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Labor Adjustment: Disentangling Firing and Mobility Costs*

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Abstract

This paper studies the costs of adjusting employment, distinguishing between firms' firing and workers' mobility costs. We construct a simple dynamic general equilibrium model of labor demand and supply and show that only the joint response of employment and wages to firm level shocks can discriminate between the two types of costs. We use matched employer-employees data for Italy to estimate the model and find that both types of costs are present, that they are sizeable (in the range of 19,000 euros in total) and that firing costs account for almost 90 percent of total adjustment costs.

JEL classification numbers: C33, D21, J63
Keywords: Adjustment costs, mobility costs, matched employer-employees data

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1 Introduction

The idea that labor markets deviate substantially from the walrasian competitive allocation mechanism has a long history in economics. Indeed, much of the macroeconomic debate on the business cycle originates from it. More recently, differences in the functioning of the labor market have been indicated as one of the main factors behind the diverging economic performances of continental Europe and the US. As a consequence, over the past fifteen years an enormous amount of research has been devoted to understanding the microeconomics of the labor market, focusing on the features that make the exchange of labor services different from other economic transactions and better characterized in terms of employment relationships in contrast to anonymous, spot exchanges. The modern analysis of the employment relationship puts the existence of frictions in the "creation" and "destruction" of employment at the very center of its research agenda.

Alongside theoretical developments, over the last decade the availability of data at the micro level has spurred a number of studies on the costs of adjusting labor, documenting the existence of nonlinearities and of non-convex costs in the adjustment policies of individual units (see **?** for a survey). This body of work, following the seminal theoretical work of **?**, is cast in a partial equilibrium framework where wage-taking firms face an infinitely elastic labor supply curve at the market wage, so that labor adjustments at the firm level can be studied in isolation from wage adjustments. On the other hand, the search and matching literature (**?**) has shown that, in the presence of frictions, employment and wages are jointly determined even at the level of the firm, questioning the unique market wage assumption. In fact, recent research has documented that, due to frictions, not only employment but also wages respond to firm-level conditions. **?** document a large heterogeneity in wages of otherwise identical workers that can be explained by search frictions. Other work has shown that idiosyncratic shocks to the firm are partially transmitted to the compensation of its employees (**?**, **?**), in contrast with the hypothesis that wages are insulated from firm level changes in business conditions.

This paper argues that the joint consideration of labor and wages response to firm-level shocks can help shed light on the nature of the frictions that characterize the employment relation. In particular, our approach allows for the separate identification of adjustment costs internal to the firm - such as firing and hiring costs - and external to it, i.e. those borne by the workers due to costly mobility across firms, such as for search, geographical mobility and re-training needs. This is clearly an important distinction. Such costs have different implications for the functioning of the labor market and for the design of policies aimed at improving it, particularly when it comes to the lifting of obstacles to employment or wage adjustment induced by institutional factors, such as employment protection legislation in Europe.

We adapt a general equilibrium model developed by **?** with firing costs on the firm side, mobility costs on the workers' side and idiosyncratic shocks to labor demand. The model features patterns of adjustments that deviate from the frictionless paradigm in important ways. Most importantly, it shows that both internal and external costs can generate the type of employment response to shocks that have been traditionally associated with firing costs, such as non-adjustment in response to small shocks and lumpiness of labor adjustment. This implies that the interpretation of the results of the previous literature as evidence of internal adjustment costs alone might be unwarranted.

While stylized, the model is flexible enough to allow for the structural identification of the adjustment cost parameters and distinguish between firing and mobility costs. It also allows for a clear and intuitive representation of our identification strategy. The idea behind the empirical test is simple. If mobility costs are important, then an expanding firm will need to compensate workers for the mobility cost they bear even if the expansion is due to a shock that is specific to the firm, not to the industry. As Joan Robinson (**?**) pointed out seventy years ago, "*..there may be a certain number of workers in the immediate neighborhood and to attract those from further afield it may be necessary to pay a wage equal to what they can earn near home plus their fares to and fro*". Stated differently, mobility costs imply an upward sloping supply for labor at the firm level. When a firm changes the level of employment, the workers' compensation should also change in the same direction if mobility costs matter, while no change in wages should be observed if the firm faces only firing/hiring costs. We therefore supplement the employment adjustment equations on the extensive and intensive margin previously used in the literature, which identify the sum of firing and mobility costs, with a wage adjustment equation, which singles out the mobility cost and allows to disentangle the two components.

The empirical problem with this approach is that it can hardly be implemented with a firm-level measure of the wage, such as the total wage bill divided by the labor force − the standard measure of wage used in the literature. This measure, in fact, is likely to be strongly influenced by changes in employment for reasons that have nothing to do with mobility costs.[1] To overcome this problem we merge company-level data for a large sample of Italian firms with social security data on worker-level compensation available for a random sample of their employees for the 1982-1994 period. The detailed information at the firm level allows to compute measures of idiosyncratic shocks to the firm and then study the response to these shocks of firm-level employment and *individual compensations* after controlling for workers' and firms' characteristics. We focus on idiosyncratic shocks for three reasons: first, using idiosyncratic shocks we abstract from aggregate events that might change aggregate labor demand, which greatly facilitates identification; second, idiosyncratic shocks constitute the bulk of shocks hitting firms (**?**) and correspondingly, most job changes take place locally;[2] finally, there is no evidence on the joint response of wage and employment to this type of shocks, while some evidence is available on the wage cost of long geographical (**?**) or sectoral (**?**) mobility.

We find that total adjustment costs are substantial. According to our preferred estimates, the per capita cost of changing employment is in the order of 19,000 euros, about 13 months of the average gross annual compensation. This figure is of the same order of magnitude as that estimated by **?** for France, a country with a labor market similar to the Italian one. In terms of external and internal costs, both components are present and statistically significant. The internal component accounts for about 90 percent of the total, indicating that internal costs are a more important impediment to labor adjustment than mobility

[1] For example, an expanding firm may hire highly skilled workers and thus pay a wage skill premia which raises the average firm wage, generating a correlation between wage and employment adjustment even with no mobility costs. Moreover, given that the number of employees would appear in the denominator of a measure of average compensation, any measurement error due to the timing with which employment is recorded would induce a spurious correlation between employment and wages adjustment.

[2] For example, in our data 2/3 of those changing job do not leave their province and 3/4 their region.

costs, which are in the order of 2,100 euros or 1.5 times the average monthly compensation. This result is robust to a number of extensions, such as accounting for heterogeneity in mobility costs across workers.

The relatively modest size of mobility costs is consistent with the fact that they are estimated using idiosyncratic shocks to firms productivity: given that we are abstracting from aggregate labor demand changes, an increase in labor demand by an individual firm will most likely be satisfied within the boundaries of the local market, without resorting to long distance mobility. This hypothesis is supported by the analysis of mobility patterns in our dataset, that indicates that workers' mobility is mostly local. The characterization of the labor market that emerges therefore is one where workers are reasonably mobile within locations but scarcely mobile across them.

Our results suggest that mobility costs faced by workers, though less important than internal costs, cannot nevertheless be neglected, implying that the assumption that firms face an infinitely elastic labor supply at the prevailing wage made in the empirical literature on adjustment costs is misleading, as it tends to overstate the role of hiring and firing costs internal to the firm. This has an important bearing on the debate on labor market flexibility.

Our paper adds to the growing literature that stresses the role of frictions in the labor market. More specifically, we contribute to the literature that estimates dynamic labor demand functions with non convex adjustment costs. Within this line of work, our paper is closer to **?** and **?** who, like us, account for the endogenous selection of the adjustment regime. These papers, however, ignore wage responses to shocks. The paper is also related to the literature on wage responses to labor demand shocks. **?** is the first to use this approach to identify mobility costs across local labor markets, defined in terms of US states. Our approach is similar, but more microeconomic in nature, as we conduct the analysis at the level of the firm: in fact, our focus is on the distinction between mobility on one side and firing and hiring costs on the other. **?** also uses firm adjustment in a wage equation, finding that wages are correlated with measures of job creation and destruction at the plant level. Also related to our approach is **?**, who estimate a wage equation together with a mobility and a participation equation, but they are interested in obtaining an unbiased estimate of the return to seniority rather than disentangling the nature of adjustment costs. To our knowledge, we are the first to use employment and individual-level wage data to jointly estimate wage and employment responses to firm-specific shocks to identify the nature of adjustment costs. We also touch on the debate on firm size/wage relationship. Many papers have found that large firms pay higher wages even controlling for workers' characteristics (**?**). In our model, firms that are expanding must compensate workers for the mobility costs incurred by the latter and therefore pay higher wages, endogenously delivering a positive correlation between firm size and wages.

The layout of the paper is as follows. Section 2 presents the institutional framework, while Section 3 introduces a simple general equilibrium model based on **?**. Section 4 details the data and Section 5 discusses estimation issues. The results are reported in Section 6, along with sensitivity analysis. Section 7 concludes.

2 Institutional aspects

Following the literature on adjustment costs at the firm level, we do not directly measure costs of hiring, firing and mobility, but rather infer them from the observed responses of employment and wages to shocks. Such costs do depend on the institutional features of the labor market: in fact, as other continental European countries, Italy has a fairly regulated labor market. We thus offer a brief sketch of its main institutional features.

According to Italian employment protection legislation (EPL), dismissals of workers with open-end contracts are only allowed for misbehavior, or because of the firm's need to downsize or reorganize its activities. Thus, it would not be possible to fire an employee with a long tenure and a high salary to replace her with a young worker paid the minimum contractual wage.

