^T)[W^T(\epsilon) - U] \qquad (44)$$

$$S^I(\epsilon) = J^I(\epsilon) + W^I(\epsilon) - V - U \qquad (45)$$
$$\beta^I[J^I(\epsilon) - V] = (1 - \beta^I)[W^I(\epsilon) - U] \qquad (46)$$

In order to guarantee tractability, we assume that the division of the surplus across contracts is the same. This assumption satisfies our belief that $\beta^I < \beta^T < \beta^P$.

$$\frac{\beta^P}{(1-\beta^P)(1+\tau^P)} = \frac{\beta^T}{(1-\beta^T)(1+\tau^T)} = \frac{\beta^I}{(1-\beta^I)}. \tag{47}$$

As a result of the Nash bargaining, we can compute the equilibrium wages for the three types of contracts:

$$\omega^P(\epsilon) = \frac{\beta^P}{(1+\tau^P)}(p+\epsilon+c\theta+rF) + (1-\beta^P)b \tag{48}$$

$$\omega^T(\epsilon) = \frac{\beta^T}{(1+\tau^T)}(p+\epsilon+(1-\xi)c\theta) + (1-\beta^T)b \tag{49}$$

$$\omega^I(\epsilon) = \beta^I(p+\epsilon-\phi\sigma+(1-\chi)c\theta) + (1-\beta^I)b \tag{50}$$

4.2.4 Steady State

The equilibrium steady state is defined by eight equations and eight endogenous parameters, which identify seven productivity thresholds and the market tightness. The equations which define the model describe the job destruction and job creation conditions for all sectors and contracts and the free entry condition $V = 0$.

The first set of equations describe the transformation decision of a firm whenever a permanent worker is hired. The threshold ϵ_A defines the level of productivity by which the firm is indifferent whether to keep the worker as a permanent employee or offer him a temporary job (and pay the firing cost F). Therefore it determines the flow from permanent to temporary employment. The threshold ϵ_S defines the level of productivity by which the firm is indifferent whether to keep the worker as permanent or to transfer the worker to a job in the informal sector (and pay the firing cost F). Therefore it regulates the job transition from permanent to informal employment. Finally the threshold ϵ_Q defines the level of productivity below which the firm is dismissing the worker and opens a new vacancy. Therefore, it defines the job destruction condition from permanent employment to unemployment.

$$J^P(\epsilon_A) + F = J^T(\epsilon_A) \tag{51}$$
$$J^P(\epsilon_S) + F = J^I(\epsilon_S) \tag{52}$$
$$J^P(\epsilon_Q) + F = 0 \tag{53}$$

The second set of equations describe the transformation decision of the firm whenever a temporary worker is employed. The threshold ϵ_G identifies the level of productivity for which the

firm is indifferent whether to offer a permanent or a temporary job. Therefore, it determines the flow from temporary employment to permanent employment. The threshold ϵ_L identifies the level of productivity for which the firm is indifferent whether to offer a temporary job in the formal sector or an informal job. Therefore, it regulates the flow from temporary employment to informal employment. Finally, the threshold ϵ_B defines the level of productivity below which the firm dismisses the worker and opens a new vacancy. Therefore it defines the job destruction condition from temporary employment to unemployment.

$$J^T(\epsilon_G) = J^P(\epsilon_G) \tag{54}$$
$$J^T(\epsilon_L) = J^I(\epsilon_L) \tag{55}$$
$$J^T(\epsilon_B) = 0 \tag{56}$$

Finally, the last set of equations determines the flow from informal employment and unemployment. The threshold ϵ_U defines the level of productivity by which the firm is hiring an informal worker formally (on a permanent or temporary basis). It also determines the hiring decision in the formal market (permanent versus temporary) for unemployed workers. The threshold ϵ_L defines the level of productivity by which the firm is indifferent whether to move an informal worker on a formal temporary position. It also determines the productivity level by which the firm is indifferent whether to hire an unemployed worker formally and temporary or informally. Finally, the threshold ϵ_V identifies the level of productivity by which the firm dismisses an informal worker. Therefore, it determines the flow from informal employment to unemployment.

$$J^I(\epsilon_U) = J^P(\epsilon_U) \tag{57}$$
$$J^I(\epsilon_L) = J^T(\epsilon_L) \tag{58}$$
$$J^I(\epsilon_V) = 0 \tag{59}$$

From equation 53 by plugging in the expression for the wage for formal workers $\omega^P(\epsilon)$ as in 48, we obtain

$$J^P(\epsilon) + F = \frac{(1-\beta^P)(\epsilon - \epsilon_Q)}{r + \alpha^P} \tag{60}$$

From equation 56 by plugging in the expression for the wage for formal workers $\omega^T(\epsilon)$ as in 49, we obtain

$$J^T(\epsilon) = \frac{(1-\beta^T)(\epsilon - \epsilon_B)}{r + \delta + \alpha^T} \tag{61}$$

From equation 59 by plugging in the expression for the wage for formal workers $\omega^I(\epsilon)$ as in 50, we obtain

$$J^I(\epsilon) = \frac{(1-\beta^I)(\epsilon - \epsilon_V)}{r + \phi + \eta + \alpha^I} \tag{62}$$

The set of equations which define the steady state equilibrium is presented in the appendix. It can be proven that equilibrium exists and it is unique.[19]

