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Dynamics of productivity and cost of labor in Italian Manufacturing firms*

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Abstract

This paper studies the impact of size on labor cost and productivity for Italian manufacturing firms. The distributions of both labor cost and productivity display a wide support, even when disaggregated by sector of industrial activity. Further, both labor cost and productivity, when considered alone, are growing with the size of the firm. We investigate this relationship on a new set of data and we are able to show that once accounted for productivity differences among firms, size still retains a positive effect on cost of labor in most of the sectors considered.

JEL codes: D21, J31, L11, L60

Keywords: Size-wage effect; Labor productivity.

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1 Introduction

The size-wage relation is known to hold for most countries and to be persistent over time. In this work we investigate if this relation still holds once productivity differences among firms are taken into account. The issue of the existence of a positive size-wage effect, while of general interest for industrial and labor economics, is particularly relevant for the Italian case due to the existence of a small size bias that characterizes the distribution of Italian firms as compared to those of other developed countries. In this work, we employ both non-parametric and parametric methods to show that, net of productivity effect, labor cost is, on average, increasing with the size of the firm.[1]

The evidence of a positive relation between employer size - measured as number of plants, employees or sales - and wages has been reported by a number of different scholars starting as early as Moore (1911). This regularity, though persistent over time and well documented for several countries (Davis and Haltiwanger, 1991; Main and Reilly, 1993; Brunello and Colussi, 1998; Arai, 2003; Lallemand et al., 2005), both at firm and establishment level, is not completely understood. In particular, the wage differential, while to some extent associated with observed differences in human capital, does not appear to be completely accounted for by them. In this respect Brown and Medoff (1989) find that among the various explanations attempting to account for the size-wage effect, the one receiving larger empirical support is the difference in workers' quality[2] among size classes. The difference in quality however only accounts for roughly *one-half* of observed mean wage differentials. Hence, the search for an explanation to the observed size-wage gap has stimulated research in different directions. For instance, scholars have also considered the relevance of corporate tournaments and compensation structure in determining wage differentials in small versus big enterprises (see, among the others, Zàbojnìk and Bernhardt, 2001; Hu, 2003). Based on these results, scholars of the field acknowledge that the analysis as such leaves the researcher uncomfortably unable to account for the part of the differential which is not explained by observable indicators of labor quality. Hence, they conclude that "the employer size-wage effect remains a fact in need of an empirically based theory (Brown and Medoff, 1989, p. 1057)." Idson and Oi (1999) using more recent U.S. Census data still report a significant size-wage relation and they also find that output elasticity is bigger than wage elasticity to size variation. Also building on this result, they advance the hypothesis that "employees at larger firms are more productive and hence command higher wages in a competitive labor market".

Similar findings about the existence of "a large, significant, and unexplained premium paid to workers of large employers" are reported by some works that rely on matched employer-employee data (see for instance Troske, 1999; Belfield and Wei, 2004; Muravyev, 2009).

Yet another stream of literature has tried to explain the size-wage effect by focusing on the hierarchical structure of organizations and how that might affect the total cost of labor in business firms. Such hypothesis is also known as the "hierarchical theory of the firm", (see among the others, Simon 1957; Williamson 1967 and more recently Rajan and Zingales 2001), and according to it the value and compensation for ability increases with the rank of a management position, and larger firms have proportionately more organizational layers than smaller firms (Meagher and Wilson, 2004).

Recent availability of firm level data has made the empirical investigation of this hypothesis possible. Findings in Delmastro (2002) and Meagher and Wilson (2004) support such conjecture. However, their results are based on sectoral surveys, thus only on a relatively small

[1] In this respect the present paper provides some complementary features to other works on Italian data, see for instance (Bottazzi et al., 2002, 2007). We refer the interested reader to those works for an investigation of the properties of the size distributions of firms, their growth processes and productivity dynamics.

[2] Typical proxies of workers' quality are education, years of experience, and the like.

NACE sector	Tot	1989 20-49	50-99	100-249	250+	Tot	2004 20-49	50-99	100-249	250+
151 - Production, process & preserv. of meat	293	22.1	14.1	24.9	38.9	407	17.5	14.4	20.6	47.5
177 - Knitted and crocheted articles	450	32.9	22.6	21.6	22.9	251	16.4	20.4	22.8	40.4
182 - Wearing apparel	1357	26.0	18.8	22.1	33.1	1360	17.3	21.9	25.4	35.3
193 - Footwear	753	35.6	23.3	24.5	16.5	869	22.4	27.2	27.8	22.5
212 - Articles of paper and paperboard	334	22.2	19.7	27.3	30.8	548	18.8	18.6	26.2	36.2
222 - Printing	521	30.4	18.5	18.3	32.8	755	24.5	22.7	25.6	26.9
252 - Plastic products	831	28.6	25.2	25.6	20.6	1569	22.8	23.9	32.7	20.4
266 - Concrete, plaster and cement	388	31.9	25.3	23.6	19.2	573	26.4	27.4	27.5	18.7
281 - Structural metal products	562	39.9	25.9	20.8	13.4	1145	34.6	29.0	27.4	8.7
285 - Treatment and coating of metals	608	51.6	28.0	18.1	2.4	1772	34.6	32.6	27.3	5.5
295 - Other special purpose machinery	853	19.2	18.8	25.7	36.3	1185	19.3	23.4	24.0	33.2
361 - Furniture	1047	39.2	25.2	22.5	13.1	1434	19.3	26.3	27.5	26.7

