Coordinated labor Supply within the Firm: Evidence and Implications

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February 15, 2013

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Abstract

This paper studies individual and plant-wide adjustment in days worked. Matched firm-worker data for North-East Italy show significant variation in mean days worked per month within plants: a one-standard deviation change amounts to about four days of worker per month. The paper then looks within the plant to document the extent of co-movement, or coordination, of labor supply among a plant's workers. After adjusting for individual and plant-specific effects, we find that the days worked of one's co-workers accounts for 20 percent of the variation in individual days worked. The effect of co-workers trumps other standard controls, such as the worker's own (daily) wage. It has been known that such an incentive to coordinate labor input can lead to downwardly-biased estimates of the labor supply elasticity if the identifying variation is idiosyncratic to a worker. Reacting to this, we study the (intensive) labor supply elasticity within the context of a model in which workers' time inputs are complements in production. This model can be estimated via minimum distance, which recovers the technology and preference parameters consistent with the observed degree of coordination and intensive-margin adjustment.

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1 Introduction

In most modern labor markets, there are important costs of adjusting employment. These take the form of recruiting and hiring costs as well as legislated penalties for layoffs.[1] The recognition that it is costly to adjust along the extensive margin has refocused attention to some degree on one of the firm's other options - to adjust labor input along the intensive margin. Raffo et al. (2012) find that separation costs in several European economies can account for why fluctuations in hours per worker in those economies are nearly as large as those in employment. In addition, recent work on inflation dynamics has emphasized that, in the presence of costly employment adjustment, flexibility along the intensive-margin is an important determinant of the elasticity of marginal cost and, thus, the frequency and size of price changes (Trigari, 2006).

In this paper, we aim to gain further insight into the workings of the intensive margin at the plant level. For this work, we are fortunate to have a unique source of data. We use a matched worker-establishment panel dataset that covers the universe of workers and firms in the northern Italian region of Veneto over the period, 1982-2001. These data include information on the number of days worker per month by each worker in each establishment.[2] This is one of the few large and representative datasets, to our knowledge, that provides information on intensive-margin adjustment across different workers within the same plant.[3]

Our main empirical analysis proceeds in two parts. We first document the extent of

[1]See Barron et al. (1997) and Caballero et al. (2004).

[2]Unfortunately, the data do not record hours. However, we believe that a considerable amount of intensive-margin adjustments are revealed through days. For instance, in the U.S. Current Population Survey, we found over 20 percent of workers who report deviations from their usual weekly hours say that they worked exactly 8 hours more or less, or roughly one day of work. Moreover, at least another 15 percent report deviations from usual hours in excess of 10 (in absolute value), a change so large that it likely required a change in the number of days.

[3]In Italy, these data have to be recorded because taxes and social insurance contributions are tied to days worked. Data are reported to the public social security organisation INPS. The dataset has then been accessed, organized and maintained by researchers at the University of Venice. We thank Prof. Tattara and the team of researchers at the University of Venice for giving us access to the dataset.

variation in plant-level average of days worked per worker. We find what strikes us as considerable flexibility along this margin. A one-standard deviation change in the growth of average monthly days worked per worker is 17 log points, which translates to about 4 extra (or fewer) days worked per month.

We then examine fluctuations in days worked among individual workers within plants. We are interested, specifically, in the reaction of days worked relative to firm and individual means; the objective to assess the *flexibility* of time inputs rather than account for differences in *average* time allocation in the cross section. Hence, all of our regressions in this subsection include firm and worker fixed effects. The latter account for over 40 percent of the variation in average monthly days worked per worker. After adjusting for fixed effects, we find that the days worked by co-workers accounts for 20 percent of the remaining variation in individual days worked. The effect of co-workers trumps other standard controls. For instance, idiosyncratic variation in a worker's own daily wage contributes much less to changes in her days worked than does variation in the days worked of her colleagues.[4]

These latter results pique our interest in the notion of coordinated labor supply. Though datasets have not allowed a plant-level analysis of this issue until recently, the notion of coordination has been discussed for decades. In Pencavel (1986) discussion of the Negative Income Tax (NIT) experiments of the 1960s and 1970s, he notes that the labor supply responses in some cases – Gary, IN, in particular – were likely subdued because only a handful of workers in a plant participated in the experiment. If workers are complementary in production, the efficient hours bargain would have called for the NIT participants to adjust their hours only modestly since the work incentives of the vast majority of the plant's

[4]This horse-race between colleagues' days worked and one's own wage rate has long been considered a useful diagnostic for the canonical model of inter-temporal labor supply model. For instance, in his test of this model, Ham (1986) uses labor market conditions in a worker's industry to instrument for that worker's weeks of unemployment. He finds that the variation in own weeks of unemployment attributed to the industry conditions has a more significant effect on one's hours of work than the own wage rate. Yet, in the standard model, any industry-wide variation relevant to individual labor supply ought to be impounded in the wage rate.

employees were unchanged. In other words, complementarity provides a strong incentive to coordinate labor supply within the firm.[5]

The notion of coordinated labor supply has potentially important implications for the identification of the labor supply elasticity. Since only a fraction of a plant's workforce is treated, the experimental variation provided by programs such as the NITs is likely to yield a downwardly-biased estimate. The same problem would afflict studies that exploit forecastable changes in a worker's individual wage rate. In the presence of coordination, sources of firm-wide variation, such as a firm-wide productivity shock or a sudden shift in demand for the firm's product, are arguably more informative.[6]

To pursue this point in more detail, we specify and estimate a model of plant-level labor dynamics in which the complementarity across workers is made explicit in the production technology. In this model, the manager observes the *firm-wide* productivity shock. She then chooses the number of workers and then bargains with the workforce over the wage rate and time input (days). The employment choice is mediated by adjustment costs chosen to mimic the legal environment faced by Italian firms. The bargain over time inputs, conditional on employment, balances the incentive to coordinate embedded in the production technology with *idiosyncratic* differences across workers' marginal values of time.

We then wish to take this model to data. The model is confronted with a few key empirical moments, namely, the estimated degree of coordination as proxied by the regressions just discussed; the variation in average monthly days worked per worker; and dispersion in residual (daily) wage rates. The latter dispersion is viewed through the lens of the model as the result, in part, of idiosyncratic variation in workers' marginal values of time. Critically,

[5]The NIT experiments were conducted in a handful of cities. In each, roughly 1000 to 2000 households were enrolled in the sample and a sub-sample (the treated) had their budget constraint altered. In particular, a household in the treated sample was given a lump-sum grant that was ratcheted down as the household's labor market income rose.

[6]Rogerson (2011) makes this point in a slightly different context. Later, we relate our work to that of Rogerson in slightly more detail.

these shocks also put pressure on the manager to allow days worked to vary across workers. Thus, the minimum distance estimator must find a set of structural parameters and stochastic processes that best reconciles the observed magnitude of this wage dispersion with the empirical moments regarding coordination and days worked variation. The tension among these moments provides the source of identification.

The estimation results will be of interest for two reasons. First, the estimated structural parameters provide discipline to macroeconomic models which take care to model both intensive and extensive adjustments. Second, the estimated model may be used a laboratory in which to interpret past studies. For instance, though the benchmark model below omits any mention of taxes, it will not be difficult to adapt it to consider a NIT-like experiment, or any comparable temporary tax change.[7] We then attempt, in accordance with the prior literature, to infer the intertemporal elasticity of supply from the simulated outcomes of the treated and control groups in this extended model. The results, especially when juxtaposed to the structural parameter estimates, will provide a useful perspective on the quantitative implications of coordination. In particular, the incentive to coordinate is expected to attenuate labor supply responses to such idiosyncratic shocks even if the structural parameters are consistent with highly variable time inputs.

Our work is related to a number of papers in the fields of plant-level dynamics and labor supply. In their study of U.S. plant-level data, Cooper et al. (2007) find that a one-standard deviation increase in the growth of average (plant-wide) weekly hours amounts to about 8 hours at a plant where mean weekly hours is 40. This translates to roughly 4 days per month, which is comparable to what we find. Our use of complementarity as a kind of hours constraint also places our paper within the broader literature on hours-constrained labor supply. Recently, Chetty et al. (2011) consider a model with an hours constraint (at the plant level) in that a manager must commit to a technology that requires a fixed number

[7] The NITs were not permanent, of course. They were typically administered for three years.

of man hours. These authors study how the menu of posted hours requirements adjusts, in equilibrium, to a change in desired labor supply after tax reform. Our work differs insofar as we focus more specifically on the implications of complementarity for plant-level fluctuations. Lastly, Rogerson (2011) studies coordination but assumes that all workers within the model economy must perfectly coordinate. Our data allow us to take a plant-level look at the degree of coordination along the intensive margin specifically.