We can now retrieve the steady state value of unemployment and formal and informal employment, by computing the workers' flows across sectors and contracts. Normalizing the labor force to unity, we get:

$$u = \frac{\alpha^P H^P(\epsilon_Q) n^P + \alpha_T H^T(\epsilon_B) n^T + (\alpha_I H^I(\epsilon_V) + \phi) n^I}{\gamma(\theta)} \tag{63}$$

$$n^P = \frac{[\alpha^T(1 - H^T(\epsilon_G)) + \xi\gamma(\theta)(1 - G(\epsilon_G))] n^T}{\alpha^P H^P(\epsilon_A)} \tag{64}$$
$$+ \frac{\alpha^I[(1 - H^I(\epsilon_U)) + \chi\gamma(\theta)(1 - G(\epsilon_U))] n^I + \gamma(\theta)(1 - G(\epsilon_U))u}{\alpha^P H^P(\epsilon_A)}$$

$$n^T = \frac{\alpha^P(H^P(\epsilon_A) - H^P(\epsilon_S)) n^P + [\alpha^I(H^I(\epsilon_U) - H^I(\epsilon_L)) + \chi\gamma(\theta)(G(\epsilon_U) - G(\epsilon_L))] n^I}{\alpha^T(1 - H^T(\epsilon_G)) + \alpha^T(H^T(\epsilon_L)) + \xi\gamma(\theta)(1 - G(\epsilon_G))} \tag{65}$$
$$+ \frac{\gamma(\theta)(G(\epsilon_U) - G(\epsilon_L))u}{\alpha^T(1 - H^T(\epsilon_G)) + \alpha^T(H^T(\epsilon_L)) + \xi\gamma(\theta)(1 - G(\epsilon_G))}$$

$$n^I = 1 - n^P - n^T - u \tag{66}$$

We can also compute the flows of workers transiting across states. In particular, the transition from unemployment to employment is given by the sum of the transition to a formal or an informal job, which are described by the following equations:

$$J_{UI} = \gamma(\theta) G(\epsilon_L) \tag{67}$$
$$J_{UT} = \gamma(\theta)(G(\epsilon_U) - G(\epsilon_L)) \tag{68}$$
$$J_{UP} = \gamma(\theta)(1 - G(\epsilon_U)) \tag{69}$$

The flows of workers transiting from a permanent to a temporary position (and viceversa) are given by:

$$J_{PT} = \alpha^P(H^P(\epsilon_A) - H^P(\epsilon_S)) \tag{70}$$
$$J_{TP} = \alpha^T(1 - H^T(\epsilon_G)) + \xi\gamma(\theta)(1 - G(\epsilon_G)) \tag{71}$$

The flows of workers transiting from a formal to an informal position (and viceversa) are given by:

$$J_{PI} = \alpha^P(H^P(\epsilon_S) - H^P(\epsilon_Q)) \tag{72}$$
$$J_{TI} = \alpha^T(H^T(\epsilon_L) - H^T(\epsilon_B)) \tag{73}$$

[19]By looking at Equation A.15, we can notice that a higher θ increases the left-hand side and lowers the right -hand side of the equation. Therefore, a unique value of θ satisfies Equation A.15.

and

$$J_{IP} = \alpha^I(1 - H^I(\epsilon_U)) + \chi\gamma(\theta)(1 - G(\epsilon_U)) \tag{74}$$
$$J_{IT} = \alpha^I(H^I(\epsilon_U) - H^I(\epsilon_L)) + \chi\gamma(\theta)(G(\epsilon_U) - G(\epsilon_L)) \tag{75}$$

Finally, the flows into unemployment are given by the flow of workers fired while hired on a permanent or temporary contract and those who are dismissed while employed in an informal job:

$$J_{PU} = \alpha^P H^P(\epsilon_Q) \tag{76}$$
$$J_{TU} = \alpha^T H^T(\epsilon_B) \tag{77}$$
$$J_{IU} = \alpha^I H^I(\epsilon_V) + \phi \tag{78}$$

After we compute the steady state of the model, we are now ready to calibrate it to match statistics (such as unemployment rate, share of formal and informal employment, informality rate) in the data.

4.3 Model calibration

In order to perform the model calibration, we choose parameter values according to the literature on the topic, the Italian legislation, and the statistics provided by the National Institute of Statistics (ISTAT). A description of the parameters can be found in table 4 (pre-reforms) and table 5 (post-reforms). A summary of the parameter values is listed in table 8. The time period for simulation is one quarter. Following Bentolila *et al.* (2012); Ljungqvist (2002); Mortensen & Pissarides (1994), we set the interest rate r equal to 0.01. We assume that the distribution of productivity is uniform. Following Bosch & Esteban-Pretel (2012), we fix the upper bounds of the distributions equal to 1. We also set the lower bounds of the distributions to be equal to -1, except for the lower bound of the G distribution, which is estimated together with the other endogenous parameters. Therefore, we assume H^F and H^I to be uniformly distributed in the range $[-1, 1]$ and G uniformly distributed in the range $[\underline{\epsilon}_G, 1]$ for the benchmark model. For the post-reforms model, H^P, H^T and H^I are uniformly distributed in the range $[-1, 1]$, while G is uniformly distributed in the range $[\underline{\epsilon}_G, 1]$.

The payroll taxes for permanent jobs, represented in the model by τ^P, are set equal to 0.35 as described in the document "Doing Business in Italy" (2008). The same tax is set to 0.25 for temporary jobs. This value is computed averaging the payroll tax rates across different types of temporary contracts in Italy. Moreover, we set the average cost of opening a vacancy c equal to 0.5, which corresponds to half of the productivity of a worker p, which is normalized to 1.

The monitoring rate ϕ is set equal to 0.05 and the penalty fee represented by σ to 0.45, as in the data on labour inspections. We assign a value to the worker's share of surplus (β) in the pre-reforms set up in order to satisfy Equation 11. This implies that β^F is set equal to 0.52 and β^I is set equal to 0.445. Following the same logic for the post-reforms set up, our goal is to satisfy Equation 47. Therefore, β^P, β^T and β^I are set respectively equal to $0.52, 0.5$ and 0.445. All these parameters fit in the range suggested by Petrongolo & Pissarides (2001). The most difficult parameter to calibrate is the one representing firing costs. Firing costs are very hard to quantify,