Workers can appeal in court against dismissal. No direct cost is imposed on the firm when a dismissal is not contested or it is ruled to be fair, although firms may want to pay some form of compensation to the dismissed workers in order to avoid litigation (this is especially true in collective dismissals, when lump-sum payments are sometimes explicitly bargained with the unions). If the judge rules in favor of the worker, she is entitled to compensation that varies according to firm size. Firms with less than 16 employees must compensate unfairly dismissed workers with a severance payment that varies between 2.5 and 6 months of salary. Firms with more than 15 employees[3] have to compensate workers for the loss of earnings from the date of the dismissal to the date of the ruling. Moreover, they are obliged to reinstate the worker, unless he or she opts for a further severance payment equal to 15 months worth of salary. Because of these differences, the costs of EPL have been traditionally thought to be substantially larger for firms above the 15 employees threshold. Recent studies that exploit the differential effects of EPL on the propensity to grow of firms just below the threshold have found significant but modest effects (**?**, **?**), suggesting that the differential effects of EPL on small and large firms might be overstated.

In terms of wage setting, Italian industrial relations are based on multi-tier collective bargaining, with economy-wide, industry-wide and company-level agreements. In **?** we show that the latter provide sufficient room for wages potentially to respond to idiosyncratic firm shocks. According to data from the Bank of Italy survey on manufacturing firms with at least 50 employees, approximately 92% of workers were covered by a firm-level contract in 1994. Data for the Metal products, Machinery and Equipment sector, for which a breakdown of the wage bill into its various components is available, show that between one sixth and one fourth of the compensation was firm specific in the period covered by our sample (1982-1994). There is therefore room for wages to have an important firm specific component, possibly related to the firms' needs to attract or expel workers following firm-specific shocks to labor demand.

There is a widespread consensus that geographical mobility in Italy is low because of high moving costs. For example, according to a 1995 survey of the National Institute of Statistics, more than 40% of unemployed workers were unwilling to take a job outside the municipality of residence and only 22% were ready to move anywhere (**?**). In fact, high unemployment rate in the South has persisted in the face of basically full employment in the rest of the country - that is, large unemployment differentials persist due to low mobility

[3] More precisely, the rule refers to establishments with more than 15 employees, and to firms with more than 15 workers in the same municipality or with more than 60 employees in all establishments combined. The different provisions according to firm size are the subject of the hotly contested Art. 18 of the "*Statuto dei Lavoratori*".

rates. Most of this anecdotal evidence refers to long-distance geographical mobility, not mobility across firms within the same local market. Since we focus on idiosyncratic shocks to firms, the most relevant concept of mobility for our exercise is across firms rather than across geographical areas. In other words, in a certain local labor market firms that have received idiosyncratic positive shocks may coexist with firms that have received negative shocks, implying that long distance mobility on the workers' side will not be necessarily observed.

3 The Model

We adapt a general equilibrium model by **?**. Time is discrete. The economy is comprised of a continuum of infinitely lived firms and workers. Firms produce output using a decreasing return to scale technology with labor as the only input and stochastic productivity (or demand) shocks and face costly labor adjustments; we only consider idiosyncratic firms' shocks, i.e. shocks that do not change aggregate productivity and labor demand. Workers supply one unit of labor inelastically; they can pay a mobility cost c and move to a different job, in the spirit of **?** island model.

The main simplifying assumption is that productivity at the level of the firm switches between two values, $\varepsilon_g > \varepsilon_b$, following a symmetric first order Markov process: $\Pr\{\varepsilon' = \varepsilon_i | \varepsilon = \varepsilon_i\} = p > \frac{1}{2}$, $i = g, b$. A general equilibrium model with non convex adjustment costs of the type we consider cannot generally be solved analytically; moreover, non-convexities bring about challenging numerical issues, that are particularly relevant in estimation routines, where the model has to be solved repeatedly. With this simplifying assumption we will be able to obtain closed form solutions that, as we will argue, can be seen as approximations of those implied by a more general model, with the additional advantage of a clear and intuitive interpretation.

Consider first the workers' problem. Workers cannot save and consume current income. In each period, a worker is employed in a "good" or a "bad" firm, which pays wages w_g and w_b respectively. In equilibrium the wage fluctuates with the firm productivity, so that with probability $p \geq \frac{1}{2}$, the wage remains constant to its good (w_g) or bad (w_b) value, with $w_g \geq w_b$. With probability $1-p$, a good (bad) wage becomes bad (good). A worker employed in a bad firm can move instantaneously to a good one by paying a moving cost c.[4] In a stationary environment, the values of working at a good or bad firm are as follows:

$$U_g = u(w_g) + \beta [pU_g + (1-p) U_b] \quad (1)$$

$$U_b = \max \{u(w_b) + \beta [(1-p) U_g + pU_b], u(w_g - c) + \beta [pU_g + (1-p) U_b]\} \quad (2)$$

The first expression shows that people that are in a good job draw utility from their wage $u(w_g)$, do not move, and get continuation utility equal to either U_g or U_b with probability p and $1-p$, respectively. The second expression shows that the mobility decision is taken (and the cost c paid) when expected lifetime utility from moving exceeds that from staying.

In an equilibrium featuring both mobility from bad to good jobs and nonzero employment in bad jobs, it must be that the workers at bad jobs are indifferent between moving or staying, which implies that the two terms in curly brackets are equal. To allow for analytical solutions, take the case of linear utility. Then, after some algebra, we obtain:

$$w_g = w_b + \theta c \quad (3)$$

where $\theta = 1 + \beta(1-2p)$. Thus with serially uncorrelated shocks ($p = \frac{1}{2}$), to attract workers the firm must pay a wage premium that equals the moving cost, $w_g = w_b + c$: given that next period the state can be good or bad with equal probability, the worker wants to recoup the cost immediately. For a similar reasoning, with full persistence ($p = 1$) the firm only needs to pay the annuity value of the moving cost: $w_g = w_b + (1-\beta)c$. **?** formally shows that the wedge between wages implied by equation (3) constitutes a lower bound with respect to the more realistic case in which workers are risk averse.[5]

Firms' productivity shocks are realized at the beginning of the period, before the em-

[4] The basic formulation assumes homogeneous mobility costs. In appendix B we extend the model to allow for heterogeneity according to occupational status.

[5] **?** shows that consumption falls upon moving: workers are trading off current consumption for expected future consumption. The expected reward must therefore be larger the more concave the utility function, because risk averse individuals suffer more from a given reduction in current consumption.

ployment decision is taken. We assume a quadratic production function

$$F(l, \varepsilon) = \varepsilon l - \frac{\phi}{2} l^2 \tag{4}$$

Following the literature on firing costs (**?**), the adjustment cost function is linear in employment changes:

$$g(\Delta l) = f * \Delta l * I_{\{\Delta l < 0\}} + h * \Delta l * I_{\{\Delta l > 0\}}$$

where $I_{\{.\}}$ is the indicator function, f is the firing and h the hiring cost.[6] Firms decide both whether to adjust when hit by a shock and, in the case they do, by how much.

The state of the firm is described by the couple (l, ε). The general formulation of the firm's problem in recursive terms is

$$V(l, \varepsilon) = Max_{l'}\{F(l', \varepsilon) - w(l' - l)l' - g(l' - l) + \beta EV(l', \varepsilon')\}$$

where, consistently with the workers' problem, we allow for the wage to depend on the labor adjustment. As stated above, this general problem is hard to solve, due to the non convex nature of the adjustment cost function and to the general equilibrium setting. The two shocks assumption greatly simplifies the analysis. If firms adjust when productivity changes, then in equilibrium employment will also take up two values l_g, l_b as productivity, implying four distinct states, (l_i, ε_j), $i, j = g, b$, in which the firm can be. Moreover, from the workers' problem, it follows that firms that want to expand employment from l_b to l_g must increase wages by θc to compensate workers for the mobility cost, while, when firing, a wage reduction of the same amount will make workers indifferent between staying or leaving. The wage rate therefore also switches between two states w_g, w_b, as assumed above. Note that, once the firm pays the wage w_g, labor supply is infinitely elastic for labor increases, and the same holds at w_b for labor decreases. The value of the firm in the four

[6]Following most of the literature, we assume that f (h) is a costs and not a transfer from the firm to the worker. We will discuss in the empirical section the consequences of this assumption. See **?** for a model that studies how the implications of a firing tax differ from those of a severance payment.

states satisfies:

$$
\begin{aligned}
V(l_i, \varepsilon_i) &= F(l_i, \varepsilon_i) - w_i l_i + \beta(pV(l_i, \varepsilon_i) + (1-p)V(l_i, \varepsilon_j)) && (5) \\
V(l_i, \varepsilon_j) &= V(l_j, \varepsilon_j) - g(l_i - l_j) && (6)
\end{aligned}
$$

for $i = \{g, b\}, j = \{b, g\}$. The first equation characterizes the value of the firm when productivity does not change, so that no employment adjustment is required; the second in the case that productivity switches, triggering adjustment.

To determine the size of employment adjustment, we use the fact that the marginal value of employment must equalize the hiring cost when hiring and the (negative of) the firing costs when firing (see the appendix for details). Then, the optimal employment change when productivity switches from ε_g and ε_b is:

$$
\Delta l = \phi^{-1}(\Delta\varepsilon - \theta(c + f + h)) \tag{7}
$$

where we use the notation $\Delta x = x_g - x_b$ throughout. The employment change is proportional to the shock and dampened by the presence of hiring, firing or mobility costs; moreover, the effects are dampened by the degree of concavity of the production function ϕ.