2 Reduced Form Analysis

Our empirical analysis utilises the Veneto Worker History (VWH) dataset, which includes virtually all private-sector workers of the northern Italian region of Veneto for years 1982-2001.[8] The VWH dataset records all employees that have been hired in Veneto for at least one day during the period of observation. The full sample contains around 3.6 million workers and 46 million observations at the worker by year level over 20 years.[9]

The VWH data has a number of unique features that recommend it for this analysis. Most crucially, for each worker, the VWH reports the number of days paid in each year and the number of months worked with each establishment.[10] It also gives a worker's annual earnings, from which we compute the average daily wage for each job in each year. Table 1 provides the relevant summary statistics. On average, workers work just under 24 days in the months in which they work at all, reflecting the prevalence of 6-day weeks in this region of Italy in this period. The average gross daily wage is around 120 Euros, and on average the number of months in which a worker is paid is about 10.

In addition, the dataset provides information on the employment arrangement that likely

[8]The region of Veneto, in the North-East of Italy, is one of the largest in Italy (its 2001 GDP ranks third among twenty of Italian regions), and it has a population of around 5 million, or 8 percent of the country's total.

[9]For more information about our dataset and about the wage setting institutions in Veneto and in Italy see our Appendix.

[10]Hence, paid holidays and sick leave are included. But our focus here is not the level of days worked, but instead the variation and co-movement in annual changes in monthly days worked.

Table 1: Summary statistics for variables used in our baseline regressions

Variable	**Mean**	**(Std. Dev.)**	**N**
Average days per month per year	23.74	(7.05)	22689645
Job seniority (in days)	1276.25	(1288.55)	22635092
Average gross daily wage (in 2003 Euros)	120.72	(422.32)	22599805
Total days worked per year	244.17	(98.34)	22689645
Number of months in which worker is paid	9.97	(3.39)	22689645

Unit of observation is the worker-year.

Source: Authors' calculations from VWH dataset.

bears on the flexibility of the intensive margin on the job. In particular, the data identify a worker as full-time or part-time and provides information on the type of contract under which a worker was hired. In Italy, a worker may be hired under a permanent contract, which includes restrictions on *individual* dismissals.[11] Alternatively, beginning in the middle of the 1980s, employers were allowed to hire hire workers under fixed-term contracts. The latter expired after two years, at which point the employer could dismiss the worker without penalty.

However, despite the presence of these more flexible margins, it should be noted that part-time and fixed-term contracts were not widespread during our sample. On average, in our data, only 7 percent of workers were part time and 11 percent of the workforce was employed on a fixed-term contract. In our baseline analysis that follows, then, we typically do not break down the workforce along these lines.

2.1 Plant-level evidence

With this basic summary of the data complete, we now seek to characterize the variation in days worked per month at the plant level. That is, we suppress (momentarily) the individual variation across workers within plants and focus on the variation in the plant-level mean.

To proceed, we identify all workers within an establishment in a year, sum over their

[11] Employers can negotiate *collective* dismissals whereby five or more workers were laid off for reasons such as slack demand. We return to this later when we introduce the structural model.

annual days worked, and divide by their total number of months worked at the establishment. This gives us, in each year, the plant-level average monthly days worked per worker. The division by the aggregate number of months ensures that our measure of the intensive margin is not contaminated by changes in the number of workers. Clearly, if a plant hires workers mid-way through the year, the average days worked per worker at the plant will fall even if each worker puts in the same number of days per month. To guard against these spurious movements, we normalize by the aggregate number of months.

It remains to specify how a worker was assigned to an establishment if that worker had multiple employers. Our baseline analysis assigns each worker in each year to her main employer in terms of time worked. We also consider an alternative in which, for each plant, we compute the annual change in average monthly days worked per worker using only workers who remained with that plant for the duration of each of the two years. This subsample is referred to as *stayers*. As we will see, the results of both exercises are very similar.

To now characterize plant-wide variation in days worked, we consider a simple regression model,

$$Y_{kt} = f_k + \delta_k t + \beta_t + \epsilon_{kt} \tag{1}$$

This relates the log of monthly days worked per worker at plant k, Y_{kt}, to a firm effect f_k; a firm-specific time trend δ_k, and a year effect β_t. We then take first differences to obtain:

$$\Delta Y_{kt} = \delta_k + \beta_t + u_{kt} \tag{2}$$

where $u_{kt} \equiv \Delta\epsilon_{kt}$ and we have simply redefined β_t to be the the first difference (since a year effect will remain). We note that the first difference operation would also annihilate any other time invariant controls in equation (1), such as sector and region.

Our main interest is the variance of the residual in (2), pooled over plants and over time. This summarizes the variation in annual changes in log monthly days worked per worker that is unaccounted for by firm and year effects. The results are reported in Table 2. For comparison, we also report results for (2) when the annual change in log employment is placed on the left side.

The table shows that a one-standard deviation change in monthly days worked per worker amounts to about 17 log points. At a plant which works 24 days per month, a 17 log-point increase (decrease) amounts to about 4 extra (fewer) days per month. This strikes us as a significant amount of variation along the intensive margin. Nonetheless, the data still indicate that employment is slightly more than twice as variable as days worked.[12]

Table 2: Standard deviations of residuals from equation (2)

	Standard Deviations	
Sample	**Days**	**Employment**
Full sample	0.1728	0.4213
Fixed term workers	0.2586	0.3443
Permanent workers	0.1806	0.4054
Part-time workers	0.2785	0.3412
Full-time workers	0.1747	0.4113
Stayers	0.1587	0.3694

Unit of observation is the firm-year.
'Days' denotes average days per month across workers.
'Stayers' identifies workers that were employed at firm k at $t-1$ as well.
Source: Authors' calculations from VWH dataset.

2.2 Individual-level Regressions

We now move to individual-level regressions to explore the main determinants of individual days worked, and the extent to which individual hours worked covary among coworkers. We

[12]In U.S. data, Cooper et al. (2007) find that the variance of the log change in hours per worker at the plant level is nearly as large as that for employment growth. As noted in the introduction, their estimate of the variation in weekly hours per worker seems comparable to our estimate of the variation in monthly days per worker. What is different is that the variance in employment growth in our sample is much larger. In this regard, it should be noted that Cooper et al. confine their analysis to very large plants; the mean size in their sample is 600.

begin with some simple regressions that build up to our main analysis.

In table 3 we regress individual days worked per month on individual wage, coworkers' days, tenure and employment. The R squared of the regression in column 1 shows that individual wage plays no role in explaining individual days worked. On the other hand, even in a regression without fixed effects, we can explain over 30 percent of the variation in days worked with coworkers' days, tenure and firm size (employment level). Column 4 includes a set of year dummies, which affect the other estimates only marginally.

Table 3: The determinants of days worked

Dependent variable: log of days worked per month				
	(1)	(2)	(3)	(4)
Log of daily wage	-0.00447***	-0.0342***	-0.112***	-0.113***
	(0.000159)	(0.000144)	(0.000142)	(0.000141)
Log days worked at the firm level		0.784***	0.572***	0.571***
		(0.000347)	(0.000332)	(0.000331)
Log tenure in the firm			0.104***	0.109***
			(0.0000490)	(0.0000501)
Log of firm employment level			0.00275***	0.00159***
			(0.0000345)	(0.0000345)
Year Fixed Effects	No	No	No	Yes
Individual Fixed Effects	No	No	No	No
Firm Fixed Effects	No	No	No	No
N	22591225	22591225	22591225	22591225
R^2	0.000	0.184	0.320	0.326

Standard errors in parentheses

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 5 shows, as confirmed by our full model below, that individual fixed effects explain a significant amount of the variation in the log level of days worked per month: some workers tend to have higher than average days worked across their careers, some tend to have lower than average days worked across their careers. In the regressions presented in table 6 we show that to extent to which variation in days worked depend on firm unobserved heterogeneity is relatively small.

Next, we move on to the main regression of interest for our analysis. The goal here is to estimate the correlation between the number of days a month worked by worker j and those of her coworkers, i..e other workers employed by the same firm in the same year. We include two sets of fixed effects in our model to control for worker and firm time-invariant unobserved heterogeneity. In some specifications, we also include year dummies and other covariates. Our basic empirical model can be written as

$$Y_{jkt} = \alpha_0 + \mathbf{X_{jt}}\alpha_\mathbf{1} + firmdays_{-jkt}\alpha_2 + \mathbf{year_t}\alpha_\mathbf{3} + \theta_j + \psi_k + \nu_{jkt} \tag{3}$$

where Y_{jkt} is our outcome variable of interest (in the baseline mode, average days worked per month worked) for individual j employed at firm k in period t. The scalar $firmdays_{-jkt}$ is our main variable of interest and measures the average number of days per month of all workers in the firm apart from worker j. The vector $\mathbf{X_{jt}}$ is a vector of time-varying individual characteristics, and $\mathbf{year_t}$ is a vector of year dummies to pick up macroeconomic components in days worked. We also include individual fixed effects θ_j and firm fixed effects ψ_k. Hence, the regression estimates the association between variation in a worker's days worked around firm- and individual-level means with variation in the days worked of her colleagues. Finally, ν_{jkt} is an error term assumed to be i.i.d. across time and agents.