particularly for the case of Italy, where a complicated legislation sets different rules according to company size, reason for firing the worker, and often allows the judicial court to decide upon. However, in this last situation, as emphasized by Ichino (1996), given the uncertainty associated with the length of the trial and the bias of the judges, it is hard to associate a number to the firing costs supported by the company. Therefore, we follow the approach used by Bentolila *et al.* (2012), who calibrate this value for France and Spain, and assign to F the value of 1.6. The unemployment benefit b is fixed as in Bentolila *et al.* (2012) to 0.55. Before the reforms, we set the probability to experience a productivity shock while employed formally represented by the parameter α^F to 0.01. The same parameter for informal workers is set equal to 0.05, which is higher than in the formal market, as in Bosch & Esteban-Pretel (2012), to take into account the heterogeneity among workers hired in the black economy. The efficiency of search, χ, performed by informal workers is set equal to 0.3, to account for the fact that looking for a job while employed is less effective. After the reforms, α^P for permanent workers, α^T for temporary workers and α^B for informal workers get respectively values 0.08, 0.2 and 0.2. The value associated with temporary contracts reflects the higher volatility of productivity among fixed term employees. We assign to the probability to fill a vacancy, λ, value 0.16 and 0.48 in the pre and post-reforms respectively; in addition, since informal workers and temporary workers look for other jobs while employed, but at a lower efficiency rate, we set the search efficiency parameters χ and ψ equal to 0.17 and 0.25, respectively. These values are selected in order to match the average unemployment rate during the four years before and after the reforms, the informality rate before and after the reforms and the share of temporary contracts after the reforms. Table 9 presents the data (target values) and the steady-state value of the unemployment rate, temporary contract share after the reforms, and informality rate. As can be observed, we are able to match fairly well the chosen target variables, in both periods.

4.4 Ex ante evaluation and Policy Implication: How to drive "emersion"

We use the model to test the effects of several potential policy interventions on the equilibrium distribution of formal versus informal and permanent versus temporary employment. First, we study the changes in the distribution caused by the perturbation of single parameters. In table 10, 11, 12 and 13, we consider a reduction of the firing costs, F, an increase of the penalty fee paid by the firm in case of inspection, σ, an increase in the inspection rate, ϕ and a reduction of the payroll taxes associated with permanent contracts, τ^P, respectively. We focus on these parameters for several reasons. First, because as we have emphasised in the introduction, increasing tax enforcement or augmenting the fines for this non compliant behaviour are commonly considered the two most compelling policy interventions to reduce evasion. The main difference between the two interventions is the burden on the government budget: while the first policy may be quite expensive, the second one would not affect the public expense. Second, we consider firing costs, since in the literature they are treated as one of the main components of the European labor markets rigidities, causing high unemployment and lower turnover. We believe that the perturbation of this parameter could change the dynamics of the labor market and have potentially beneficial effects in terms of emersion. Finally, we take into consideration the payroll taxes associated with permanent

contracts, since they are considered quite high in the Mediterranean countries, and as such they could create disincentives for firms to hire workers in the formal sector. In addition, the difference in the payroll taxes between permanent and temporary contracts is one of the reasons which lead to the creation of the duality problem in the Mediterranean labor markets (Saint-Paul, 1997).

We find that as the value of the firing costs decreases, total employment decreases due to both lower permanent and temporary employment. At the same time both informal employment and unemployment are higher. The explanation behind this result is in the fact that whenever firing costs are lower, the job destruction of permanent positions is higher and the worker flows directed towards the informal sector (the majority) or the unemployment pool increase. Temporary contracts, which before represented a substitute for permanent contracts due to their higher flexibility, are not anymore as appealing for the firm. Therefore, the ratio of temporary versus permanent employment is lower. In summary, by reducing the firing costs per se, we are not only unable to achieve emersion, but we are actually worsening the labor market conditions in terms of employment, formal and informal, and unemployment. We also find that for higher values of the penalty fee and for higher values of the inspection rate, the informality rate decreases and the share of temporary employment increases, leaving unemployment approximately constant. This result is quite intuitive: by creating disincentives to hire in the informal sector, firms choose the best alternative option, i.e., hiring workers in the formal sector with temporary contracts. However, it is interesting to notice that the range of variation is much higher whenever the inspection rate increases, i.e., increasing the probability to inspect firms is more effective in reducing informal employment. This leads us to conclude that, even though it is more costly from a public finance perspective, increasing enforcement has a bigger deterrence effect on the likelihood of hiring in the informal sector compared to increasing the fine. Finally, we find that reducing the payroll taxes associated with permanent contracts has positive effects on the informality rate, while the unemployment rate is also lower. In addition, we detect a strong substitution effect between temporary and permanent employment, which drives the share of temporary employment to significantly lower levels. This result is explained by the fact that by reducing the payroll taxes associated with permanent contracts, the incentives for firms to hire permanent workers are higher, while the benefits for hiring them on a temporary basis are not as strong as before. This reduces both the share of temporary work and of informal work.

We then consider combinations of interventions to investigate whether pairing several policies could generate stronger effects in terms of emersion. Specifically, we focus on four different policy mix: we pair an increase of the inspection rate, ϕ, first, with an increase of the penalty fee, σ, and later, with an increase in firing costs, F. We then repeat the same exercise by considering instead of an increase of the rate at which informal workers are caught, ϕ an increase of the penalty fee, σ.

The results of these policy experiments are shown in table 14, 15, 16 and 17, respectively. Looking at the first two policy experiments, we find that reducing the payroll taxes associated with permanent contracts has a stronger effect on the reduction of the informality rate, compared to a reduction of the firing costs. In addition, while in the first scenario, both permanent and temporary employment increase, leading to a slight increase in the share of temporary contracts, in the second scenario, the increase of temporary employment is significantly higher compared to permanent employment. In fact, in the first scenario, an increase in the inspection rate leads to

a higher job destruction of informal employees, which comes along with a reduction of the flow of temporary workers into the informal sector and a lower job creation in the informal sector; therefore, the informality rate is lower. Moreover, since due to the lower payroll taxes, the job destruction of permanent employees is lower and the flow of workers from temporary to permanent positions is higher, we observe an increase in the share of permanent employment. In the second scenario, while the effect on the informal sector is the same, the lower firing costs generate an increase in the job destruction and a decrease in the job creation of permanent positions. This, associated with a reduced flow of workers from temporary to permanent work, creates a reduction in the share of permanent employment. Whenever we consider an increase in the penalty fee instead of an increase in the inspection rate, we notice similar trends for the informality rate and the share of temporary employment, but a smaller range of variation. Therefore, we confirm the higher degree of effectiveness in reducing informality associated with the inspection rate rather than with the penalty fee.

Finally, our last experiment involves a reduction of the penalty fee, ϕ, together with an increase of the payroll taxes associated with temporary contracts, τ^T (table 18). We find that informal employment is lower and permanent employment increases, while temporary employment declines. In this scenario, in fact, we detect a substitution effect between temporary and permanent employment: both the job creation of permanent employment and the flow of workers from temporary to permanent positions increase. Overall, the share of temporary employment is therefore lower.