Consider now the optimality of adjusting. To determine the conditions under which adjustment is the optimal policy, we use the one-step-deviation condition: if adjustment is optimal, it must deliver a higher payoff than not adjusting and resuming the optimal policy from next period onward:[7]

$$
V(l_i, \varepsilon_j) > F(l_i, \varepsilon_j) - w_i l_i + \beta(p(V(l_j, \varepsilon_j) - g(l_i - l_j)) + (1-p)V(l_i, \varepsilon_i)) \tag{8}
$$

In the appendix we show that, assuming that the labor force is of mass 1 and firms are of total mass 2, the model can be fully characterized and the inequality in (8) directly solved.

[7] This formulation implies that the firm takes into account the fact that, when changing employment, wages change too: in fact, the payoff from deviating is computed using the wage that results from not changing employment. Alternatively, one could assume that firms take state contingent wages as given, in which case w would follow the same process as ε even in the deviating stage. Given that we are considering firm-level labor supply, it seems more reasonable to assume that a firm knows that it has to increase wages if it wants to increase employment.

The optimality of adjusting can be expressed in terms of threshold levels for the changes in productivity above (and below) which adjustment is preferable to inaction:

$$\Delta\varepsilon^{*} = \frac{1}{2}\left(\theta(c + 2(h + f)) + \sqrt{\theta c(\theta c + 4\phi)}\right) \tag{9}$$

when hiring and

$$\Delta\varepsilon^{**} = \frac{1}{2}\left(\theta(c + 2(h + f)) + \sqrt{\theta c(\theta c - 4\phi)}\right) \tag{10}$$

when firing.

Equations (3, 7, 9, 10) form the basis of the moment conditions we will use in the empirical analysis. They supply two extensive conditions for wages and employment conditional on adjusting and two intensive conditions for employment for the optimality of adjusting. Even if derived under the two shocks assumption, they have the same structure that would result from a model with a continuum of shocks. For example, the partial equilibrium investment model with a continuum of shocks of **?** also delivers a binary condition on the optimality of adjustment and a size of adjustment condition.

There are some important aspects to notice. First, in all the equilibrium conditions we are going to use for identification purposes, firing and hiring costs enter as sum. This implies that the model can only identify the total amount of internal adjustment costs, $k = h + f$, not its two components. While this is a shortcoming of the model, our primary interest is in distinguishing internal from external costs, rather than firing from hiring costs. We thus believe this is a relatively unimportant issue. From now on, we will refer to k as total internal costs and neglect the distinction between f and h.

Another important aspect is that, given the continuum of firms assumption and the symmetric Markov transition matrix, in the aggregate there is a constant and equal share of firms in each state. This is therefore an economy with only idiosyncratic shocks, i.e., shocks that affect the single production units without altering aggregate outcomes. This aspect will have a strict counterpart in the empirical analysis, where the shocks will be defined at the level of the single firm, after filtering out aggregate and local shocks.

Finally, our identification relies on the fact that firing costs do not enter the wage change equation. This does not imply that wage *levels* are independent from firing costs: indeed, the appendix shows that firing costs increase equilibrium wages; however, they do so exactly in the same way for wages in good and bad firms, so that the wage changes are independent from them.

Summary of predictions

We summarize the predictions that we will use in the empirical analysis. First, in a frictionless world, in which both $k = 0$ and $c = 0$, firms face an infinite elastic labor supply at the prevailing wage, which does not respond to the idiosyncratic firm conditions: $\Delta w = 0$. Moreover, there is no lumpiness or attenuation in the employment response to shocks:

$$\Delta\varepsilon^* = 0 \tag{11}$$

$$\Delta l = \phi^{-1}\Delta\varepsilon \tag{12}$$

The introduction of frictions has several implications. First, the response of employment becomes lumpy: firms only adjust when the shocks are sufficiently large. The smallest change in the frictionless employment at which adjustment occurs even with frictions is:

$$\Delta\widetilde{l}^* = \phi^{-1}\Delta\varepsilon^* = \gamma^H \tag{13}$$

and similarly for downward adjustment. One important implication of (13) is that *any* type of friction induces lumpiness: in fact, from (9) and (10) it follows that $\Delta\widetilde{l}^* \neq 0$ if either $c \neq 0$ or $k \neq 0$. This implies that lumpy adjustments will signal the presence of frictions, but cannot be used to determine their nature. This is in contrast with most of the literature on employment adjustment at the level of the firm, where lumpy behavior is usually taken as signaling hiring or firing costs (**?**).

The second implication relates to employment changes. With respect to a frictionless world, frictions not only induce lumpy adjustments, but also dampen employment changes when they take place, as can be seen by expressing actual adjustment in deviation from the frictionless counterpart:

$$\Delta l = \Delta\widetilde{l} - \psi \tag{14}$$

where $\psi = \phi^{-1}\theta(c + k)$.

The third implication relates to wage changes. Given that firms need to compensate workers from the moving costs they bear upon changing employer, wage changes only occur together with employment changes. Moreover, the wage response to the shocks is due to the cost of moving: if firing costs were the only friction in the market, then we should observe no wage response at the firm level. In particular, one can write $\Delta w = \theta c$ for workers employed in firms that adjust employment upward, and $\Delta w = -\theta c$ for firms that adjust downward.

4 Data

We rely on two administrative data sets, one for firms and one for workers. Data for firms are obtained from *Centrale dei Bilanci* (Company Accounts Data Service, or CAD for brevity), while those for workers are supplied by *Istituto Nazionale della Previdenza Sociale* (National Institute for Social Security, or INPS). Since for each worker we can identify the firm he/she works for, we combine the two data sets and use them in a matched employer-employee framework. There is a burgeoning empirical literature on the use of matched employer-employee data sets (See **?** for a recent overview).

The CAD data span from 1982 to 1994, a period that comprises two complete business cycles. It contains detailed information on a large number of balance sheet items together with a full description of firm characteristics (geographical location, year of foundation, sector of operation, ownership structure), plus other variables of economic interest usually not included in balance sheets, such as employment and flow of funds. Balance sheets are collected for approximately 30,000 firms per year by *Centrale dei Bilanci*, an organization established in the early 1980s jointly by the Bank of Italy, the Italian Banking Association, and a pool of leading banks to gather and share information on borrowers. Since the banks rely heavily on it in granting and pricing loans to firms, the data are subject to extensive quality controls by a pool of professionals, ensuring that measurement error should be negligible.

INPS provides us with data for the entire *population* of workers registered with the social security system whose birthday falls on either April first or October first. Data are available on a continuous basis from 1974 to 1994. We use the data after 1981 for consistency with the timing of the CAD data. The INPS lacks information on self-employment and on public employment. The INPS data set derives from forms filled out by the employer that are roughly comparable to those collected by the Internal Revenue Service in the US.[8] Misreporting is prosecuted.

Given that the INPS data set includes a fiscal identifier for the employer which is also present in the CAD data set, linking the employer's records to the employees is relatively straightforward. As in other countries where social security data are available, the Italian INPS data contain some detailed information on worker compensation but information on demographics is scant.

Table 1 reports various descriptive statistics for the firms (Panel A) and workers (Panel B) present in our sample. We report separate statistics for the whole sample and for the sample obtained after matching firm and worker information. From an initial sample of 177,654 firm/year observations, we end up with 116,686, corresponding to 16,037 firms. The number of usable observations is less than that due to the dynamics of the estimation procedure. We exclude firms with intermittent participation (40,225 observations) and those with missing values on value added, employment, industry, or geographical area (20,620 observations) or extreme employment changes (123 observations). The panel we create is unbalanced.

The whole sample ranges from very small firms to firms with almost 180,000 employees, with an average of 204 and a median of 60. As expected, most of the firms are in the North (75 percent). As for the distribution by industry, manufacturing firms account for about 75 percent of the final sample, construction for about 15 percent and the remaining

[8]While the US administrative data are usually provided on a grouped basis, INPS has truly individual records. Moreover, in the US earnings records are censored at the top of the tax bracket, while the Italian data set is not subject to top-coding.

10 percent is scattered in the service sectors. The matched sample includes larger firms, but the distribution by region and industry is similar to that in the whole sample.

Panel B reports sample characteristics for the workers in the 1982-1994 INPS sample. We start with an initial sample of 267,539 worker/year observations (including multiple observations per year for the same worker due to multiple jobs, intra-firm position change, and inter-firm mobility) and end up with 255,954. Of these, 125,211 can be matched to a firm in the CAD data set. Here as well, the number of usable observations is less than that due to the dynamics of the estimation procedure. Sample selection is made with the explicit aim of retaining workers with stable employment and tenure patterns. First we exclude those younger than 18 or older than 65 (2,652 observations), circumventing the problem of modeling human capital accumulation and retirement decisions. We keep only individuals with non-zero recorded earnings in all years (105 observations lost), and eliminate those with missing values on the variables used in the empirical analysis (8,627 observations). If an individual has multiple spells at the same firm, we treat each spell as a separate match. To avoid dealing with complex situations, we eliminate jobs that are held simultaneously with the main one (i.e., if a person works for a firm continuously between 1980 and 1992 and has a spell at another firm between 1984 and 1985, we discard the latter), and the shorter spells for individuals with overlapping spells at two (or more) firms (i.e., if an individual works continuously for one firm between 1980 and 1992, and continuously for another firm between 1983 and 1992, we discard the latter).