We are aware that equation (3) above suffers from is usually referred to as the 'reflection problem' first discussed in Manski (1993). To the extent that days worked of all coworkers is correlated, our measure of coworker days on the right hand side is endogenous by construction. However, for the main goal of our paper it is not crucial to identify a causal relationship since the main message from this a correlational relationship. Secondly, given the fact that firms have on average 27 employees this feedback mechanism is very unlikely to be sufficient to explain our results.

2.2.1 Results

In this section we present our baseline results for the empirical model presented in equation (3) above. Our empirical model builds upon the structure of the model of Abowd et al. (1999). As in their empirical model, the separate identification of firm effects and person effects requires employment histories to be sufficiently connected.[13] Because we have such a dataset with large N and relatively large T, the observations that are excluded are a tiny fraction of the total. Around 45 percent of all workers are employed in more than one firm within the period of our dataset (this is a lower bound on actual mobility because of the sample restrictions we have imposed). In addition, over 40 percent of all firms have more than one hundred workers who move across plants, and only 8.2 percent of all firms have less than five workers who are mobile. In the Appendix, we present details on the degree of mobility of workers and firms in our data.

Table 4 presents our main results. Column 1 presents a model that includes individual and firm effects and where the only dependent variable is average days worked among coworkers. We find the coefficient of log average days among coworkers to be 0.410: when average days among coworkers increase by one percent, days of individual j increase by 0.41 percent on average. But the quantitative importance of coworkers' days worked can perhaps better be seen from a simple linear variance decomposition into the various components of our regression. Individual fixed effects explain around 36.6 percent of the overall variation in log average individual days per month worked. We find that coworker average days are also important: they account for 17 percent (9.6 divided by 9.6+46.9) of the variation in our dependent variable that is left unexplained by individual and firm effects. This result seems to suggest that there is the potential for firm-level coordination to be an important determinant of the (intensive-margin) labor supply elasticity.[14]

[13] A connected group of firms and workers contains all the workers that ever worked for any of the firms in the group and all the firms where any of the workers were ever employed (Abowd et al., 2002).

[14] The negative association between days worked and the own wage is not entirely unsurprising. It is

Table 4: Own days worked and coworker days worked

Dependent variable: log average days of worker j	Models		
	(1)	**(2)**	**(3)**
Regression Estimates			
Log average days worked of coworkers	.410	0.405	0.371
	(.001)	(0.001)	(0.000)
Log tenure			0.106
			(0.000)
Log employment			0.004
			(0.000)
Controls for Unobserved Heterogeneity			
Individual Fixed Effects	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes
Year dummies	No	Yes	Yes
R^2	0.531	0.531	0.573
N	22,599,805	22,599,805	22,599,805
Variance decomposition			
Individual Fixed Effects	0.366	0.368	0.260
Firm Fixed Effects	0.068	0.067	0.045
Year Effects		0.011	0.005
Coworkers Avg Days	0.096	0.095	0.087
Tenure			0.189
Employment			0.001
Unexplained $(1 - R^2)$	0.469	0.469	0.427

Unit of observation is the individual-year.
'Days' denotes average days per month.
Standard errors in parenthesis
Source: Authors' calculations from VWH dataset.

In column 2 of table 4 we add a set of year dummies for 1982-2001. Our results are basically unaffected; our estimate of the role of coworker average days worked decreases only slightly. In column 3 we also add job tenure (the number of days in which worker j has worked for firm k) and firm employment, both in logs. The effects of log average days worked by coworkers is now lower, but only by three log points. Moreover, the percentage of the variation in our dependent variance that can be attributed to coworkers average days

reminiscent, for instance, of Abowd and Card's (1983) analysis of U.S. panel data.

is only slightly lower. We conclude that the associated between own and coworkers' days is quite robust to alternative specifications.

3 A model

This section sketches a simple model of dynamic factor demand in which workers are complements in production. It includes frictions on the extensive margin, which, in turn, make the intensive margin operative.

3.1 Preliminaries

Preferences. Workers experience disutility from labor of the form $\xi g(h)$, with $g(h) = \frac{h^{1+\varphi}}{1+\varphi}$ and $\varphi > 0$. Here, h is the number of days worked by the individual and ξ is a taste parameter. We allow that workers differ in their "taste" for work, ξ. Specifically, we assume that a worker takes an iid draw of ξ per period. We impose a finite number, M, of types, or tastes, and refer to a worker who draws ξ_j, with $j \in [1, M]$, as a type-j worker.

Technology. Imagine that final output is an aggregate over a continuum of intermediate tasks. Formally, if $y(i)$ is the output of task i, suppose final output takes the form, $Z\left(\int_0^1 y(i)^\rho \, \mathrm{d}i\right)^{\alpha/\rho}$, where $\alpha < 1$, $\rho \in (-\infty, 0)$, and Z is plant-wide productivity. (We return in a moment to the restrictions on α and ρ.) The manager may allocate workers into a number of teams, and each team is responsible for an equal measure, μ, of tasks.[15] Assume, then, that the output of team k on any given task within its set is $n_k h_k/\mu$, where n_k is the measure of workers on the team and h_k is the time input per worker. It follows that, given

[15]Our approach here follows in the spirit of Becker and Murphy (1992), who argue that workers are more often differentiated ex post, after their assignment to tasks, than ex ante, based on their intrinsic differences.

K teams, each team is assigned a measure $\mu = 1/K$ of tasks and final output is

$$Z\left(\sum_{k=1}^{K}\left\{\int_{\frac{k-1}{K}}^{\frac{k}{K}}(n_k h_k/\mu)^{\rho}\,\mathrm{d}i\right\}\right)^{\alpha/\rho} = Z\left(\sum_{k=1}^{K}(n_k h_k)^{\rho}\right)^{\alpha/\rho},$$

where Z now subsumes the constant, $\mu^{(1-\rho)\frac{\alpha}{\rho}}$.

The assumption on ρ implies that teams are complements (though not perfectly so), in that the marginal product of a team is greater if the labor input of another team is increased. Accordingly, it is straightforward to see that the manager would like to organize workers into a single team, rather than $K > 1$ distinct units.[16] However, we make the restriction that teamwork is feasible only among workers with the same "schedules". Noting that teams are not *perfect* complements, and foreseeing that (the efficient choice of) working time will thus vary (to some degree) according to taste, the manager forms $K = M$ teams, giving a production function,[18]

$$F(\mathbf{h}, \mathbf{n}, z) = Z\left(\Sigma_{i=1}^{M}(n_i h_i)^{\rho}\right)^{\alpha/\rho}, \tag{4}$$

where $\mathbf{h} \equiv (h_1, \ldots)$ and $\mathbf{n} \equiv (n_1, \ldots)$ denote the vector of time inputs (per team) and the size of each team, respectively. The presence of $\alpha < 1$ here implies that there are decreasing returns to the plant-wide workforce, which ensures a well-posed employment demand problem (see below).

Timeline. At the beginning of a period, the firm has a workforce of measure N_{-1}. Firm productivity, Z, is realized, and workers draw ξ. In particular, we assume that a nonstochastic share $\lambda_j \in (0, 1)$ of the start-of-period workforce draws ξ_j, where $\Sigma_j \lambda_j = 1$.[19]

[16]If $\rho < 0$, then for any given vector of inputs $\{n_k, h_k\}^{17}$, a single team is preferred as long as $\Sigma_k (\eta_k)^{\rho} > (\Sigma_k \eta_k)^{\rho}$, where $\eta_k \equiv n_k h_k$. Because $y(\eta) \equiv \eta^{\rho}$ is convex to the origin (if $\rho < 0$), this inequality holds. The notion that complementarity gives an incentive for "large" teams was noted by Becker and Murphy (1992) in their study of the gains from specialization.

[18]If teams could commit to a common work schedule, it might be possible to raise output by aggregating teams of different types into a single unit. But if commitment is infeasible, the team with less of a "distaste" for work will seek to renegotiate its time input; the common-time allocation would be unstable.