5 Conclusions

In this paper we investigate whether different types of policy interventions may be able to stimulate the transition of workers from the informal to the formal sector. To reach this objective we perform both an ex post and ex ante program evaluation analysis. We test whether the 2003 Italian labor market reform was effective in reducing the share of informal employment. From this ex post evaluation, we conclude that there was no significant effect neither on the intensive nor on the extensive margin. We use this evidence as a motivation and background for the development of a search model where the informal sector coexist with a formal decor, in which both permanent and temporary contracts are available. By calibrating the model according to the Italian labor market characteristics, we study combinations of policy interventions which could generate "emersion". The findings of this ex ante evaluation suggest that combining lower taxation with stronger enforcement could be effective in achieving our goal. In particular, we show that by lowering the payroll taxes associated with permanent contracts and increasing the inspection fee, informality is significantly lower and unemployment is stable. Similar results are obtained when lowering firing costs and increasing the inspection fee, even though this may increase the share of temporary contracts, worsening the duality which already characterizes several European labor markets. Performing a cost-benefit analysis to identify which combination of policies is more implementable and sustainable is in the top list of our future research agenda.

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A Appendix

A.1 Steady state equilibrium pre-reforms

The equilibrium of the model pre-reforms is defined by the following set of equations:

$$\frac{1+\tau(1-\beta^F)}{(1+\tau)(1-\beta^F)}\left[\frac{(1-\beta^F)(\epsilon_R-\epsilon_F)}{r+\alpha^F}-F\right]=\frac{(\epsilon_R-\epsilon_I)}{r+\phi+\eta+\alpha^I} \tag{A.1}$$

$$\left[\frac{(1+\tau(1-\beta^F))(\epsilon_T-\epsilon_F)}{(1+\tau)(r+\alpha^F)}\right]=\frac{(\epsilon_T-\epsilon_I)}{r+\phi+\eta+\alpha^I} \tag{A.2}$$

$$\epsilon_F=-p+\frac{\beta^F}{(1-\beta^F)}rF+(1+\tau)b+\frac{\beta^F}{(1-\beta^F)}c\theta- \tag{A.3}$$

$$\alpha^F\int_{\epsilon_{H_F}}^{\epsilon_T}\left[\frac{(1-\beta^I)}{(1-\beta^F)}\frac{(\epsilon'-\epsilon_I)}{(r+\phi+\eta+\alpha^I)}\right]dH^F(\epsilon')-\alpha^F\int_{\epsilon_T}^{\bar{\epsilon}_{H_F}}\left[\frac{(\epsilon'-\epsilon_F)}{(r+\alpha^F)}\right]dH^F(\epsilon')$$

$$\epsilon_I=-p+b+\frac{\beta^I}{(1-\beta^I)}(1-\chi)c\theta+\phi\sigma-\alpha^I\int_{\epsilon_{H_I}}^{\epsilon_R}\frac{(\epsilon'-\epsilon_I)}{(r+\phi+\eta+\alpha^I)}dH^I(\epsilon') \tag{A.4}$$

$$-\frac{\alpha^I}{(1-\beta^I)}\int_{\epsilon_R}^{\bar{\epsilon}_{H_I}}(1-\beta^F)\left[\frac{(\epsilon'-\epsilon_F)}{(r+\alpha^F)}-F\right]dH^I(\epsilon')$$

$$\frac{c}{\lambda}=\int_{\underline{\epsilon}^G}^{\epsilon_R}\frac{(1-\beta^I)(\epsilon'-\epsilon_I)}{(r+\phi+\eta+\alpha^I)}dG(\epsilon')+\int_{\epsilon_R}^{\bar{\epsilon}^G}\left[\frac{(1-\beta^F)(\epsilon'-\epsilon_F)}{(r+\alpha^F)}-F\right]dG(\epsilon') \tag{A.5}$$

By analyzing the equations above we can claim that the equilibrium exist and is unique.[20]

[20]Higher θ increases the left hand side of Equation A.1 and it lowers both formal and informal surplus, by decreasing the right hand side of equation A.1 as both thresholds ϵ^F and ϵ^I depend positively on θ, while ϵ^R does not affect the expected profit from opening a vacancy. Therefore, there is a unique value of θ that satisfies the equation.

A.2 Steady state equilibrium post-reforms

$$\frac{1}{(1-\beta^T)}\left[\frac{(1-\beta^P)(\epsilon_G-\epsilon_Q)}{r+\alpha^P}-F\right]=\frac{(\epsilon_G-\epsilon_B)}{r+\delta+\alpha^T} \tag{A.6}$$

$$\frac{1}{(1-\beta^I)}\left[\frac{(1-\beta^P)(\epsilon_U-\epsilon_Q)}{r+\alpha^P}-F\right]=\frac{(\epsilon_U-\epsilon_V)}{r+\phi+\eta+\alpha^I} \tag{A.7}$$

$$\frac{(1-\beta^T)}{(1-\beta^I)}\frac{(\epsilon_D-\epsilon_B)}{r+\delta+\alpha^T}=\frac{(\epsilon_D-\epsilon_V)}{r+\phi+\eta+\alpha^I} \tag{A.8}$$

$$\frac{(1-\beta^P)}{(1-\beta^T)}\frac{(\epsilon_A-\epsilon_Q)}{r+\alpha^P}=\frac{(\epsilon_A-\epsilon_B)}{r+\delta+\alpha^T} \tag{A.9}$$

$$\frac{(1-\beta^P)}{(1-\beta^I)}\frac{(\epsilon_S-\epsilon_Q)}{r+\alpha^P}=\frac{(\epsilon_S-\epsilon_V)}{r+\phi+\eta+\alpha^I} \tag{A.10}$$