Our measure of earnings covers remuneration for regular and overtime pay plus non-wage compensation. We deflate earnings using the CPI (1995 prices). For workers with intermittent participation we treat two strings of successive observations separated-in-time as if they pertained to two different individuals.

Workers in the whole sample are on average 39 years old in 1991; production workers account for 62 percent of the sample, 37 percent are clericals, and about 2 percent managers. Males are 73 percent of our sample and those living in the South 14 percent. Finally, gross earnings in 1991 are roughly 17,000 euro on average. In the matched sample individual characteristics are fairly similar to the ones in the whole sample.

5 Identification

The identification procedure is based on the equilibrium relations obtained from the model. The most important shortcoming of the simple general equilibrium model is that it has only two productivity states, a clearly untenable assumption when bringing it to the data. We depart from the model and generalize this structure by allowing the shock (and the consequent labor adjustment) to take any value. Without the two-shocks assumption, we would not be able to directly calculate the value functions and obtain a closed form solution. Without closed form, the estimation procedure would still take the form of a threshold rule plus an extensive equation but would require the numerical solution of a nested fixed point problem, with the additional complexity of determining equilibrium wages.[9] While doable in principle, this would greatly increase the computational complexity and reduce the transparency of our procedure; moreover, the estimation results would still depend on the functional form and distributional assumptions. On balance, we believe that the increase in complexity is not matched by the increase in explanatory power. The main advantage of the strategy proposed here is that it is simple and transparent without imposing too high a cost in terms of realism. Indeed, the conditions obtained from the two shocks model can be thought of as approximations to the exact solution with a continuum of productivity shocks.

Equation (12) indicates a linear relation between shocks and frictionless labor changes that we maintain. However, we also include an error term that captures unobserved determinants of frictionless employment change, i.e.,[10]

$$\Delta\widetilde{l}_{jt} = \phi^{-1}\Delta\varepsilon_{jt} + \zeta_{jt} \tag{15}$$

[9]The only paper we are aware of that estimates a dynamic programming model of labor demand is **?**. However, they take wages as given at the plant level, and so their setting is partial equilibrium in nature. Other authors (**?**) derive an approximated labor demand Euler equation in the presence of adjustment costs.

[10]For the remainder of the paper i, j, and t index workers, firms, and years, respectively.

Our theory delivers the adjustment thresholds:

$$\gamma^H = \phi^{-1} \frac{\theta(c+2k) + \sqrt{\theta c(\theta c + 4\phi)}}{2} \tag{16}$$

$$\gamma^L = -\phi^{-1} \frac{\theta(c+2k) + \sqrt{\theta c(\theta c - 4\phi)}}{2} \tag{17}$$

and the wage equation $\Delta w = \theta c$.

We estimate our structural parameters using a multi-step strategy. First, we estimate the parameters that affect the probability of adjusting using observations on all firms; then, the size of adjustment equation using only the observations on the firms that adjust; finally, the wage equation using the individual workers' data. The parameters we estimate at these three stages are non-linear combinations of the structural ones; the latter are over-identified from these restrictions and therefore we can test the overidentifying restrictions. We use optimal minimum distance to map reduced form parameters onto structural parameters.

More specifically, rewrite actual labor adjustment as:

$$\Delta l_{jt} = \begin{cases} \Delta \widetilde{l}_{jt} + \psi & \text{if } \Delta \widetilde{l}_{jt} < \gamma^L \\ 0 & \text{if } \gamma^L \leq \Delta \widetilde{l}_{jt} \leq \gamma^H \\ \Delta \widetilde{l}_{jt} - \psi & \text{if } \Delta \widetilde{l}_{jt} > \gamma^H \end{cases} \tag{18}$$

Firms can be in one of three regimes: hiring, firing, or doing nothing. These regimes are defined by the dummies:

$$s^+_{jt} = \mathbf{1}\left\{\Delta \widetilde{l}_{jt} > \gamma^H\right\} = \mathbf{1}\left\{\zeta_{jt} > \gamma^H - \phi^{-1}\Delta\varepsilon_{jt}\right\}$$
$$s^-_{jt} = \mathbf{1}\left\{\Delta \widetilde{l}_{jt} < \gamma^L\right\} = \mathbf{1}\left\{\zeta_{jt} < \gamma^L - \phi^{-1}\Delta\varepsilon_{jt}\right\}$$
$$s^0_{jt} = \mathbf{1}\left\{\gamma^L \leq \Delta \widetilde{l}_{jt} \leq \gamma^H\right\} = \mathbf{1}\left\{\gamma^L - \phi^{-1}\Delta\varepsilon_{jt} \leq \zeta_{jt} \leq \gamma^H - \phi^{-1}\Delta\varepsilon_{jt}\right\}$$

with $s^+_{jt} + s^-_{jt} + s^0_{jt} \equiv 1$.[11] Assume that $\zeta \sim N\left(0, \sigma^2_\zeta\right)$. The likelihood function for the regime a firm happens to be in is:

[11] We only observe net employment changes, so that we define adjustment based on them. **?** estimate the probability of adjustment for Portuguese firms using both net and gross adjustment, finding very similar results.

$$L = \prod_{s_{jt}^{-}=1} \Phi_{jt}^{L} \prod_{s_{jt}^{+}=1} \left(1 - \Phi_{jt}^{H}\right) \prod_{s_{jt}^{0}=1} \left(\Phi_{jt}^{H} - \Phi_{jt}^{L}\right) \tag{19}$$

with $\Phi\,(.)$ the c.d.f. of the standard normal, $\Phi_{jt}^{k} = \Phi\left(\frac{\gamma^{k} - \phi^{-1}\Delta\varepsilon_{jt}}{\sigma_{\zeta}}\right)$ $(k = H, L)$, and σ_{ζ} the scale factor. Thus, γ^{H}, γ^{L}, and ϕ^{-1} can only be identified up to scale at this stage.

The next step is to consider the continuous aspect of the labor adjustment process. Given that, by definition, $E\left(\Delta l_{jt}|s_{jt}^{0} = 1\right) = 0$, we can use the law of iterated expectations to write:

$$E\left(\Delta l_{jt}|\Delta\varepsilon_{jt}\right) = E\left(\Delta l_{jt}\left|s_{jt}^{+} + s_{jt}^{-} = 1, \Delta\varepsilon_{jt}\right.\right) \Pr\left(s_{jt}^{+} + s_{jt}^{-} = 1|\Delta\varepsilon_{jt}\right)$$

where $s_{jt}^{+} + s_{jt}^{-} = 1$ identifies an adjusting firm. Since the probability of adjusting is $\Pr\left(s_{jt}^{+} + s_{jt}^{-} = 1_{jt}|\Delta\varepsilon_{jt}\right) = 1 - \Phi_{jt}^{H} + \Phi_{jt}^{L}$, it follows that -using again the law of iterated expectations-

$$E\left(\Delta l_{jt}\left|s_{jt}^{+} + s_{jt}^{-} = 1, \Delta\varepsilon_{jt}\right.\right) = \phi^{-1}\Delta\varepsilon_{jt} - \psi\frac{1 - \Phi_{jt}^{H} - \Phi_{jt}^{L}}{1 - \Phi_{jt}^{H} + \Phi_{jt}^{L}} + \sigma_{\zeta}\frac{\phi_{jt}^{H} - \phi_{jt}^{L}}{1 - \Phi_{jt}^{H} + \Phi_{jt}^{L}} \tag{20}$$

where we have used the properties of the truncated normal distribution repeatedly, together with equations (15) and (18). This regression can be run on the subset of firms that adjust their level of employment. The terms $\frac{\phi_{jt}^{H} - \phi_{jt}^{L}}{1 - \Phi_{jt}^{H} + \Phi_{jt}^{L}}$ and $\frac{1 - \Phi_{jt}^{H} - \Phi_{jt}^{L}}{1 - \Phi_{jt}^{H} + \Phi_{jt}^{L}}$ are generalized selection terms that account for the fact that we are selecting only the firms that are adjusting their level of employment. A two step strategy can then be adopted. In the first step, we estimate (19) and construct consistent estimates of $\frac{\phi_{jt}^{H} - \phi_{jt}^{L}}{1 - \Phi_{jt}^{H} + \Phi_{jt}^{L}}$ and $\frac{1 - \Phi_{jt}^{H} - \Phi_{jt}^{L}}{1 - \Phi_{jt}^{H} + \Phi_{jt}^{L}}$. In the second step, we estimate (20) by OLS using the estimates of $\frac{\phi_{jt}^{H} - \phi_{jt}^{L}}{1 - \Phi_{jt}^{H} + \Phi_{jt}^{L}}$ and $\frac{1 - \Phi_{jt}^{H} - \Phi_{jt}^{L}}{1 - \Phi_{jt}^{H} + \Phi_{jt}^{L}}$ in the place of the true ones.[12]

The use of the firms' adjustment policies allows the identification of the total costs of

[12] Needless to say, one could estimate the two equations in one single step by writing the likelihood function as an ordered Tobit. The two step strategy used here greatly reduces the computational burden. Indeed, it is well known that estimating this type of likelihood function in one step tends to give rise to serious convergence problems (see, for example **?**). Efficiency is not an issue here because all the standard errors are computed by the block bootstrap.

adjustment. In fact, by combining the parameters of the ordered probit (which identify γ^H, γ^L, and ϕ up to a scale) and that of the size of adjustment (which identify the scale), one can recover the value of $\theta(c+k)$. This is in fact the strategy that, under different forms, has been followed by the literature on factor demand in the presence of adjustment costs (**?**). Unfortunately, these estimates do not help to separately identify c and k since the two parameters enter the structural equations jointly.[13] However, the separate identification of c and k can be achieved by considering the implications that our model has for the behavior of wages, which offer an equation that, with matched data, allows to uniquely identify θc.