[19]We thus remove any uncertainty regarding the realization of the ξs: in each period, a known share of

At that point, the firm and (some of) its workers may jointly decide to separate, with s_j the number of separations of type-j workers. The firm may also post a vacancy, which will be filled (with probability 1) at the end of the period (after production takes place). The number of new hires, v, join the firm in the next period.[20] After separations and vacancies are decided, wages and time inputs are bargained. Of course, these bargaining sessions only involve the subset of those workers retained by the firm.[21]

3.2 The intensive margin

We begin with the determination of time inputs (days worked). For our baseline specification, we assume the firm bargains with a representative of each team. For given realizations $\xi \equiv (\xi_1, \ldots)$ and conditional on a vector of workers $\mathbf{n} \equiv (n_1, \ldots)$, the time input of team j is determined by the static necessary (and sufficient) condition for an efficient allocation of time, namely $n_j \xi_j g'(h_j) = \partial f(\mathbf{h}, \mathbf{n}, Z) / \partial h_j$. This equates (left side) the marginal disutility of time worked to the n_j workers of team j to (right side) the marginal product of an increase in time worked among team members.[22] Given our functional forms, one may show that this collapses to

$$h_j = (\alpha Z)^{\frac{1}{1+\varphi-\alpha}} \cdot \left(n_j^{1-\rho} \xi_j\right)^{-\frac{1}{1+\varphi-\rho}} \cdot \Omega(\mathbf{n}, \xi), \qquad j = 1, 2, \ldots, M. \tag{5}$$

the workforce draws a known type.

[20] This delay inhiring, along with the assumption of i.i.d. draws of ξ, removes any incentive to screen new hires for their types.

[21] The seemingly high volatility of days worked was likely supported during the 1980s by an easing of restrictions on overtime. In large manufacturers, this legal shift has been credited with leading to a doubling of the overtime share of total hours during this decade (Demekas, 1994). Even in the 1990s, 25-30 percent of workers in a given year worked overtime in Italy (Giannelli and Braschi, 2002).

[22] The reader will note the absence of the marginal value of wealth here. This is justified only if utility is linear over consumption or if each worker's consumption is fully insured with respect to the idiosyncratic variation that they face in the model. Each of these assumptions is likely incorrect, of course. What recommends this paper's approach is that it allows us to focus on the fi rm-worker relationship and the joint determination of time inputs, which distinguishes this paper's model from the life-cycle labor supply literature. The drawback is that the model is unsuitable for the analysis of relatively persistent policy shifts or shocks, since these will affect the marginal value of wealth. In later work, we hope to embed this framework within a general equilibrium model.

where $\Omega(\mathbf{n},\xi) \equiv \left(\Sigma_i \left(n_i^{\varphi}/\xi_i\right)^{\frac{\rho}{1+\varphi-\rho}}\right)^{\frac{1}{\rho}\frac{\alpha-\rho}{1+\varphi-\alpha}}$.

Equation (5) provides a hint that the identification of the structural parameter, φ, might be aided by the use of firm-wide variation. The elasticity of individual time input with respect to Z identifies φ up to the deviation from constant returns: $\partial h_j/\partial Z = (\varphi+1-\alpha)^{-1}$. Thus, if one had external data on α, one could obtain a tight bound on φ based on the response of time inputs to firm-wide shifts in productivity or demand. In contrast, the response of time input to idiosyncratic variation in a worker's marginal value of time depends, in principle, on the entire joint distribution of $\mathbf{n} \equiv (n_1, \ldots)$ and $\xi \equiv (\xi_1, \ldots)$:

$$\frac{\partial \ln h_j}{\partial \ln \xi_j} = -\frac{1}{1+\varphi-\rho}\left\{1+\frac{\alpha-\rho}{1+\varphi-\alpha}\frac{\left(n_j^{\varphi}/\xi_j\right)^{\frac{\rho}{1+\varphi-\rho}}}{\Sigma_i\left(n_i^{\varphi}/\xi_i\right)^{\frac{\rho}{1+\varphi-\rho}}}\right\}.$$

Moreover, the absolute value of this elasticity is *bounded above* by $\frac{1}{1+\varphi-\alpha}$. Thus, the elasticity with respect to Z unambiguously provides an estimate of φ closer to the truth. The informativeness of firm-wide variation follows, of course, from the complementarity in production.

At this point, we ought to discuss the suitability of this model of the intensive margin for the labor market under study. One point to note, for instance, is that one third of the Italian labor force is unionized (and another 45 percent is covered by a union agreement). This raises the question as to whether time inputs are determined in the decentralized manner just described. We are not aware of any direct evidence on this, though we do note that it is typically thought that unions bargain over wages, rather than time inputs (CITE). In that case, perhaps the more relevant question is whether to assume efficient contracts, as we have done, or to impose right-to-manage bargaining. The latter assumes the manager adjusts workers' time inputs *after* wages are determined. It is not clear to us why one of these regimes is more likely in a unionized labor market. We choose to start with the efficient benchmark and will revisit right-to-manage bargaining later.

One institutional feature of the Italian labor market that is omitted here is the Cassa

Integrazione Guadagni, which subsidizes workers on temporary layoff. In one sense, though, this idea would not be hard to incorporate. For instance, in the wage bargain discussed below (see appendix specifically), we could express the worker's felicity as the sum of wages less disutility plus a subsidy that is proportional to the difference between a time endowment and the number of actual days worked. That subsidy would reflect the Cassa Integrazione and it will serve to make attachment to the firm more attractive. Hence, separations will be diminished, and the volatility of the intensive margin increased.

3.3 The extensive margin

The firm's employment demand problem may now be formulated. To make the presentation transparent, we here restrict the number of types (tastes) to two. Then period profit is defined by

$$\pi\left(\mathbf{n},Z\right) \equiv Z\left(\left(n_1 h_1\left(\mathbf{n}\right)\right)^{\rho} + \left(n_2 h_2\left(\mathbf{n}\right)\right)^{\rho}\right)^{\alpha/\rho} - n_1 h_1\left(\mathbf{n}\right) w_1\left(\mathbf{n}\right) - n_2 h_2\left(\mathbf{n}\right) w_2\left(\mathbf{n}\right).$$

This presumes the wage depends on the number of workers of each type - we return to this momentarily. The dependence of the time inputs on $\mathbf{n}$ is made apparent from (5), which, if specialized to the case where $M = 2$, becomes

$$\begin{aligned} h_1\left(\mathbf{n}\right) &= \left(\frac{\alpha Z}{\xi_1} n_1^{\alpha-1}\right)^{\frac{1}{1+\varphi-\alpha}} \Xi\left(\kappa\right) \\ h_2\left(\mathbf{n}\right) &= \left(\frac{\alpha Z}{\xi_2} n_2^{\alpha-1}\right)^{\frac{1}{1+\varphi-\alpha}} \Xi\left(\kappa^{-1}\right) \end{aligned}$$

with $\kappa \equiv \left(\frac{n_2}{n_1}\right)^{\varphi}\frac{\xi_1}{\xi_2}$ and $\Xi(\kappa) \equiv \left(1+\kappa^{\frac{\rho}{1+\varphi-\rho}}\right)^{\frac{1}{\rho}\frac{\alpha-\rho}{1+\varphi-\alpha}}$. The value of the firm may then be expressed recursively as

$$\Pi\left(N_{-1}, z\right) = \max_{s_1, s_2, v}\left\{\pi\left(\mathbf{n}, Z\right) - c^{+}v - c^{-}\left(s_1 + s_2\right) + \beta\int \Pi\left(N, Z'\right)\mathrm{d}G\left(Z'|Z\right)\right\}. \qquad (6)$$

where c^{+} is the cost of a vacancy and c^{-} is the cost of a separation. The firm solves the problem in (6) subject to

$$s_1 = \lambda N_{-1} - n_1 \geq 0$$
$$s_2 = \left(1-\lambda\right)N_{-1} - n_2 \geq 0$$
$$N = n_1 + n_2 + v, \qquad v \geq 0$$

where, to recall, λ $(1-\lambda)$ is the share of the initial workforce that draws ξ_1 (ξ_2). These expressions simply define the number of separations (and make explicit the associated non-negativity constraints) as well as the start-of-next-period level of employment. The latter is given by the sum of the two types of incumbents, $n_1 + n_2$, and the number of new hires, who join the firm next period.

The firm's employment demand is chosen with the foreknowledge of the wage bargain, to which we now turn. Our benchmark bargaining protocol is Stole and Zwiebel (1996), which was designed to study decentralized bargaining within multi-worker firms. However, Italy is often viewed as a country where collective bargaining is the main mechanism for wage determination. In reality, though, there are many sources of wage heterogeneity across workers, particularly at the smaller firms that dominate the labour market of Veneto. National regulations are typically silent about compensation levels. Trade union contracts specify non-binding minimum wages at the industry level. Although these are relevant for bargaining inside the firm, they simply represent an industry-specific floor for total compensation, and in the region of Veneto actual compensation is typically higher. Individual bargaining and firm-level agreements are also important, and wage premia are highly heterogeneous across firms (Erickson and Ichino, 1993), and higher for small firms, where individual bargaining plays a larger role (Cingano, 2003). Reacting to these considerations, we first consider Stole and Zwiebel before turning to other wage-setting games.