$$\epsilon_Q=-p+\frac{\beta^P}{(1-\beta^P)}rF+(1+\tau^P)b+\frac{\beta^P}{(1-\beta^P)}c\theta \tag{A.11}$$
$$-\frac{\alpha^P}{(1-\beta^P)}\int_{\epsilon^Q}^{\epsilon_S}\left[(1-\beta^I)\frac{(\epsilon'-\epsilon_V)}{(r+\phi+\eta+\alpha^I)}\right]dH^P(\epsilon')$$
$$-\frac{\alpha^P}{(1-\beta^P)}\int_{\epsilon_S}^{\epsilon_A}\left[(1-\beta^T)\frac{(\epsilon'-\epsilon_B)}{(r+\delta+\alpha^T)}\right]dH^T(\epsilon')-\alpha^P\int_{\epsilon_A}^{\bar{\epsilon}_P}\left[\frac{(\epsilon'-\epsilon_Q)}{(r+\alpha^P)}\right]dH^P(\epsilon')$$

$$\epsilon_B=-p+(1+\tau^T)b+\frac{\beta^T}{(1-\beta^T)}(1-\xi)c\theta \tag{A.12}$$
$$-\frac{\alpha^T}{(1-\beta^T)}\left[\int_{\epsilon^B}^{\epsilon_D}(1-\beta^I)\frac{(\epsilon'-\epsilon_V)}{(r+\phi+\eta+\alpha^I)}dH^P(\epsilon')+\int_{\epsilon_D}^{\epsilon_G}\frac{(\epsilon'-\epsilon_B)}{(r+\delta+\alpha^T)}dH^P(\epsilon')\right]$$
$$-\frac{\alpha^T}{(1-\beta^T)}\int_{\epsilon_G}^{\bar{\epsilon}_P}\left[(1-\beta^P)\frac{(\epsilon'-\epsilon_Q)}{(r+\alpha^P)}-F\right]dH^P(\epsilon')$$

$$\epsilon_V=-p+b+\frac{\beta^I}{(1-\beta^I)}(1-\chi)c\theta+\phi\sigma-\alpha^I\int_{\epsilon_V}^{\epsilon_D}\frac{(\epsilon'-\epsilon_V)}{(r+\phi+\eta+\alpha^I)}dH^I(\epsilon') \tag{A.13}$$
$$-\frac{\alpha^I}{(1-\beta^I)}\left[\int_{\epsilon_D}^{\epsilon_G}(1-\beta^T)\frac{(\epsilon'-\epsilon_B)}{(r+\delta+\alpha^T)}dH^I(\epsilon')-\int_{\epsilon_G}^{\bar{\epsilon}_I}\left[(1-\beta^P)\frac{(\epsilon'-\epsilon_Q)}{(r+\alpha^P)}-F\right]dH^I(\epsilon')\right]$$

$$\frac{c}{\lambda(\theta)}=\int_{\underline{\epsilon}_G}^{\epsilon_D}\frac{(1-\beta^I)(\epsilon'-\epsilon_V)}{(r+\phi+\eta+\alpha^I)}dG(\epsilon')+\int_{\epsilon_D}^{\epsilon_N}\frac{(1-\beta^T)(\epsilon'-\epsilon_B)}{(r+\delta+\alpha^T)}dG(\epsilon') \tag{A.14}$$
$$+\int_{\epsilon_N}^{\bar{\epsilon}_G}\left[\frac{(1-\beta^P)(\epsilon'-\epsilon_Q)}{(r+\alpha^P)}-F\right]dG(\epsilon')$$

Again it can be proven that an equilibrium exist and is unique.

Table A-1. Descriptive statistics of the sample.

	Mean	s.d.	No. of observations
Undeclared worker	0.048	0.214	48700
Fixed-term job	0.117	0.322	48700
Age	39.692	10.403	48700
Tertiary education	0.135	0.342	48700
Secondary education	.458	0.498	48700
Women	0.415	0.492	48700
Part-time work schedule	0.101	0.301	48700
Years of potential experience	19.507	11.270	48591
Living in urban area	0.131	0.338	48700
Non-native	0.066	0.249	48700
Blue-collars	0.463	0.498	42319
White-collars	0.424	0.494	42319
Executives and Managers	0.077	0.267	48700
Industry sectors:			
Agriculture, forestry and fishing	0.0472	0.212	48700
Mining and quarrying; Manufacturing; Electricity and gas supply; Water supply	0.280	0.449	48700
Construction	0.063	0.244	48700
Wholesale and retail trade	0.119	0.324	48700
Transporting and storage	0.041	0.200	48700
Financial and insurance activities	0.034	0.181	48700
Real estate activities; Information and communication; Professional, scientific and technical activities	0.062	0.242	48700
Activities of households as employers	0.047	0.212	48700
Public administration and defense; Education; Human health and social work activities	0.300	0.458	48700
Extraterritorial organizations and bodies	0.003	0.059	48700
Nuts 1 regions:			
ITC: Northwestern Italy	0.281	0.450	48700
ITD: Northeastern Italy	0.200	0.426	48700
ITE: Central Italy	0.191	0.400	48700
ITF: Southern Italy	0.191	0.393	48700
ITG: Insular Italy	0.086	0.281	48700

NOTE. - To save space the summary statistics of only three occupations dummies and four NUTS 1 regions are shown. In the estimates the full set of region dummies and occupation dummies is instead used.

Table A-2. Placebo estimates of the impact of apprenticeship reform on the probability of being undeclared.

	i	ii	iii	Young	Men
Reform	0.00	0.01	0.01	-0.00	0.01
	(0.01)	(0.01)	(0.01)	(0.03)	(0.01)
Individual covariates	no	yes	yes	yes	yes
Region FE	yes	yes	yes	yes	yes
Time FE	yes	yes	yes	yes	yes
Sector FE	yes	yes	yes	yes	yes
Region-specific linear trend	no	no	yes	no	no
N	48700	48591	48591	9508	28296

NOTE. - Dependent variable is equal to one if individual declares to have not received paid or have not paid the SSCs. Reform is lagged one period. Ordinary least squares estimates given. Robust standard errors (in brackets) allow for arbitrary correlation of residuals within each region. Young: 16-29 year-old people.

Table A-3. Placebo estimates of the impact of apprenticeship reform on hours worked.

	i	ii	iii	Young	Men
Reform	1.46	0.26	0.43	-1.03	-0.49
	(0.68)	(0.53)	(0.60)	(1.65)	(0.30)
Individual covariates	no	yes	yes	yes	yes
Region FE	yes	yes	yes	yes	yes
Time FE	yes	yes	yes	yes	yes
Sector FE	yes	yes	yes	yes	yes
Region-specific linear trend	no	no	yes	no	no
N	48700	48591	48591	9508	28296

NOTE. - Dependent variable: hours worked by undeclared and declared workers; Undeclared: it is equal to one if individual declares to have not received paid or have not paid the SSCs. Ordinary least squares estimates given. Robust standard errors (in brackets) allow for arbitrary correlation of residuals within each region. Young: 16-30 year-old people.