Wage changes in our model depend on the employment change behavior of the firm, and in particular

$$\Delta w_{ijt} = \begin{cases} \theta c + X'_{ijt}\beta + \omega_{ijt} & \text{if } s^+_{jt} = 1 \\ X'_{ijt}\beta + \omega_{ijt} & \text{if } s^0_{jt} = 1 \\ -\theta c + X'_{ijt}\beta + \omega_{ijt} & \text{if } s^-_{jt} = 1 \end{cases}$$

or

$$\Delta w_{ijt} = X'_{ijt}\beta + \theta c \left(s^+_{jt} - s^-_{jt} \right) + \omega_{ijt} \tag{21}$$

where X'_{ijt} is a vector of observable individual characteristics affecting wage growth (such as age or tenure). The variable $\left(s^+_{jt} - s^-_{jt} \right)$ is an adjustment indicator defined for the firm the individual is working for. It equals 1 (-1) if the firm is expanding (shrinking) and zero if it has remained inactive. Note that $\left(s^+_{jt} - s^-_{jt} \right)$ is *not* an indicator for whether the worker has moved, but one for whether the firm has changed its labor force.

A first approach to estimation is simply to estimate the coefficients in (21) by OLS. This gives unbiased and consistent estimates provided $E\left(\omega_{ijt} | X'_{ijt}, \left(s^+_{jt} - s^-_{jt} \right)\right) = 0$. However, it is clear that wages and employment are jointly determined at the firm level, so that this assumption is not likely to hold. Consider an exogenous increase in labor costs, due for

[13] In principle, the two parameters could be identified by the non-linearity implied by the the functional form assumptions of the adjustment thresholds. In practice, this identification strategy is very tenuous when not supplemented by the information coming from the wage equation.

example to a change in the bargaining procedure for wage determination or an increase in the minimum wage. The firm might respond to this by reducing employment, against the exogeneity assumption. In general, any labor supply shock will invalidate the assumption above. Moreover, while $\left(s_{jt}^{+} - s_{jt}^{-}\right)$ is supposed to be related to gross labor adjustment, we only observe net labor adjustment. This is a standard measurement error argument, which again means that $E\left(\omega_{ijt}|X_{ijt}', \left(s_{jt}^{+} - s_{jt}^{-}\right)\right) \neq 0$. Both problems can be dealt with by using Instrumental Variables (IV).

To summarize, the identification procedure entails the following steps:

1. Obtain a measure of idiosyncratic shocks to the marginal product of labor ($\Delta\varepsilon_{jt}$) (see below);

2. Estimate (19), i.e., an ordered probit for negative, zero, and positive adjustments using the shock and possibly other covariates as explanatory variables; recover estimates of Φ_{jt}^{H}, Φ_{jt}^{L}, ϕ_{jt}^{H}, and ϕ_{jt}^{L}.

3. Estimate the size of adjustment equation (20) using data on adjusting firms.

4. Estimate the (worker level) wage change equation (21) including an indicator of the firms' adjusting policy, accounting for endogeneity;

5. Recover the main structural parameters of interest θc, θk, ϕ, σ from the reduced form estimates of the previous four steps using optimal minimum distance.

If one uses the theoretical restrictions imposed on γ^{H} and γ^{L}, the thresholds of the adjustment decision, the model is over-identified with three overidentifying restrictions. In what follows we use optimal minimum distance on the reduced form estimates to recover estimates of the structural parameters. We use the block bootstrap-generated covariance matrix (based on 200 replications) as the weighting matrix. We do not use the theoretical restriction on γ^{L} because, as (17) shows, it depends on a square root term that is not defined for some values of the parameters, and so we have two overidentifying restrictions.

Note that we can separately identify θc and θk, but θ cannot be identified. Given that $\theta = 1 + \beta(1 - 2p) \leq 1$, our estimates will provide lower bounds for the true costs of adjustments. We will return to these point when discussing the results.

6 Results

6.1 Employment adjustment

We start by documenting the lumpiness of employment adjustment. Figure 1 plots the distribution of employment changes pooling all years together, excluding for readability the first and last percentile of the distribution (approximately + and -100). The first thing to note is that the amount of adjustment is fairly modest: about 95% of the observations lie between -28 and $+25$. The median employment change is exactly zero (the mean is similar), and about 17% of the firms in our sample do not change their employment from one year to the next; 40% adjust downward, and 42% adjust upward. Not surprisingly, this indicates that lumpiness is an important component of the employment choice.

The model predicts that firms will respond to changes in the marginal product of labor induced by shocks to productivity. We do not have a direct measure of it. There are two strategies one could follow to obtain an estimate of the productivity shock. The first is to be fully faithful to the structural model and obtain an estimate of the shock from estimation of the production function (4). The second is to follow the previous literature on q-models of adjustment (**?**) and estimate a reduced form equation for the change in value added and use the residual of this equation as an estimate of the shock. Both strategies have advantages as well as disadvantages. The first strategy is consistent with the model, but given the endogeneity of labor, requires finding instruments that are powerful enough to allow identification of the production function parameters. The structural model, in this respect, provides no hints of which instruments could be valid or useful.[14] The second strategy requires assuming that we have the correct specification for the reduced form equation for value added. The advantage, however, is that it does not require finding instruments outside the model. Moreover, the production function parameters are still identified from other moments of the data. In the end, given the lack of adequate instruments, we have followed the second strategy. Given that we want our shock not to reflect firm fixed effects, we estimated a specification in first differences. In particular, we regressed value added (in

[14]Attempts of estimating the production function gave very unstable results due to the low power of the instruments (lags of the endogenous variables).

thousand of 1991 euros) at time t divided by employment at time $t-1$, $\Delta y_t = \Delta \frac{VA_t}{l_{t-1}}$ (the change in value added/lagged labor)[15] on a full set of time dummies, regional dummies, and industry dummies.[16] This is in fact in line with the theoretical counterpart, where labor adjustment is prompted by changes in productivity.[17]

As argued above, the costs estimated using idiosyncratic shocks will be related to those entailed by an employer change in the local market rather than to long distance geographical mobility. In fact, by netting out time, region and industry effects, we are excluding shocks that change aggregate labor demand, and focus on those that only shift the demand of each single firm relatively to the others. Most of these changes will be resolved by job changes that do not entail significant geographical mobility. This is confirmed by our data: by considering the location of the employer, we find that 33% of workers that change job remain within the same municipality, 63% within the same province, and 75% within the same region (see Table 7).[18]

We then run an ordered probit for the choice of employment change regime (positive, zero, or negative change in employment). Table 2 reports the results for the regression with the shock as sole regressor in column 1. We find that the effect of the shock is positive and statistically significant, as expected: larger shocks imply a higher likelihood of moving from negative to zero to positive adjustments.[19] The two adjustment thresholds are also precisely estimated with signs in line with theoretical predictions. Note that such estimates

[15]As usual in this type of regressions, we scale value added with the lagged value of employment to avoid simultaneity biases with the left-hand side variable. The use of current value added is justified by the idea that, due to "time to build", it might take some time before new workers are fully operative. We also experimented with lagged value added, obtaining very similar results.

[16]Given that, due to accounting rules or special events, such as acquisitions, mergers or breaking-ups, balance sheet data might record extreme values related to events beyond our interests, we run a procedure to exclude outliers. In particular, we exclude the first and last percentile of the resulting shock distribution. The distribution is in fact characterized by extreme values. The median value of the shock is -239 euros, the first and the extreme percentiles are -45,865 and 42,787 euros. We also exclude firms whose employment increases more than 20-folds and those that have negative growth greater than 90% in absolute value and an initial size of more than 100.

[17]We have also experimented with a shock obtained as the residual of a firm fixed effects regression with year dummies. In this case, a shock is measured as the deviation of value added per worker from a firm-specific average. This definition is less in line with the model; at the same time, the level of productivity has a more natural interpretation than changes in productivity in terms of state variable. Results are similar to those reported in the paper.

[18]Italy is divided into 20 regions and about 100 provinces. A province is roughly of the same size as a US county.

[19]In all cases, to account for generated regressor bias, we calculate the standard errors by the block bootstrap, based on 500 replications.

are identified up to scale, so that their size cannot be interpreted directly. However, we can already infer from these estimates that the (total) costs of adjustment are nonzero.

One potential criticism to this regression, especially when considered in conjunction with the size of adjustment one that follows, is the lack of any exclusion restriction, so that identification of the effects only comes from functional form assumptions (**?**). We have experimented using the number of periods since last adjustment as an exclusion restriction.[20] In fact, in general models where productivity follows a random walk as in **?**, the martingale property implies that the expected value of the shock (and therefore the size of the adjustment) is not dependent on the number of periods elapsed since last adjustment, while the variance (and therefore the likelihood of adjusting) increases with them. This makes the number of periods since last adjustment a natural candidate for an exclusion restriction relative to the size of adjustment equation. Results from adding this variable are reported in column 2. Adding the exclusion restriction has no effect on the estimates. The number of periods since last adjustment has a positive and significant coefficient. To improve precision, we use this specification for the rest of the exercise.