The details of the wage-setting problem are collected in the Appendix. Here, we just report the solution. We find that the wages of workers at a firm with labor demand summarized by the tuple ($\mathbf{n}$,N) satisfy the system of differential equations

$$(1-\upsilon)\, w_i(\mathbf{n})\, h_i(\mathbf{n}) = \upsilon\left[\frac{\partial \pi(\mathbf{n})}{\partial n_i} - \beta c^{-}\mathcal{S}(N,Z)\right] + (1-\upsilon)\left[\omega + \xi_i g\left(h_i(\mathbf{n})\right)\right], \quad i=1,\ldots,M, \tag{7}$$

where υ is the worker's bargaining power. The right side of this consists of two parts. The first is the instantaneous marginal value of a worker less than anticipated discounted cost of separation, $\beta c^{-}\mathcal{S}(N,Z)$. Here, $\mathcal{S}(N,Z)$ is the anticipated (next-period) separation probability of a worker currently with the firm. The second part gives the worker's reservation wage, which is the sum of a fixed component, ω, and the disutility of labor. The term, ω, is, in effect, the flow value of non-employment. The problem of (6) subject to (7) constitutes an Ss-like factor demand problem that may be solved by (almost) standard methods.[23] In the section, we (plan to) discuss how we estimate the structural parameters of this model.

4 Estimation

[TO BE COMPLETED]

[23]The principle complication is the presence of the anticipated separation probability. Recall that $N = n_1 + n_2 + v$, where v is the number of new hires. Hence, if the firm hires this period, N depends on the optimal choice of v, which is unknown before (6) is solved. Thus, one has to conjecture the wage, solve (6), and then confirm the conjecture. However, the solution to (7) in the special case $c^{-} = 0$ serves as a good initial guess for the wage.

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Appendices

A Wage Bargaining

Before we turn to the wage, it is helpful to review the basic structure of the optimal labor demand policy. To this end, recall that the production technology, conditional on the optimal choice of time input, is

$$\hat{F}(n_1, n_2, Z) \equiv Z\left((n_1 h_1(\mathbf{n}))^{\rho} + (n_2 h_2(\mathbf{n}))^{\rho}\right)^{\alpha/\rho}.$$

It is important to note that workers are complements here in that $\frac{\partial}{\partial n_j}\left\{\frac{\partial \hat{F}}{\partial n_i}\right\} > 0$ for $i, j \in \{1, 2\}$ with $i \neq j$. Moreover, Z is complementary to each, so $\hat{f}$ is supermodular jointly in (n_1, n_2, Z). Our strategy is to conjecture that the wage bargain is such that flow profit gross of the adjustment costs, π, is supermodular and confirm this in what follows. For now, we note that, under this conjecture, profit net of the adjustment costs may be shown to be supermodular jointly in $(\mathbf{n}, N_{-1}, Z)$. Moreover, if we make the induction hypothesis that Π is supermodular jointly in its arguments, then a standard recursive argument (which exploits the contraction property of the operator embedded in (6)) confirms that Π is indeed the unique fixed point in the space of (bounded, compact, concave, and) supermodular functions.[24]

Supermodularity implies that, if a firm has initiated separations with type-i workers, then separations with respect to that type must remain positive if the firm chooses to also discharge type-j workers. To see this point more clearly, we inspect the FOCs, conditional

[24]See Dixit (1997) for a lucid discussion of supermodularity in the context of a dynamic factor demand problem.

on positive separations,[25]

$$\begin{array}{l} s_1 > 0 : \frac{\partial}{\partial n_1}\pi\left(\mathbf{n},Z\right) + \beta \int \Pi_N\left(N,Z'\right) \mathrm{d}G\left(Z'|Z\right) = -c^- \\ s_2 > 0 : \frac{\partial}{\partial n_2}\pi\left(\mathbf{n},Z\right) + \beta \int \Pi_N\left(N,Z'\right) \mathrm{d}G\left(Z'|Z\right) = -c^- \end{array} . \tag{8}$$

By supermodularity, the left sides of the FOCs in (8) are monotone functions of z. Hence, there is a threshold ζ_1^- such that the marginal value of type-1 labor of lies below $-c^-$ for all $Z < \zeta_1^-$, given N_{-1} (and, thus, given the initial endowments of type-1 and 2 workers, λN_{-1} and $(1-\lambda) N_{-1}$). The same may be said, of course, of type-2 workers. For concreteness, suppose now that $\zeta_2^- < \zeta_1^-$.[26] It follows that, as z declines, s_1 turns positive before type-2 workers are separated. Moreover, if Z falls beneath ζ_2^-, and type-2 workers are also separated, supermodularity implies that the marginal value of type-1 workers must decline further and, thus, remain below $-c^-$.

The final aspect of employment demand relates to the decision to hire. If the firm does do so, it sets v according to the FOC,

$$v > 0 : \beta \int \Pi_N\left(N,Z'\right) \mathrm{d}G\left(Z'|Z\right) = c^+. \tag{9}$$

[25] Since new tastes are drawn in the subsequent period, the future marginal value of labor is identical across worker types. This is why the forward value in each line of (8) is identical.

[26] It is not possible, at this stage (without a solution for the wage bargain), to pinpoint the conditions under which this will hold. But we can get some insight from the marginal products of labor. We compute that, given the endowed types of labor $(n_1, n_2) = (\lambda N_{-1},\ (1-\lambda) N_{-1})$, the marginal product of type-1 workers will lie beneath that of type-2 workers if

$$\frac{n_2}{n_1} = \frac{1-\lambda}{\lambda} < \left(\frac{\xi_1}{\xi_2}\right)^{\frac{\rho}{(1-\rho)(1+\varphi)}} .$$

This says that the relative productivity of type-1 workers is mediated by two forces. On the one hand, if there are many of them, their marginal product is low. On the other hand, if they show a strong distaste for work, their time inputs will be lower, and so their marginal product will be higher. If the former outweighs the latter, type-1 workers are relatively less productive, suggesting (though only suggesting) that type-1 workers will be dismissed first. Now rearranging what we have above, we have $1 < \lambda \left\{1 + \left(\frac{\xi_1}{\xi_2}\right)^{\frac{\rho}{(1-\rho)(1+\varphi)}}\right\}$; conveniently, all variables on the right on known to the modeler, giving us a rough rule-of-thumb regarding the calibration needed to enforce $\zeta_2^- < \zeta_1^-$.

Because of the option value of work and the temporal independence of the ξs, firms should not separate from a worker unless the instantaneous marginal value of her labor ($\partial\pi/\partial n_i$) is negative. Comparing (8) and (9), it follows that, for any start-of-period value of employment N_{-1}, the value of Z at which the firm is just indifferent between hiring and "doing nothing" exceeds the maximum of the separation thresholds, ζ_1^- and ζ_2^-. We refer to this hiring threshold as ζ^+. This implies an optimal range of inaction: the firm prefers setting $N = N_{-1}$ for values of Z between $\max\left\{\zeta_1^-\left(N_{-1}\right), \zeta_2^-\left(N_{-1}\right)\right\}$ and $\zeta^+\left(N_{-1}\right)$.

We now turn to the details of the wage bargain. We assume that the firm and workers follow the Stole and Zwiebel (1996) protocol. This means that each type receives a surplus from employment equal to an exogenous fraction of the total surplus, υ. Formally, for a type-i worker,

$$\mathcal{W}_i = \upsilon\left(\mathcal{W}_i + \mathcal{J}_i\right), \tag{10}$$

where $\mathcal{W}$ is the worker's surplus and $\mathcal{J}$ is the firm's surplus. We first investigate $\mathcal{J}$.