Table 1. Difference-in-differences estimates of the impact of apprenticeship reform on the probability of being undeclared.

	i	ii	iii	Young	Men
Reform	-0.03	-0.03	-0.03	-0.01	-0.03
	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
Individual covariates	no	yes	yes	yes	yes
Region FE	yes	yes	yes	yes	yes
Time FE	yes	yes	yes	yes	yes
Sector FE	yes	yes	yes	yes	yes
Region-specific linear trend	no	no	yes	no	no
N	48700	48591	48591	9508	28296

NOTE. - Dependent variable is equal to one if individual declares to have not received paid or have not paid the SSCs. Ordinary least squares estimates given. Robust standard errors (in brackets) allow for arbitrary correlation of residuals within each region. Young: 16-30 year-old people.

Table 2. Difference-in-differences estimates of the impact of apprenticeship reform on hours worked.

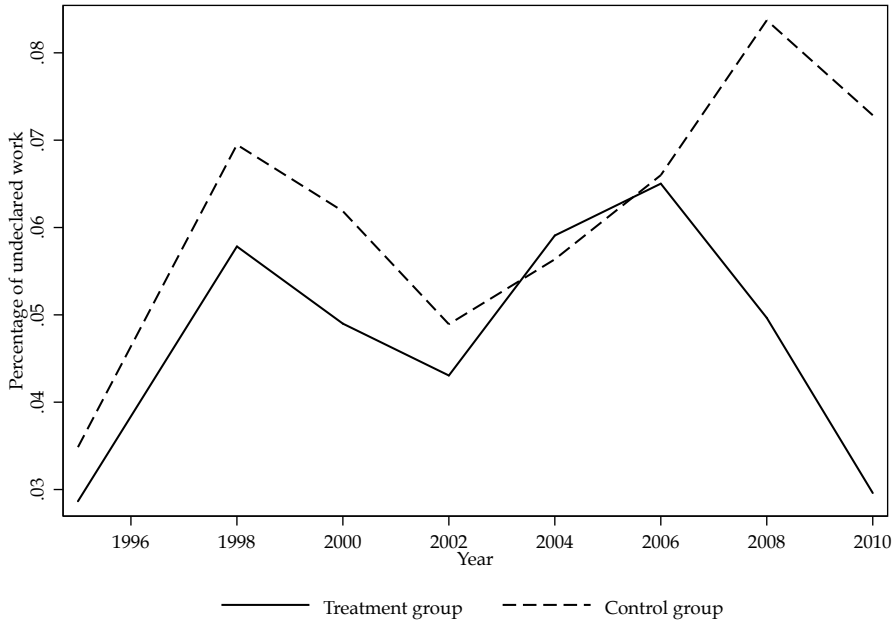
	i	ii	iii	Young	Men
Reform × undeclared	-0.02	-0.15	0.07	0.64	-0.62
	(0.75)	(0.52)	(0.61)	(1.05)	(0.59)
Undeclared	-2.87	-0.73	-0.75	-0.94	-0.78
	(0.63)	(0.39)	(0.40)	(0.46)	(0.48)
Reform	-0.02	-0.07	-0.12	-0.80	0.23
	(0.23)	(0.25)	(0.27)	(0.84)	(0.22)
Individual covariates	no	yes	yes	yes	yes
Region FE	yes	yes	yes	yes	yes
Time FE	yes	yes	yes	yes	yes
Sector FE	yes	yes	yes	yes	yes
Region-specific linear trend	no	no	yes	no	no
N	48700	48591	48591	9508	28296

NOTE. - Dependent variable: hours worked by undeclared and declared workers; Undeclared: it is equal to one if individual declares to have not received paid or have not paid the SSCs. Ordinary least squares estimates given. Robust standard errors (in brackets) allow for arbitrary correlation of residuals within each region. Young: 16-30 year-old people.

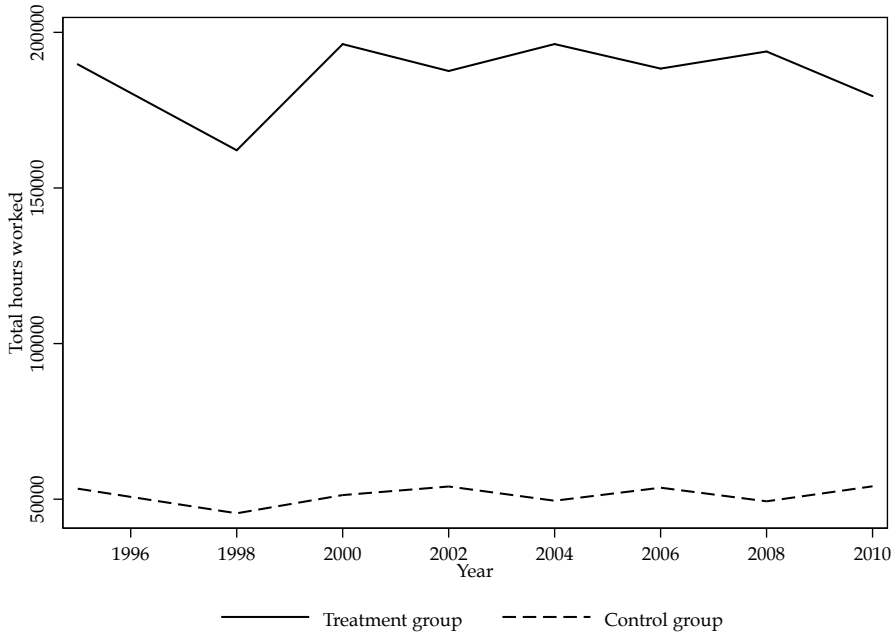
Table 3. Difference-in-difference-in-differences estimates of the impact of apprenticeship reform on the probability of being undeclared and hours worked.