Using the estimates of the ordered probit, we construct the variables included in the size of adjustment equation (20), that we run on firms that do adjust. We find that the shock has a positive and significant impact on the size of adjustment (Table 3). The estimate of the other two coefficients have the correct theoretical signs, but are quite imprecise. In fact, one typically obtains much more precise estimates on the discrete margin (adjust/don't), while, conditioning on this, the additional information obtained from the continuous one is rather limited. The relative precision of the estimates will in any case be taken into account by our optimal minimum distance procedure to recover the structural parameters.

6.2 Wage adjustment

To disentangle the external and internal components of total adjustment costs, we now turn to the wage equation. We construct wages as the sum of annual normal compensation and fringe benefits. We include in the wage growth regression a variable, $\left(s_{jt}^{+} - s_{jt}^{-}\right)$ which

[20]This variable is, of course, subject to left censoring.

equals -1 if the firm is reducing employment, 1 if it is expanding it and zero otherwise. As shown in equation 21, the coefficient on this variable is crucial for the identification of the extent of mobility costs, θc.

In Table 4 we report the results of the wage growth equation. We include the usual regressors of wage equations suggested by the literature, i.e. age, tenure, year, sector, geographical area, and job title dummies;[21] since we estimate a wage change equation, we also net out all time invariant-individual specific unobserved heterogeneity. The variable of interest is the employment policy of the firm at which the worker is currently attached. The first specification is an OLS regression with $\left(s_{jt}^{+} - s_{jt}^{-}\right)$ assumed exogenous. The results, reported in column 1, show that adjustment does entail external costs: the (reduced form) estimate of θc is positive and statistically significant, with a bootstrap standard error one order of magnitude lower. In absolute terms, the value is rather modest: it implies that expanding firms pay a yearly premium of 131 euros to their workers. Note that this is an estimate of θc, not of the mobility cost c alone. Given that $\theta < 1$, it represents a lower bound for the cost of adjusting, a point to which we will come back later.

All other regressors in our wage change equation have estimated effects that are in line with expectations: wage growth decreases with age and tenure (reflecting concavity of the wage *level* functions with respect to such variables). The wage of male workers increases on average by 328 euros more that than of females, and blue and white collar are characterized by lower wage growth than managers (the excluded category). Wages also grow less in the South (results not reported). Given that these estimates are very stable throughout the specifications, we will not comment on them any more in what follows.

Even keeping in mind the lower bound argument, the wage premium attached to mobility seems surprisingly low. In fact, the conventional wisdom is that the Italian labor market is characterized by a low willingness of workers to move in the face of better job opportunities. Part of the explanation can be traced back to the fact that we are considering idiosyncratic firm shocks, so that mobility tends to resolve mostly locally. Even so, the value we estimate would imply that mobility costs represents a very small fraction of total adjustment costs.

[21] There are four sectors (manufacturing, constructions, retailing, other), three geographical areas (north, center, south), and three occupations (blue collar, white collar, manager).

However, the estimate may be low simply because it is downward biased due to the fact that the wage and employment adjustments are determined simultaneously, as discussed above. To account for this, in column (2) we use an IV procedure - using the shock to value added as an instrument for $\left(s_{jt}^{+} - s_{jt}^{-}\right)$. The results change quite dramatically, confirming the importance of the endogeneity issue. The estimate of θc increases by one order of magnitude to 1.3, or 1,300 euros.

Up to now, we have assumed that labor is homogeneous. Appendix B extends the basic model by allowing for heterogeneous labor in terms of both the contribution to production and the mobility cost, assuming fixed proportions in the demand of different types of labor. In our data, we observe the workers' occupational status: production, non production and managers. These workers might face different mobility costs, for example due to different degree of specificity of their human capital. In Table 5 we allow for heterogeneity in mobility costs according to the occupational status and let the coefficient on $\left(s_{jt}^{+} - s_{jt}^{-}\right)$ in the wage equation vary for the three categories. We find a nice monotonic relationship, i.e.,the mobility cost increases going from production to non production to managers, with statistically significant coefficients. For an expanding firm it is 3.5 times more costly to attract managers than blue collars, while white collars have only marginally higher mobility costs.

6.3 Structural estimates

As discussed above, our model is overidentified. In Table 6 we use optimal minimum distance (OMD) on the reduced form parameters to back up the structural parameters. Define the distance vector between the reduced form parameters $\mathbf{b}$ and the function $f(\boldsymbol{\pi})$ of the structural parameters $\boldsymbol{\pi}$, $\mathbf{b} - f(\boldsymbol{\pi})$, where $\pi = \begin{pmatrix} \phi & \sigma_\zeta & \theta c & \theta k \end{pmatrix}'$, (see Appendix C for more details). Our optimal minimum distance procedure consists of

$$\min_{\boldsymbol{\pi}} \left(\mathbf{b} - f(\boldsymbol{\pi})\right)' \mathbf{W} \left(\mathbf{b} - f(\boldsymbol{\pi})\right)$$

The weighting matrix of OMD is obtained from the block bootstrap. We do not use the theoretical restriction on γ^L because, as (17) shows, it depends on a square root term that is not defined for some values of the parameters, and so we have 2 overidentifying restrictions.

The results show that the coefficients of interest are all very precisely estimated, and the test of overidentifying restrictions signals a good fit of the model - despite its simplicity. The estimate of ϕ (the curvature of the production function) is about 1.5. The estimate of the scale, σ_ζ, is around 40. Both coefficients are well measured. The "implied" estimates of γ^H and γ^L obtained using the estimates from Table 2 and the estimate of σ_ζ are 8.22 and -9.23, respectively, implying that firms adjust upward if they are at least 8 workers below the frictionless optimal level and downward if they are 9 or more above.[22] The estimate of $\theta(c+k)$ is 11,818 euro. Due to the presence of the scaling parameter $\theta < 1$, this only represents a lower bound for the absolute level of total adjustment costs. However, the relative contribution of internal and external costs is identified from the ratio of the estimate of θc, equal to 1,283, and θk, equal to 10,535. Our results imply that the latter clearly dominates, accounting for around 89% of total costs. Still, the share attributable to moving costs is non trivial and shows that, by disregarding this component, one would overestimate the internal costs of adjustment.

While we have no direct measure of θ that may be used to pin down the absolute level of total adjustment costs, some inference can be drawn for illustrative purposes. Assume that $\beta = .96$, in line with the fact that our data are annualized. Recalling that $\theta = 1 - \beta(2p-1)$ and that $1/2 \leq p \leq 1$, it follows that θ varies between 0.04 ($p = 1/2$, or no persistence) and 1 (full persistence). This implies that the costs of adjusting are included in the rage $11,818 \leq (c+k) \leq 295,450$. While indicative of the bounds, the range is too wide to provide an idea of the size of the costs. We use our data to get an empirical counterpart to p, the measure of productivity persistence. To map actual productivity changes into the two state space of the model, we adopt the following strategy. We first estimate an AR(1) regression of $\Delta\varepsilon_t$ onto $\Delta\varepsilon_{t-1}$ (using the $\Delta\varepsilon_{t-2}$ as an instrument), finding a coefficient of 0.39.[23] We then use the fact that the transition probability for shocks can be written as $\Pr\{\varepsilon_t|\varepsilon_{t-1}\} = (1-p)(\varepsilon_g+\varepsilon_b)+(2p-1)\varepsilon_{t-1}$. Then, in a regression of $\Delta\varepsilon_t$ on $\Delta\varepsilon_{t-1}$ the AR(1)

[22] The "implied" estimates are obtained dividing the threshold estimates from the ordered probit equation (Table 2) by the OMD estimate of the scale parameter σ_ζ. An alternative way to obtain estimates of γ^H and γ^L is to use the expressions (16) and (17) and the estimates of the structural parameters ϕ, θc and θk from Table 6. We find that this alternative estimate of γ^H is identical to the one reported in Table 6. However, since $\widehat{\theta}c(\widehat{\theta}c - 4\widehat{\phi}) < 0$, the alternative estimate of γ^L is not defined.

[23] We don't observe the level of the productivity shock, just its first difference. However, the AR(1) process

coefficient ρ can be used to obtain the corresponding value of $p = \frac{1}{2}(1 + \rho) = 0.695$. Using this and $\beta = .96$, we obtain a value for $\theta = 0.6256$, which implies a total cost of adjusting employment of approximately 18,890 euros, or 13 months of gross compensation.[24] Internal costs are $16,812$ euros, equal to almost one year of average pay. If we relate the internal costs to legal firing costs, our estimates seem reasonable. As seen in the section on the institutional aspects, costs for a firing ruled as unfair by the judge vary between 2.5 and 6 months of salary for small firms to up to 15 months in addition to the forgone compensation between firing and the court's ruling for large firms, that represent the majority of our sample. Our value lies in this range.

Using the same calculations, moving costs are around 2,080 euros. It is harder to assess how plausible this value is, because there is not even indirect evidence on mobility costs. Our estimates imply that the cost of changing a job is around 1.5 months of gross salary. This value seems rather modest. For example, using data from the CPS, **?** estimates a value of switching *sector* that can be as high as 75% of annual salary. Differently from them, we are not restricting the analysis to workers that change sector. Moreover, most of our job changes take place locally. This is documented in Table 7, that reports the share of workers moving within a given geographical area when changing job. Approximately one third of job changes are confined within the same municipality, more than half within the same Local Labor System (LLS),[25] two thirds within the same province, and less that

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$$\varepsilon_{jt} = \rho\varepsilon_{jt-1} + v_{jt}$$

can be first-differenced to obtain:

$$\Delta\varepsilon_{jt} = \rho\Delta\varepsilon_{jt-1} + \Delta v_{jt}$$

Note that OLS will be invalid because $E\left(\Delta v_{jt}|\Delta\varepsilon_{jt-1}\right) \neq 0$. However, $\Delta\varepsilon_{jt-2}$ can be used as an instrument.