Returning to (6), we see that the firm's surplus from employment of a worker of type i is given by

$$\mathcal{J}_i\left(\mathbf{n}, Z\right) = c^- + \frac{\partial}{\partial n_i}\pi\left(n_1, n_2, Z\right) + \beta\int \Pi_N\left(N, Z'\right) \mathrm{d}G\left(Z'|Z\right) \equiv c^- + \bar{\mathcal{J}}_i\left(\mathbf{n}, Z\right). \tag{11}$$

The presence of c^- reflects that, if a worker does separate, the firm is taxed c^-. (The cost of hiring this worker is, at this juncture, sunk, so it does not enter into the surplus.) The key to (11) evidently lies in the forward value. To that end, note that the form of the optimal labor demand policy implies that we may decompose the future value of the firm according to

$$
\begin{array}{c}
\int \Pi\left(N, Z'\right) \mathrm{d}G\left(Z'|Z\right) \\
= \begin{array}{l}
\int_0^{\zeta_2^-(N)} \Pi^{2-}\left(N, Z'\right) \mathrm{d}G\left(Z'|Z\right) + \int_{\zeta_2^-(N)}^{\zeta_1^-(N)} \Pi^{1-}\left(N, Z'\right) \mathrm{d}G\left(Z'|Z\right) \\
+ \int_{\zeta^-(N)}^{\zeta^+(N)} \Pi^{0}\left(N, Z'\right) \mathrm{d}G\left(Z'|Z\right) + \int_{\zeta^+(N)}^{\infty} \Pi^{+}\left(N, Z'\right) \mathrm{d}G\left(Z'|Z\right)
\end{array} .
\end{array}
$$

Here, we have assumed $\zeta_2(N) < \zeta_1(N)$, though none of the results rely on this precise order. The value function, Π^{2-}, refers to the value of the firm in those states of the world in which both types of workers are separated. the other value functions are defined analogously. Hence, Π^{1-} is the value of the firm in states when just one type of worker is separated; Π^0 is the value in the region of inaction; and Π^+ gives the value of the firm when it is hiring.

By continuity of the value function, differentiation of the forward value yields

$$
\begin{array}{c}
\int \Pi_N\left(N, Z'\right) \mathrm{d}G\left(Z'|Z\right) \equiv D\left(N, Z\right) \\
= \begin{array}{l}
\int^{\zeta_2^-(N)} \Pi_N^{2-}\left(N, Z'\right) \mathrm{d}G\left(Z'|Z\right) + \int_{\zeta_2^-(N)}^{\zeta_1^-(N)} \Pi_N^{1-}\left(N, Z'\right) \mathrm{d}G\left(Z'|Z\right) \\
+ \int_{\zeta^-(N)}^{\zeta^+(N)} \Pi_N^{0}\left(N, Z'\right) \mathrm{d}G\left(Z'|Z\right) + \int_{\zeta^+(N)}^{\infty} \Pi_N^{+}\left(N, Z'\right) \mathrm{d}G\left(Z'|Z\right)
\end{array} .
\end{array}
\tag{12}
$$

By the Envelope Theorem, $\Pi_N^{2-}\left(N, Z'\right) = -c^-$. In the states where $z' \in \left(\zeta_2^-(N),\ \zeta_1^-(N)\right)$, the marginal value of employment can be seen by first noting that, in these states, $n_2' = (1-\lambda) N$ but $s_1' > 0$. Now, returning to (6), forwarding one period, and differentiating with respect to N (while conditioning on $s_1' > 0$ and $s_2' = 0$) yields

$$
\Pi_N^{1-}\left(N, Z'\right) = -\lambda c^- + (1-\lambda)\left\{\delta_2 \pi\left(\mathbf{n}_1^-\left(N, Z'\right),\ Z'\right) + \beta \int \Pi_N\left(N', Z''\right) \mathrm{d}G\left(Z''|Z'\right)\right\}
$$

where δ_2 is the differentiation operator and $\mathbf{n}^{1-}\left(N, Z'\right) \equiv \left(n_1^-\left(N, Z'\right),\ (1-\lambda) N\right)$ is the choice of labor when $s_1' > 0$ and $s_2' = 0$[27] The first term here is the marginal value of worker

[27]To be precise, $n_1^-\left(N, Z'\right)$ satisfies the identity

$$
\left.\frac{\partial}{\partial n_1} \pi\left(\mathbf{n}, Z\right)\right|_{n_1 = n_1^-,\ n_2 = (1-\lambda) N} + \beta \int \Pi_N\left(n_1^-\left(N, Z'\right) + (1-\lambda) N,\ Z''\right) \mathrm{d}G\left(Z''|Z'\right) \equiv -c^-.
$$

Note that the Envelope Theorem implies that any terms in $\Pi_N^{1-}\left(N, Z'\right)$ which involve $\frac{\partial n_1}{\partial N}$ vanish, as n_1 is in the event that she is a type-1 worker next period, weighted by the probability that she draws ξ_1. The second term reflects the marginal value if the worker is type-2, in which case she is retained. Hence, $N' = n_1^- (N, Z') + (1 - \lambda) N$, and so we must account for the effect of the type-2 worker in future periods. Now recalling the definition of the surplus in (11EQU), note that we can write what we have above as

$$\Pi_N^{1-} (N, Z') = -\lambda c^- + (1 - \lambda) \bar{\mathcal{J}}_2 \left(\mathbf{n_1^-} (N, Z'), Z \right).$$

Next, if $z' > \zeta^+ (N)$, we derive the marginal value of employment in a similar fashion. Forwarding (6) one period, setting $n_1' = \lambda N$ and $n_2' = (1 - \lambda) N$ (since no separations of any type are made), and differentiating with respect to N (while conditioning on $v' > 0$) yields

$$\begin{aligned} &\Pi_N^+ (N, Z') \\ &= \lambda \delta_1 \pi \left(\mathbf{n}^{/-} (N), \ Z' \right) + (1 - \lambda) \delta_2 \pi \left(\mathbf{n}^{/-} (N), \ Z' \right) - c^+ + \beta D (N', Z'') \\ &= \lambda \delta_1 \pi \left(\mathbf{n}^{/-} (N), \ Z' \right) + (1 - \lambda) \delta_2 \pi \left(\mathbf{n}^{/-} (N), \ Z' \right) \end{aligned}$$

where the second line follows from the optimality condition (9) and $\mathbf{n}^{/-} (N) \equiv (\lambda N, \ (1 - \lambda) N)$ is the workforce in states where there are no separations. It remains to confront the marginal value of labor in the case of (complete) inaction, Π_N^0. Again setting $n_1' = \lambda_1 N$ and $n_2' = \lambda_2 N$ and differentiating with respect to N (while conditioning on $s_1 = s_2 = v = 0$),

$$\begin{aligned} &\Pi_N^0 (N, Z') \\ &= \lambda \delta_1 \pi \left(\mathbf{n}^{/-} (N), \ Z' \right) + (1 - \lambda) \delta_2 \pi \left(\mathbf{n}^{/-} (N), \ Z' \right) + \beta D (N, Z'') \ \cdot \\ &= \lambda \bar{\mathcal{J}}_1 \left(\mathbf{n}^{/-} (N), \ Z' \right) + (1 - \lambda) \bar{\mathcal{J}}_2 \left(\mathbf{n}^{/-} (N), \ Z' \right) \end{aligned}$$

The second line uses the definition the surplus in (11). Putting all of this together with (12)

evaluated at the optimum.

and substituting into (11),

$$\bar{\mathcal{J}}_i(\mathbf{n},Z) = \delta_i \pi(n_1,n_2,Z) + \beta \left\{ \begin{array}{c} -c^- \int_0^{\zeta_2^-(N)} \mathrm{d}G(Z'|Z) \\ + \int_{\zeta_2^-(N)}^{\zeta_1^-(N)} \left[-\lambda c^- + (1-\lambda)\bar{\mathcal{J}}_2\left(\mathbf{n}_1^-(N,Z'),Z\right)\right] \mathrm{d}G(Z'|Z) \\ + \int_{\zeta_1^-(N)}^{\zeta^+(N)} \left[\lambda \bar{\mathcal{J}}_1\left(\mathbf{n}^{/-}(N),\ Z'\right) + (1-\lambda)\bar{\mathcal{J}}_2\left(\mathbf{n}^{/-}(N),\ Z'\right)\right] \mathrm{d}G(Z'|Z) \\ + \int_{\zeta^+(N)}^{\infty} \left[\lambda\delta_1\pi\left(\mathbf{n}^{/-}(N),Z'\right) + (1-\lambda)\delta_2\pi\left(\mathbf{n}^{/-}(N),Z'\right)\right] \mathrm{d}G(Z'|Z) \end{array} \right\}. \tag{13}$$

We next turn to the value of work to the employee. A worker of type i derives felicity $w_i(\mathbf{n})\,h_i(\mathbf{n}) - \xi_i g(h_i(\mathbf{n}))$ from the job, where, to recall, $\xi_i g(h_j(\mathbf{n})) = \xi_i h_i(\mathbf{n})^{1+\varphi}/(1+\varphi)$ is the disutility of h_j units of time input. In the next period, the worker remains with the firm with probability 1 if $Z' > \zeta_i^-(N)$. Otherwise, separations are assumed to be conducted randomly. We let ϕ_i' represent the next period probability of separation conditional on $Z' \leq \zeta_i^-(N)$. If the worker is separated, she receives the present value of unemployment, U. The latter is assumed to be determined by the aggregate state of nature, which is held fixed (we consider a steady state). Hence, in what follows, we treat U parametrically.