	Probability of being undeclared			Hours worked		
	i	ii	iii	iv	v	vi
Reform	0.00	0.01	0.01	-1.16	-0.81	-0.90
	(0.02)	(0.02)	(0.02)	(1.99)	(2.16)	(2.13)
Individual covariates	no	yes	yes	no	yes	yes
Region FE	yes	yes	yes	yes	yes	yes
Time FE	yes	yes	yes	yes	yes	yes
Sector FE	yes	yes	yes	yes	yes	yes
Region-specific linear trend	no	no	yes	no	no	yes
N	16891	16848	16848	16880	16837	16837

NOTE. - Dependent variable in columns i-iii is equal to one if individual declares to have not received paid or have not paid the SSCs; dependent variable in columns iv-vi is hours worked by undeclared and declared workers. Estimates in columns i-iii are the coefficients of the interaction, Reform×16-30 year-old; in columns iv-vi of the interaction, Reform×Undeclared×16-30 year-old. Ordinary least squares estimates given. Robust standard errors (in brackets) allow for arbitrary correlation of residuals within each region.



(a) Share of undeclared work over total employment



(b) Undeclared and declared hours worked.

Figure 1. Share of undeclared over total employment and hours worked in treatment and control groups.

Table 4. Model parameters-Pre-reforms

Parameter	Description
r	Interest rate
β^F	Worker's share of surplus in the formal sector
β^I	Worker's share of surplus in the informal sector
$\overline{\epsilon}^G$	Upper bound of the G distribution
$\underline{\epsilon}^G$	Lower bound of the G distribution
$\overline{\epsilon}^F$	Upper bound of the F distribution
$\underline{\epsilon}^F$	Lower bound of the F distribution
$\overline{\epsilon}^I$	Upper bound of the I distribution
$\underline{\epsilon}^I$	Lower bound of the I distribution
ϕ	Rate at which the informal job is discovered
σ	Penalty fee for informal jobs
η	Rate at which informal workers find a better job
α^F	Rate at which a productivity shock hits the match in the formal sector
α^I	Rate at which a productivity shock hits the match in the informal sector
b	Unemployment benefits
p	General productivity level
ξ	Search efficiency of an informal worker
λ	Rate at which a vacancy is filled
θ	Market tightness
τ^P	Payroll tax rate
π	Utility of a worker out of the labor force
n^F	Number of formal workers
n^I	Number of informal workers
u	Number of unemployed
F	Firing cost

Table 5. Model parameters-Post-reforms

Parameter	Description
r	Interest rate
$\overline{\epsilon}^G$	Upper bound of the G distribution
$\underline{\epsilon}^G$	Lower bound of the G distribution
$\overline{\epsilon}^P$	Upper bound of the P distribution
$\underline{\epsilon}^P$	Lower bound of the P distribution
$\overline{\epsilon}^T$	Upper bound of the T distribution
$\underline{\epsilon}^T$	Lower bound of the T distribution
$\overline{\epsilon}^B$	Upper bound of the B distribution
$\underline{\epsilon}^B$	Lower bound of the B distribution
β^P	Permanent worker's share of surplus in the formal sector
β^T	Temporary worker's share of surplus in the formal sector
β^I	Worker's share of surplus in the informal sector
ϕ	Rate at which the informal job is discovered
σ	Penalty fee for informal job
η	Rate at which informal workers find a better job
α^P	Rate at which a productivity shock hits a permanent match
α^T	Rate at which a productivity shock hits a temporary match
α^B	Rate at which a productivity shock hits an informal match
b	Unemployment benefits
p	General productivity level
ξ	Search efficiency of an informal worker
ψ	Search efficiency of a temporary worker
λ	Rate at which a vacancy is filled
θ	Market tightness
τ^P	Payroll tax rate for permanent workers
τ^T	Payroll tax rate for temporary workers
π	Utility of a worker out of the labor force
n^P	Number of permanent workers
n^T	Number of temporary workers
n^B	Number of informal workers
u	Number of unemployed
F	Firing costs

Table 6. Calibration exogenous parameter values

Parameter	Pre-reforms	Post-reforms
r	0.010	0.010
β^F	0.520	$--$
β^I	0.445	0.445
β^P	$--$	0.520
β^T	$--$	0.500
α^F	0.01	$--$
α^I	0.05	0.200
α^P	$--$	0.080
α^T	$--$	0.200
τ^P	0.35	0.35
τ^T	$--$	0.25
F	1.60	1.60
b	0.550	0.550
c	0.500	0.500
p	1.000	1.000
λ	0.160	0.480
η	0.200	0.200
δ	$--$	0.150
ϕ	0.050	0.050
σ	0.450	0.450
ξ	$--$	0.170
χ	0.300	0.250
$\overline{\epsilon}^G$	1.00	1.00
$\overline{\epsilon}^F$	1.00	$--$
$\underline{\epsilon}^F$	-1.00	$--$
$\overline{\epsilon}^I$	1.00	$--$
$\underline{\epsilon}^I$	-1.00	$--$
$\overline{\epsilon}^P$	$--$	1.00
$\underline{\epsilon}^P$	$--$	-1.00
$\overline{\epsilon}^T$	$--$	1.00
$\underline{\epsilon}^T$	$--$	-1.00
$\overline{\epsilon}^B$	$--$	1.00
$\underline{\epsilon}^B$	$--$	-1.00

Table 7. Endogenous variables-Pre-reforms

Parameter	Pre-reforms
ϵ_T	0.537
ϵ_R	0.609
ϵ_F	0.472
ϵ_I	−0.367
$\underline{\epsilon}_G$	−1.00

Table 8. Endogenous variables-Post-reforms

Parameter	Post-reforms
ϵ_A	0.426
ϵ_S	0.397
ϵ_Q	0.230
ϵ_G	0.831
ϵ_L	0.290
ϵ_B	−0.330
ϵ_U	0.607
ϵ_V	−0.420
$\underline{\epsilon}_G$	−1.000

Table 9. Data vs model

	Pre-reforms		Post-reforms	
	Data	Model	Data	Model
Unemployment rate	8.9	8.3	7.1	7.2
Temporary/Permanent contracts	−−	−−	12.9	13.3
Informal rate	15.3	15.2	15.3	15.2

Table 10. Employment share for lower firing costs, F.