[24]Previous studies have also find significant costs of adjusting employment. For example, using direct measures the costs of termination from survey data for France in 1992, **?** find values in the range of 17,000 and 40,000 euros. Differently from their study, our measure also incorporates any indirect cost of adjusting, such as that coming from productive disruption; moreover, it represents the sum of both the internal and the external adjustment cost.

[25]LLS are defined as groups of municipalities characterized by a self-contained labor market with intense commuting, as determined by the National Statistical Institute on the basis of the degree of work-day commuting by the resident population. Using 1991 census data, the NSI procedure identified 784 LLSs

20 percent entails a change of macro area (North-East, North-West, Center, South and Islands). If we exclude neighboring macro areas, where mobility might still be local for workers located close to the boundaries, then long distance mobility is even lower. In Panel B of the table we report mobility flows across macro areas. The only substantial flows that surely entail long distance mobility are those from the poor and high unemployment regions of the South and Islands to the rich regions of the North. These flows are part of a secular migration movement South to North that characterizes the Italian labor market. If we exclude this flow, there is little evidence that firms satisfy their employment needs on the whole national territory, as seems more common in the US labor market: most of the job changes occur locally. The picture that emerges is therefore one of fairly high segmentation across local labor markets, while the cost of moving within each market is contained though not negligible.[26]

7 Conclusions

In this paper, we have proposed and implemented a method for distinguishing between the internal and the external component of the costs of adjusting employment at the level of the firm. We find that the external costs, ignored by the previous literature, are non trivial, but that the internal ones account for a larger proportion of total labor adjustment costs.

These results have important policy implications. Adjustment costs imply that labor might not be allocated to its most productive utilization. Reducing them would imply a more efficient allocation of resources. From this perspective, our results indicate that, while mobility is an issue, larger gains would occur from reducing adjustment costs internal to the firm, such as firing restrictions or other impediments to employment changes.

This does not imply that mobility costs are unimportant. Indeed, as already stressed above, our estimates of the moving costs should be interpreted as related to costs of changing employer locally, rather than location or sector. An important extension would be to apply

covering the whole national territory.

[26]This feature is consistent with the traditional view of industrial clusters, where workers move fairly easily within the local market. This is one of the main features of industrial district, that are an important component of the Italian economy (see, for example, **?**).

this paper's methodology to measure the cost of long-range mobility, a task that we plan to undertake in future work.

A Appendix: Model solution

Consider first the optimal adjustment level. It is easier to work with the marginal shadow value of labor, that in equilibrium also follows the two state structure:

$$\begin{aligned} V_g &= F_l(l_g, \varepsilon_g) - w_g + \beta[pV_g - (1-p)V_b] \\ V_b &= F_l(l_b, \varepsilon_b) - w_b + \beta[pV_b - (1-p)V_g] \end{aligned}$$

Optimality requires that $V_b = -k$ and $V_g = h$: by firing an additional worker a firm pays k, so it will fire workers until the marginal product of labor is $-k$; similarly, when hiring it pays h, so the marginal worker must be worth exactly h. Substituting we obtain:

$$h = F_l(l_g, \varepsilon_g) - w_g + \beta[ph - (1-p)k] \tag{22}$$

$$-k = F_l(l_b, \varepsilon_b) - w_b + \beta[(1-p)h - pk] \tag{23}$$

By using $F_l = \varepsilon - \phi l$ and after some algebra (7) follows.

To obtain equilibrium levels, note that (3), (22), (23) and the condition $l_g + l_b = 1$ are four equations in four unknown that can be solved out to yield:

$$\begin{aligned} l_g &= \frac{\Delta\varepsilon - \theta(c+k+h) + \phi}{2\phi} \\ l_b &= \frac{-\Delta\varepsilon + \theta(c+k+h) + \phi}{2\phi} \\ w_g &= \frac{1}{2}(\varepsilon_g + \varepsilon_b + \theta c - (1-\beta)(h-k) - \phi) \\ w_b &= \frac{1}{2}(\varepsilon_g + \varepsilon_b - \theta c - (1-\beta)(h-k) - \phi) \end{aligned}$$

Consider now the optimality of adjusting. To save on notation, define $V_{ji} = V(l_i, \varepsilon_j)$. Then, the recursive equations for the value of the firm in the four states, conditional on adjustment being optimal are:

$$V_{gg} = F_{gg} - w_g l_g + \beta(pV_{gg} + (1-p)V_{gb}) \tag{24}$$

$$V_{bb} = F_{bb} - w_b l_b + \beta(pV_{bb} + (1-p)V_{bg}) \tag{25}$$

$$V_{gb} = V_{bb} - k\Delta l \tag{26}$$

$$V_{bg} = V_{gg} - h\Delta l \tag{27}$$

Then, substitute to reduce the system to two equations in two unknowns:

$$V_{gg} = F_{gg} - w_g l_g + \beta(pV_{gg} + (1-p)V_{bb} - (1-p)k\Delta l) \quad (28)$$
$$V_{bb} = F_{bb} - w_b l_b + \beta(pV_{bb} + (1-p)V_{gg} - (1-p)h\Delta l) \quad (29)$$

To determine the optimality of increasing employment when productivity switches from ε_b to ε_g we use Bellman's optimality principle, and check if deviating from one period delivers a higher payoff with respect to following the optimal policy. For adjustment to be optimal, it must be that

$$V_{bg} = F_{gg} - w_g l_g + \beta(pV_{gg} + (1-p)V_{bb} - (1-p)k\Delta l) - h\Delta l \geq$$
$$> F_{bg} - w_b l_b + \beta\{pV_{gg} - ph\Delta l + (1-p)V_{bb})\} \quad (30)$$

Simplifying,

$$F_{gg} - w_g l_g - (\beta(1-p)k + (1-\beta p)h)\Delta l \geq F_{bg} - w_b l_b \quad (31)$$

Using the quadratic production function and the relations $(l_g^2 - l_b^2) = (l_g - l_b)(l_g + l_b) = \Delta l$, $w_b = w_g - \theta c$ and substituting for w_g the condition simplifies to

$$\Delta\varepsilon^2 - \theta(c + 2(h+k))\Delta\varepsilon + \theta(\theta(c+k+h)(h+k) - c\phi) > 0$$

This is a quadratic in $\Delta\varepsilon$ whose solution is (9). Similar calculations yield the condition (10).

B Appendix: Heterogeneous labor

This appendix shows how the model can be extended to allow for different mobility costs for different workers. We use this extension as the basis for a wage equation where we identify the mobility costs of different types of workers. At the level of the firm, we only observe employment changes and not which workers are hired ore laid off, so that we cannot separately estimate firing costs for the different types of workers. We assume that different workers are used in production in fixed proportions, which implies that the firm always modify employment in the same proportion, making the identity of movers irrelevant from the firm's perspective. This arguably strong assumption can be defended on the ground that we will distinguish between production workers, non production workers and managers, whose degree of substitutability is likely to be rather limited.

Labor is heterogeneous in production. Each worker's problem is identical to the one in Section 3. There are two types of workers (but extending the model to n types is immediate), P (production) and N (non production), that differ both for their contribution to production (see below) and for their moving cost, c^s, $s = P, N$. In each period, a worker is employed in a "good" or a "bad" firm, which pay wages w_g^s and w_b^s respectively. Applying the same reasoning for each type of worker as in Section 3 , we obtain:

$$w_g^N = w_b^N + \theta c^N \quad (32)$$
$$w_g^P = w_b^P + \theta c^P \quad (33)$$

Firms produce output using a mix of the two types of workers in fixed proportion.

We define effective labor l as obtained by combining the two types of labor P, N in fixed proportion:

$$l = \min\{\frac{1}{a}l^P, \frac{1}{1-a}l^N\},\ 0 \le a \le 1.$$

This specification implies that 1 unit of effective labor l is obtained combining $1-a$ units of l^P and a units of l^N, so that a is the share of N type workers in the total labor force. Given the wages w^N and w^P, the effective wage rate is

$$w = aw^N + (1-a)w^P$$

At an optimum, $l^N = al$ and $l^P = (1-a)l$. At the level of the firm, we can therefore consider directly l, weighting each type of labor for its share. Note that, from (32-33), it follows that

$$\begin{aligned} w_g - w_b &= aw_g^N + (1-a)w_g^P - aw_b^N + (1-a)w_b^P = \\ &= a(w_g^N - w_b^N) + (1-a)(w_g^P - w_b^P) = \theta(ac^N + (1-a)c^P) = \theta c \end{aligned}$$

The wage change by effective unit of labor can be expressed as a weighted average of the mobility costs of each type of worker. One can therefore solve the firm problem using the labor data directly, without distinguishing between P and N. The analysis in the main text then applies. The full model solution follows the one in the previous appendix and is available from the authors on request.