We then have the value of work to an employee of type-i at a firm with a workforce $\mathbf{n}$:

$$\begin{gathered} W_i(\mathbf{n},Z) = w_i(\mathbf{n})\,h_i(\mathbf{n}) - \xi_i g(h_i(\mathbf{n})) \\ +\beta\left\{\ \lambda\mathbb{E}\left[W_1(\mathbf{n}',Z')\,|Z\right] + (1-\lambda)\,\mathbb{E}\left[W_2(\mathbf{n}',Z')\,|Z\right]\ \right\}, \end{gathered}$$

where $\mathbb{E}[W_i(\mathbf{n}',Z')]$ represents the value of employment if the worker is of type i next period. Rearranging this, one can express it in terms of the surplus from work, $\mathcal{W}_i \equiv W_i - U$:

$$\begin{gathered} \mathcal{W}_i(\mathbf{n},Z) = w_i(\mathbf{n})\,h_i(\mathbf{n}) - \xi_i g(h_i(\mathbf{n})) - (1-\beta)\,U \\ +\beta\left\{\ \lambda\mathbb{E}\left[\mathcal{W}_1(\mathbf{n}',Z')\,|Z\right] + (1-\lambda)\,\mathbb{E}\left[\mathcal{W}_2(\mathbf{n}',Z')\,|Z\right]\ \right\}, \end{gathered} \tag{14}$$

To be concrete, and in line with the analysis of the firm's problem, we suppose that $\zeta_2^- < \zeta_1^-$.

As a result, one may show that

$$\mathbb{E}\left[\mathcal{W}_i\left(\mathbf{n}',Z'\right)\right] = \begin{array}{c} \int_0^{\zeta_2^-(N)}\left(1-\phi_i'\right)\mathcal{W}_i^{2-}\left(\mathbf{n}^{2-}\left(Z'\right),Z'\right)\mathrm{d}G\left(Z'|Z\right) \\ +\int_{\zeta_2^-(N)}^{\zeta_1^-(N)}\left(1-\phi_i'\right)\mathcal{W}_i^{1-}\left(\mathbf{n}^{1-}\left(N,Z'\right),Z'\right)\mathrm{d}G\left(Z'|Z\right) \\ +\int_{\zeta_1^-(N)}^{\zeta^+(N)}\mathcal{W}_i^{0}\left(\mathbf{n}^{/-}\left(N\right),Z'\right)\mathrm{d}G\left(Z'|Z\right)+\int_{\zeta^+(N)}^{\infty}\mathcal{W}_i^{+}\left(\mathbf{n}^{/-}\left(N\right),Z'\right)\mathrm{d}G\left(Z'|Z\right) \end{array}. \tag{15}$$

Here, $\mathbf{n}_{\mathbf{2}-}\left(Z'\right)$ denotes the workforce if both types are separated; $\mathbf{n}_{\mathbf{1}-}\left(N,Z'\right)\equiv\left(n^{1-}\left(Z'\right),\ \left(1-\lambda\right)N\right)$ is the workforce if only type-1 workers are separated; and $\mathbf{n}^{/-}\left(N\right)\equiv\left(\lambda N,\ \left(1-\lambda\right)N\right)$ is the workforce in the next period if the firm does not separate. The superscripts attached to the $\mathcal{W}$s indicate the regime, with "2−" representing states of the world in which both types are separated and so on.

To simplify (15), we use the surplus-splitting rule (10) and the conditions of optimal labor demand. For instance, if the firm is hiring, it must be that

$$\begin{array}{c} \mathcal{W}_1^{+}\left(\mathbf{n}_{/-},Z'\right)=\frac{\upsilon}{1-\upsilon}\delta_1\pi\left(\mathbf{n}^{/-}\left(N\right),Z'\right) \\ \mathcal{W}_2^{+}\left(\mathbf{n}_{/-},Z'\right)=\frac{\upsilon}{1-\upsilon}\delta_2\pi\left(\mathbf{n}^{/-}\left(N\right),Z'\right) \end{array}$$

since the right side of this represents the marginal value of worker i to the firm in these states of the world. Alternatively, if the firm is separating from both types, then $\mathcal{W}_i^{2-}\left(\mathbf{n}^{2-}\left(Z'\right),Z'\right)=-\frac{\upsilon}{1-\upsilon}c^-$ for all i. Note, though, that if only type-1 workers are separated, then

$$\begin{array}{c} \mathcal{W}_1^{1-}\left(\mathbf{n}^{1-}\left(N,Z'\right),Z'\right)=-\frac{\upsilon}{1-\upsilon}c^- \\ \mathcal{W}_2^{1-}\left(\mathbf{n}^{1-}\left(N,Z'\right),Z'\right)=\frac{\upsilon}{1-\upsilon}\bar{\mathcal{J}}_2\left(\mathbf{n}_{\mathbf{1}}^{-}\left(N,Z'\right),Z\right) \end{array},$$

and $\phi_2'=0$. Lastly, if there is inaction, then

$$\mathcal{W}_i^{0}\left(\mathbf{n}^{/-}\left(N\right),Z'\right)=\frac{\upsilon}{1-\upsilon}\bar{\mathcal{J}}_i\left(\mathbf{n}^{/-}\left(N\right),\ Z'\right).$$

Putting all of this together with (15), substituting into (14) and recalling (13), the surplus-splitting rule collapses to

$$\begin{gathered}\upsilon\delta_i\pi(\mathbf{n}) = (1-\upsilon)\left[w_i(\mathbf{n})\,h_i(\mathbf{n}) - \xi_i g(h_i(\mathbf{n})) - (1-\beta)\,U\right] \\ +\beta\upsilon c^- \left\{\int_0^{\zeta_2^-(N)} \left[\lambda\phi_1' + (1-\lambda)\,\phi_2'\right] \mathrm{d}G(Z'|Z) + \int_{\zeta_2^-(N)}^{\zeta_1^-(N)} \lambda\phi_1' \mathrm{d}G(Z'|Z)\right\}\end{gathered}.$$

Now note that if $Z' < \zeta_2^-(N)$, then

$$\phi_1' = \phi_1^{2-}(N, Z') \equiv \frac{\lambda N - n_1^{2-}(Z')}{\lambda N} \quad \text{and} \quad \phi_1' = \phi_2^{2-}(N, Z') \equiv \frac{(1-\lambda)\,N - n_2^{2-}(Z')}{(1-\lambda)\,N}$$

where as if $Z' \in \left(\zeta_2^-(N), \zeta_1^-(N)\right)$, then

$$\phi_1' = \phi_1^{1-}(N, Z') \equiv \frac{\lambda N - n_1^{1-}(N, Z')}{\lambda N} \quad \text{and} \quad \phi_2' = 0.$$

Thus, we define the anticipated separation probability of a present worker as

$$\begin{gathered}\mathcal{S}(N, Z) \equiv \int_0^{\zeta_2^-(N)} \left[\lambda\phi_1^{2-}(N, Z') + (1-\lambda)\,\phi_2^{2-}(N, Z')\right] \mathrm{d}G(Z'|Z) \\ + \int_{\zeta_2^-(N)}^{\zeta_1^-(N)} \lambda\phi_1^{1-}(N, Z')\,\mathrm{d}G(Z'|Z).\end{gathered}$$

The system of differential equations which determines wages may then be written as

$$(1-\upsilon)\,w_i(\mathbf{n})\,h_i(\mathbf{n}) = \upsilon\left[\delta_i\pi(\mathbf{n}) - \beta c^- \mathcal{S}(N, Z)\right] + (1-\upsilon)\left[\omega + \xi_i g(h_i(\mathbf{n}))\right],$$

with $\omega \equiv (1-\beta)\,U$.

B Our dataset

Our empirical work utilises Veneto Worker History (VWH) dataset,[28] which includes virtually all private-sector workers of the Italian region of Veneto[29] for years 1982-2001.[30] The VWH dataset includes register-based information on all firms and employees that have been hired by those firms for at least one day during the period of observation. Most crucially, for each worker the VWH reports the number of days paid in each year. The entire employment history in the period 1982-2001 has been reconstructed for each employee.[31] The full sample contains around 3.6 million workers and 46 million observations at the worker by year level over 20 years. The region of Veneto, in the North East of Italy, is the third Italian region by GDP and has a population of around 5 million people, around 8 percent of the country's total.