	F					
	1.6	1.55	1.50	1.45	1.40	1.35
Permanent	68.0	67.7	67.4	67.1	66.8	66.5
Temporary	10.5	10.0	9.6	9.0	8.7	8.2
Informal	14.1	14.8	15.5	16.1	16.8	17.5
Unemployment	7.2	7.3	7.4	7.5	7.5	7.6
Informality rate	15.2	15.9	16.7	17.4	18.1	18.9
Temps/Perms ratio	13.3	12.8	12.4	11.8	11.5	10.9

Table 11. Employment share for higher penalty fee, σ.

	σ					
	0.45	0.50	0.55	0.60	0.70	0.80
Permanent	68.0	68.3	68.6	68.8	69.2	69.6
Temporary	10.5	10.9	11.4	11.8	12.7	13.5
Informal	14.1	13.4	12.7	12.1	10.9	9.8
Unemployment	7.2	7.2	7.1	7.1	7.0	6.9
Informality rate	15.2	14.4	13.6	13.0	11.7	10.5
Temps/Perms ratio	13.3	13.7	14.2	14.6	15.5	16.2

Table 12. Employment share for higher values of the probability of an informal worker to be caught, ϕ .

	ϕ					
	0.050	0.055	0.06	0.065	0.070	0.075
Permanent	68.0	68.5	68.9	69.2	69.5	69.7
Temporary	10.5	12.3	13.7	14.8	15.8	16.6
Informal	14.1	11.9	10.2	8.8	7.6	6.6
Unemployment	7.2	7.1	7.1	7.0	7.0	6.9
Informality rate	15.2	12.8	10.9	9.4	8.1	7.0
Temps/Perms ratio	13.3	13.2	14.1	14.9	15.4	15.9

Table 13. Employment share for lower payroll taxes associated with permanent contracts, τ^P.

	τ^P					
	0.35	0.33	0.31	0.29	0.27	0.25
Permanent	68.0	70.8	73.4	75.7	77.8	79.7
Temporary	10.5	9.0	7.7	6.5	5.5	4.6
Informal	14.1	12.9	11.9	10.8	9.9	8.9
Unemployment	7.2	7.1	7.0	6.8	6.7	6.6
Informality rate	15.2	13.8	12.7	11.5	10.6	9.5
Temps/Perms ratio	13.3	11.2	9.4	6.9	6.6	5.4

Table 14. Employment share for different values of the probability of an informal worker to be caught, ϕ and lower payroll taxes associated with permanent contracts, τ^P.

ϕ	**0.050**	0.055	0.060	0.065	0.065	0.070	0.075
τ^P	**0.35**	0.33	0.33	0.33	0.31	0.31	0.31
Permanent	68.0	71.2	71.6	71.8	74.3	74.5	74.7
Temporary	10.5	10.7	12.0	13.1	11.6	12.5	13.2
Informal	14.1	10.9	9.3	8.0	7.2	6.1	5.3
Unemployment	7.2	7.0	7.0	6.9	6.8	6.7	6.7
Informality rate	15.2	11.7	10.0	8.6	7.7	6.5	5.6
Temps/Perms ratio	13.3	13.0	14.3	15.4	13.5	14.3	15.0

Table 15. Employment share for different values of the probability of an informal worker to be caught, ϕ and different firing costs, F.

ϕ	**0.05**	0.055	0.060	0.065	0.070	0.070	0.075
F	**1.6**	1.55	1.55	1.55	1.55	1.5	1.5
Permanent	68.0	68.2	68.6	69.0	69.2	69.0	69.3
Temporary	10.5	11.9	13.3	14.5	15.5	15.2	16.1
Informal	14.1	12.5	10.7	9.2	8.0	8.4	7.4
Unemployment	7.2	7.2	7.2	7.1	7.1	7.1	7.1
Informality rate	15.2	13.3	11.5	9.9	8.6	9.0	7.9
Temps/Perms ratio	13.3	14.8	16.2	17.3	18.2	18.0	18.8

Table 16. Employment share for different values of the penalty fee, σ and lower payroll costs associated with permanent contracts, τ^P.

	σ	**0.45**	0.50	0.55	0.60	0.65	0.65
	τ^P	**0.35**	0.33	0.33	0.33	0.33	0.31
Permanent		68.0	71.1	71.3	71.5	71.7	74.2
Temporary		10.1	9.4	9.8	10.3	10.7	9.3
Informal		14.1	12.3	11.7	11.1	10.5	9.6
Unemployment		7.2	7.0	7.0	7.0	6.9	6.8
Informality rate		15.2	13.2	12.5	11.9	11.2	10.3
Temps/Perms ratio		13.3	11.6	12.0	12.6	12.9	11.1

Table 17. Employment share for different values of the penalty fee, σ and lower firing costs, F.

	σ	**0.45**	0.50	0.55	0.60	0.065	0.065
	F	**1.6**	1.55	1.55	1.55	1.55	1.50
Permanent		68.0	68.0	68.3	68.5	68.8	68.5
Temporary		10.5	10.5	10.9	11.4	11.8	11.4
Informal		14.1	14.1	13.4	12.7	12.1	12.7
Unemployment		7.2	7.2	7.2	7.2	7.1	7.2
Informality rate		15.2	15.2	14.4	13.6	13.0	13.6
Temps/Perms ratio		13.3	13.3	13.7	14.2	14.6	14.2

Table 18. Employment share for different values of the probability of an informal worker to be caught, ϕ and higher payroll taxes associated with temporary contracts, τ^T.

	ϕ	**0.05**	0.055	0.060	0.065	0.065	0.070	0.075
	τ^T	**0.25**	0.28	0.28	0.28	0.30	0.30	0.30
Permanent		68.0	72.7	73.2	73.6	76.0	76.4	76.7
Temporary		10.5	6.9	8.5	9.8	6.9	8.0	9.0
Informal		14.1	13.2	11.1	9.5	10.0	8.5	7.3
Unemployment		7.2	7.1	7.1	7.0	7.0	6.9	6.8
Informality rate		15.2	14.2	11.9	10.2	10.7	9.1	7.8
Temps/Perms ratio		13.3	8.6	10.4	11.7	8.3	9.4	10.5

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