C Appendix: The minimum distance mapping

The objective of the minimum distance procedure is to minimize the distance between the vector of reduced form parameters $\mathbf{b}$, and $f(\boldsymbol{\pi})$, a function of the structural parameters $\pi = \begin{pmatrix} \phi & \sigma_\zeta & \theta c & \theta k \end{pmatrix}'$. The exact mapping is as follows:

$$\mathbf{b} = \begin{pmatrix} b_{OP,UT} \\ b_{OP,LT} \\ b_{OP,\Delta\varepsilon} \\ b_{SA,\Delta\varepsilon} \\ b_{SA,\frac{\phi_{jt}^H - \phi_{jt}^L}{1-\Phi_{jt}^H+\Phi_{jt}^L}} \\ b_{SA,\frac{1-\Phi_{jt}^H - \Phi_{jt}^L}{1-\Phi_{jt}^H+\Phi_{jt}^L}} \\ b_{W,s^+-s^-} \end{pmatrix},\ f(\boldsymbol{\pi}) = \begin{pmatrix} (2\phi\sigma_\zeta)^{-1}\left[\theta(c+2k) + \sqrt{\theta c(\theta c + 4\phi)}\right] \\ -(2\phi\sigma_\zeta)^{-1}\left[\theta(c+2k) + \sqrt{\theta c(\theta c - 4\phi)}\right] \\ (\phi\sigma_\zeta)^{-1} \\ \phi^{-1} \\ \sigma_\zeta \\ -\phi^{-1}\theta(c+k) \\ \theta c \end{pmatrix}$$

where $b_{E,V}$ is the reduced form estimate of the coefficient on variable V ($V = UT$ the upper threshold in the ordered probit equation, LT the lower threshold in the ordered probit equation, $\Delta\varepsilon_{jt}$, $\frac{\phi_{jt}^H - \phi_{jt}^L}{1-\Phi_{jt}^H+\Phi_{jt}^L}$, $\frac{1-\Phi_{jt}^H - \Phi_{jt}^L}{1-\Phi_{jt}^H+\Phi_{jt}^L}$, and the IV $s^+ - s^-$) in equation E ($E = OP$ ordered probit, SA size of adjustment, and W wage equation). In practice, in our OMD procedure we do not use $b_{OP,LT}$, and so $\mathbf{b}$ contains only 6 elements. Since π contains 4 parameters, there are two overidentifying restrictions overall.

Table 1
Firms' and workers' characteristics

Panel A reports summary statistics for the firms in our data set. Panel B shows descriptive statistics for the sample of workers. All statistics refer to 1991. The matched firm sample includes firms that area matched at least once with a worker in the workers' data set.

Panel A: Firm characteristics

	Mean		Stand. dev.	
	Whole sample	Matched sample	Whole sample	Matched sample
Value added (thousand euros)	8,712	15,485	127,028	116,589
Number of employees	203	370	2355	2642
South	0.0884	0.0892	0.2839	0.2851
Center	0.1627	0.1672	0.3691	0.3731
North	0.7489	0.7436	0.4337	0.4367
Manufacturing	0.7750	0.7964	0.4176	0.4027
Construction	0.1549	0.1317	0.3619	0.3382
Retail	0.0253	0.0278	0.1571	0.1644
Services	0.0447	0.0441	0.2067	0.2052

Panel B: Workers' characteristics

	Mean		Stand. dev.	
	Whole sample	Matched sample	Whole sample	Matched sample
Earnings (thousand euros)	16.94	17.25	9.39	9.02
Age	38.93	39.15	10.43	10.40
Male	0.7284	0.7423	0.4448	0.4374
Productions	0.6164	0.6188	0.4863	0.4857
Clericals	0.3662	0.3655	0.4818	0.4816
Managers	0.0173	0.0157	0.1305	0.1242
South	0.1427	0.1244	0.3498	0.3301
Center	0.1880	0.1859	0.3907	0.3890
North	0.6693	0.6897	0.4705	0.4626

Table 2
Employment Adjustment: Ordered probit estimates

Dependent variable: a discrete variable taking the value -1 for negative employment changes, 0 for no changes, and 1 for positive changes. Firm shock is the residual in first differences of a regression of value added per (lagged) worker on year, sector, and regional dummies. Bootstrap standard errors in parenthesis.

Regressor	(1)	(2)
Lower threshold	-0.2292	-0.2255
	(0.0063)	(0.0063)
Higher threshold	0.2003	0.2042
	(0.0060)	(0.0060)
Firm shock	0.0162	0.0162
	(0.0004)	(0.0004)
N. periods since last adj.		0.0151
		(0.0055)
# observations	84,771	84,771

Table 3
Employment Adjustment: size of the adjustment

The dependent variable is employment change from one year to the next. The regression only include adjusting firms. See Table 3 for the definition of the firm shock. The other two variables are functionals of the normal p.d.f. and c.d.f. obtained from the estimates of the ordered probit of Table 3, column 1. Bootstrap standard errors are in parenthesis.

Regressor	
Firm shock	1.7357 (0.6102)
$\frac{\phi_H - \phi_L}{1-\Phi_H+\Phi_L}$	411.6794 (323.3357)
$\frac{1-\Phi_H-\Phi_L}{1-\Phi_H+\Phi_L}$	-159.9843 (87.7931)
# observations	70,610

Table 4
Wage adjustment

The dependent variable is yearly wage change (in thousand euros). For stayers, the change is computed as the difference in the wage from year to year; for movers, it is the change in the annualized wage following the job move. All regressions include sector (1 digit: manufacturing, constructions, retailing, other), year, and location (3 macro-areas: north, center, south) dummies. $s^+$is a dummy equal to 1 if the firm the worker is employed at has increased its workforce in the current year; $s^-$is one if it has decreased it. Bootstrap standard errors are in parenthesis.

Regressor	OLS (1)	IV (2)
$s^+ - s^-$	0.1310 (0.0148)	1.2964 (0.1651)
Age	−0.0050 (0.0015)	−0.0038 (0.0018)
Tenure	−0.0009 (0.0003)	−0.0003 (0.0004)
Male	0.3276 (0.0186)	0.3369 (0.0223)
Blue collar	−3.3010 (0.2307)	−3.3284 (0.2142)
White collar	−2.7391 (0.2238)	−2.7461 (0.2157)
N. obs.	104,798	85,673

Table 5
Wage Adjustment, Controlling for heterogeneity

The dependent variable is yearly wage change (in thousand euros). See Table 4 for details.

Regressor	IV (1)
$(s^+ - s^-) \times$Blue collar	1.1562 (0.0891)
$(s^+ - s^-) \times$White collar	1.3837 (0.4245)
$(s^+ - s^-) \times$Manager	4.9453 (2.1133)
Age	-0.0039 (0.0019)
Tenure	-0.0003 (0.0004)
Male	0.3380 (0.0222)
Blue collar	-3.4696 (0.2603)
White collar	-2.8699 (0.2589)
N. obs.	$85,673$

Table 6
Optimal Minimum Distance results

The table reports structural estimates of the parameters, obtained by applying OMD to the reduced form regression coefficients. The "implied" estimates are obtained dividing the threshold estimates from the ordered probit equation (Table 2) by the OMD estimate of the scale parameter σ_ζ. The variance-covariance weighting matrix is obtained from the block bootstrap.

Structural estimates	
Implied γ_H	8.2210
Implied γ_L	−9.2275
σ_ζ	40.2595 (3.8858)
ϕ	1.5365 (0.1667)
θc	1.2832 (0.1635)
θk	10.5351 (0.4768)
OID test	3.6627 (2 d.f.; p-value 16.34%)

Table 7
Workers' geographical mobility

The first panel reports the share of workers that move within a given geographical unit. LLS are local labor systems (see footnote 25); Macro-areas are the ones reported in the second panel of the table. The second panel reports the matrix of mobility flows across macro areas.

Panel A: Share of mobility within:

Municipality	LLS	Province	Region	Macro-Area
.33	.54	.63	.74	.81

Panel B: Mobility Across Macro Areas

	To					
	N-W	N-E	Center	South	Islands	N. Obs.
From						
N-W	0.86	0.07	0.04	0.02	0.01	3627
N-E	0.11	0.84	0.03	0.01	0.01	2276
Center	0.18	0.06	0.68	0.07	0.01	1030
South	0.21	0.07	0.13	0.56	0.03	382
Islands	0.16	0.13	0.07	0.03	0.62	259

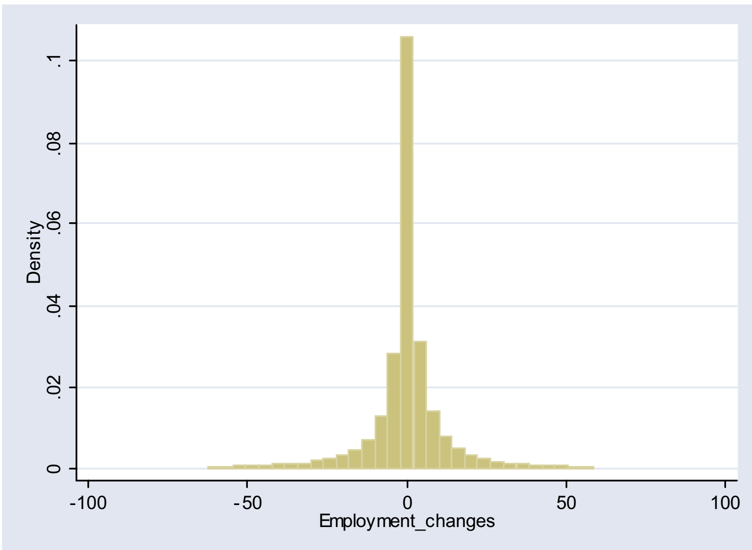

Figure 1: Histogram of employment changes