The goal of our paper is to investigate the role of firm-level coordination on labor supply dynamics. Italy is often viewed as a country where collective bargaining is the main mechanism for wage determination, and where flexibility in the labor market is very limited. In reality however, and especially for small firms, which dominate the labor market of Veneto, there are many sources of wage heterogeneity across workers. National regulations are typically silent about compensation levels. Trade union contracts specify non-binding minimum wages at the industry level. Although these are relevant for bargaining inside the firm, they only represent an industry-specific floor for total compensation, and in Veneto compensation are almost always higher, as discussed in Bartolucci and Devicienti (2012),

[28]This panel dataset has been constructed by a team led by Prof. Giuseppe Tattara of the University of Venice, using the Social Security administrative data of the *Istituto Nazionale per la Previdenza Sociale* (INPS).

[29]State and local government employees, farm workers and some category of professionals, such as doctors, lawyers, notaries and journalists, are not included because they have alternative social security funds. Additional information on the dataset available in Card et al. (2010) and in Tattara and Valentini (2010)

[30]The period covered by the dataset is 1976-2001, but because coding errors concerning wages have been found for the period 1976-1981, we will only use the 20-year period between 1982 and 2001. The VWH dataset has not been updated for the years after 2001.

[31]Considering the occupational spells out of the region of Veneto as well for individual regressors.

who find for the same population that almost all employees earn a wage premium, and that the median wage premium is 24 percent. Individual bargaining is very important: wage variability within firms is around two thirds of overall wage variability in Italy (Lazear and Shaw, 2008). Wage premia are also highly heterogeneous across firms (Erickson and Ichino, 1994), and higher for small firms (Cingano, 2003).

Our main variable of interest, is days worked by worker. While a growing number of matched employer employees panel datasets have become available to researchers in the last decade or so, it is still typically not the case that one has any individual level information on labor supply. In order to be able to understand more about coordination among workers inside firms as well as understanding the dynamics of individual labor supply decision, one would ideally like to observe hours worked for each individual day fr each worker. Our dataset does not include information of such detail. What we do observe is the number of days paid for each worker in each job (worker-firm pair), as well as a variable reporting for each month whether a certain worker is employed at a certain firm. The number of days paid will not exactly equal the number of days worked since holidays will not be controlled for, but it is as good a measure of individual labor supply as one can get in administrative datasets that include all workers of each firm.[32] Using the full dataset, we see that 25 percent of all observations report 312 days, i.e. full time full year. We consider this evidence of a high variation of days paid suggesting the usefulness of that measure.[33] This is probably driven by full time no-fixed term contract, which are not very flexible. Days paid are self reported by the employer but the employer need to pay taxes and contributions for those days, and so will not be able to alter the actual days paid without incurring the risk of a legal procedure.

The VWH dataset is is composed of a worker archive, a job archive and a firm archive.

[32]For simplicity but somehow imprecisely we will refer to this as 'days worked' as opposed to 'days paid'.

[33]Regressing days paid on weeks paid, we find an R squared of 0.44. This suggests that the days worked are not derived from weeks worked.

We merge the three datasets together using firm and worker identifiers, which are both present in the job archive. The researchers of the University of Venice that have constructed the dataset have created a version of the firm identifier that attempts to identify firms as economic entities, employing standard procedure to try to eliminate spurious births and deaths using mobility of workers. Using the information we have on days worked in each job, we construct experience and tenure measures for each worker, which we use in some of the regressions discussed below.[34] We also construct dummies for white collar workers, temporary, seasonal, fixed term and part time workers using information on the type of contracts they are under. We eliminate observations for firms that have not been founded in the region of Veneto, which we need to use as proxy for the location of the job, to eliminate observations for firms for which we cannot observe all workers.

From the contract qualification variable, we construct a variable for fixed term employees, to be able to separate permanent employees from fixed term employees, since they face a very different environment in terms of the degree of flexibility of labor supply both at the intensive and extensive margin. Our dummy variable shows that across all years observations of fixed term contracts represent 10.75 percent of the total, part time on the other hand are 6.95 of total observations, concentrated in the latter part of our panel.

Keeping one observation for each firm in each year we can investigate the distribution of firm size in the data. On average firms have 27 employees; 25 percent of firms have up to four employees, the median firm has 11 employees and the firm at the 75th percentile has 24 employees.

[34]For our experience measure, we use workers that we see from the beginning of their careers and match them to workers that are of the same gender and skill class to construct an experience measure for workers that we do not see from the beginning of their careers.

C Worker Mobility in our Data

Table 1: Number of firms workers are employed in

Number of firms	Frequency	Percent	Cumulative
1	1,621,477	54.57	54.57
2	635,646	21.39	75.96
3	345,561	11.63	87.59
4	186,413	6.27	93.86
5	95,145	3.20	97.07
6	46,496	1.56	98.63
7	21,833	0.73	99.37
8	10,270	0.35	99.71
9	4,660	0.16	99.87
10	2,171	0.07	99.94
11	1,007	0.03	99.98
12	434	0.01	99.99
13	184	0.01	100.00
14	61	0.00	100.00
15	41	0.00	100.00
16	13	0.00	100.00
17	4	0.00	100.00
18	2	0.00	100.00
19	1	0.00	100.00
Total	2,971,419	100.00	

Source: Authors' calculations from VWH dataset.

Unique worker-firm combinations: 5,748,923

Table 2: Number of movers

	Frequency	Percent	Cumulative
Stayers	1,621,477	54.57	54.57
Movers	1,349,942	45.43	100.00
Total	2,971,419	100.00	

Source: Authors' calculations from VWH dataset.

Unique worker-firm combinations: 5,748,923

Table 3: Number of observations per person

Observations per person	**Frequency**	**Percent**	**Cumulative**
1	515,843	17.36	17.36
2	330,210	11.11	28.47
3	232,806	7.83	36.31
4	190,118	6.40	42.71
5	170,168	5.73	48.43
6	162,377	5.46	53.90
7	132,085	4.45	58.34
8	120,510	4.06	62.40
9	102,873	3.46	65.86
10	102,834	3.46	69.32
11	101,079	3.40	72.72
12	94,265	3.17	75.90
13	98,221	3.31	79.20
14	80,155	2.70	81.90
15	84,299	2.84	84.74
16	71,461	2.40	87.14
17	77,978	2.62	89.76
18	53,053	1.79	91.55
19	55,535	1.87	93.42
20	195,549	6.58	100.00
Total	2,971,419	100.00	

Source: Authors' calculations from VWH dataset.
Unique worker-firm combinations: 5,748,923

Table 4: Number of movers per firm

Movers per firm	**Frequency**	**Percent**	**Cumulative**
0	4	0.01	0.01
1- 5	5,814	8.20	8.21
6- 10	4,126	5.82	14.03
11- 20	6,173	8.71	22.74
21- 30	4,746	6.70	29.44
31- 50	7,432	10.49	39.93
51- 100	12,161	17.16	57.09
More than 100	30,413	42.91	100.00
Total	70,869 100.00		

Source: Authors' calculations from VWH dataset.
Unique worker-firm combinations: 5,748,923

D Additional Regression Tables

Table 5: The determinants of days worked - Introducing individual fixed effects

Dependent variable: log of days worked per month				
	(1)	(2)	(3)	(4)
Log of daily wage	-0.212***	-0.209***	-0.279***	-0.272***
	(0.000207)	(0.000200)	(0.000196)	(0.000198)
Log days worked at the firm level		0.505***	0.401***	0.405***
		(0.000421)	(0.000405)	(0.000404)
Log tenure in the firm			0.0868***	0.103***
			(0.0000586)	(0.0000696)
Log of firm employment level			0.00915***	0.00912***
			(0.0000674)	(0.0000671)
Constant	4.116***	2.527***	2.576***	2.384***
	(0.000966)	(0.00162)	(0.00155)	(0.00167)
Year Fixed Effects	No	No	No	Yes
Individual Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	No	No	No	No
N	22591225	22591225	22591225	22591225
R^2	0.512	0.545	0.592	0.597

Standard errors in parentheses

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 6: The determinants of days worked - Introducing firm fixed effects

Dependent variable: log of days worked per month				
	(1)	(2)	(3)	(4)
Log of daily wage	-0.0739***	-0.0689***	-0.143***	-0.141***
	(0.000175)	(0.000171)	(0.000159)	(0.000158)
Log days worked at the firm level		0.536***	0.403***	0.418***
		(0.000531)	(0.000486)	(0.000483)
Log tenure in the firm			0.113***	0.123***
			(0.0000515)	(0.0000538)
Log of firm employment level			0.0176***	0.0110***
			(0.000151)	(0.000151)
Constant	3.474***	1.776***	1.722***	1.590***
	(0.000818)	(0.00186)	(0.00183)	(0.00187)
Year Fixed Effects	No	No	No	Yes
Individual Fixed Effects	No	No	No	No
Firm Fixed Effects	Yes	Yes	Yes	Yes
N	22591225	22591225	22591225	22591225
R^2	0.172	0.207	0.348	0.358

Standard errors in parentheses

$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$