Table 1: Total number of firms per sector and employment share (percentages) per size class measured in terms of number of employees. Selected 3 digit sectors in the Manufacturing, 1989 and 2004.

sample of firms.[3]

While following a similar spirit, in this paper we take a different empirical approach: we employ the census of Italian firms with more than 20 employees to investigate the existence and the pervasiveness of the size-wage effect in the Italian manufacturing industry. In order to avoid the potentially dangerous comparison of firms operating in different markets and facing very different cost structures, we perform our analysis at a disaggregated level, investigating the relation between the size of the firm, its cost of labor, and its workforce composition at three and four-digit sectoral level. In this respect the present work also contributes to the investigation of inter-industry wage differentials (see for instance Thaler, 1989). Due to space constraint, we can only present detailed results for an exemplar selection of sectors, appropriately chosen among the ones having the largest number of firms in order to roughly cover the different types of economic activities. These results confirm the existence of a significant and positive relation between the size of the firm and its unitary cost of labor.

After a detailed presentation of the database in Section 2, Section 3 tackles the relation between the cost of labor bore by a firm, its productivity and its size one at a time. Then in Section 4 we propose a multivariate framework which allows to account for the residual effect of size when contemporaneously conditioning on labor productivity. Section 5 concludes.

2 Data description

The database employed for the analyses, Micro.3, has been built through to the collaboration between the Italian statistical office, ISTAT, and a group of LEM researchers from the Scuola Superiore Sant'Anna, Pisa.[4] The database covers the period 1989-2004 and represents a development of the former Micro.1 dataset, which was based on the census of all the Italian firms with more than 20 employees conducted by ISTAT over the period 1989-1997. Micro.3 embodies Micro.1, and extends it for seven years, by combining census data with information appearing in firms' financial statement. After performing this link, Micro.3 contains information about 134625 Italian firms.

In the following, we are going to focus our empirical analysis only on firms in the man-

[3]The hierarchical hypothesis is investigated using Italian data in Bottazzi and Grazzi (2010).

[4]The database has been made available for work after careful censorship of individual information. More detailed information concerning the development of the database Micro.3 are in Grazzi et al. (2009).

ufacturing industry which, according to the NACE classification, are those belonging to the tabulation category D, that is, firms having their principal activity in sectors ranging from 15 to 37 (UNSD, 2002). After this selection we are left with a total of 97 three-digit sectors. Given this relative large number, we cannot present a complete sector by sector study. Even if one considers the sectors with more companies, i.e. the ones with an average number of firms larger than 100, their number remains higher than 20. Moreover considering only the sectoral size as a selection variable would ultimately introduce biases in the adopted sample, with the possible lack of relevant activities. In order to avoid this effect, in the following analysis we will consider a representative collection of sectors, chosen among the most populous but built with the idea of possibly accounting for the variegated activities covered by the manufacturing classification.

The first column of every year in Table 1 reports the number of observations available in the sectors under investigation in 1989 and 2004. Notice that, as explained above, the possibility to combine census data to administrative sources resulted in a higher number of observations after 1997. The other columns of Table 1 report a first descriptive statistics, employment share per size class, that is purported at representing the existing differences, and their persistency, between industrial sectors. Consider for instance the sector of production and process of meat (151); there a high proportion of employment is concentrated in the biggest firms (more than 250 employees) and such tendency persists always in the most recent years, when observations from a higher number of firms are available. On the contrary, in the sector of treatment and coating of metals (285) the highest proportion of employment is channeled through smaller firms. The intersectoral differences are in general persistent over time, with a relative tendency to observe higher employment share in bigger firms in more recent years. Quite obviously sectoral differences will affect the analysis of the relation between size of the firm and its labor cost and productivity.

For the analyses that follow, we need a proxy for size, labor cost and productivity of the firm. We choose the number of employees as our proxy for firm size. Then, since our main focus here is on the productive efficiency of Italian Manufacturing sector, a natural proxy is to consider the bulk of expenditures related to workforce by every firm. This includes *a)* salary paid to employees (comprising wage, overtime pay and bonus); *b)* social security contribution paid by the employer (*oneri sociali*); *c)* retirement pay (*Trattamento Fine Rapporto*). We take the ratio between value added and number of employees as our proxy of (labor) productivity. If reliable data on capital stock and cost of capital use were available one could have estimated Total Factor Productivity (TFP) as a proxy for firm-level productivity. Unfortunately, such data were not available to us. This should not result, however, in a large bias in regression coefficients. Let us explain how this is possible. *First*, the possibility to perform the same analysis at four-digit (Section 4.1) allows us to confirm the findings at the three-digit level of disaggregation. In this respect, investigating the size-wage relation at a higher level of disaggregation lowers the risk of comparing firms that employ a different technology, as characterized for instance by different capital intensities, or different quality in the composition of the workforce. *Second*, other works (see for instance Foster et al., 2001) have recently shown on comparable firm level data that labor and multifactor productivity are closely correlated, in this respect also refer to analysis in Haltiwanger et al. (1999). *Third*, in conclusion it could be that bigger firms are indeed characterized by a higher capital intensity. Plausibly, this will translate in higher labor productivity and also in higher cost of labor (more skilled employees are required when larger/newer machines have to be operated). The question however remains of whether and to what extent, in the Italian manufacturing sector, the increase in the latter exceeds the increase in the former. This is precisely the point of our paper.

In the analyses that follow monetary variables are at constant prices, base year is 2000, and have been deflated employing the sectoral index of production price provided by ISTAT.[5]

[5]Istat, the Italian statistical office provides many time series of the Italian economy online at:

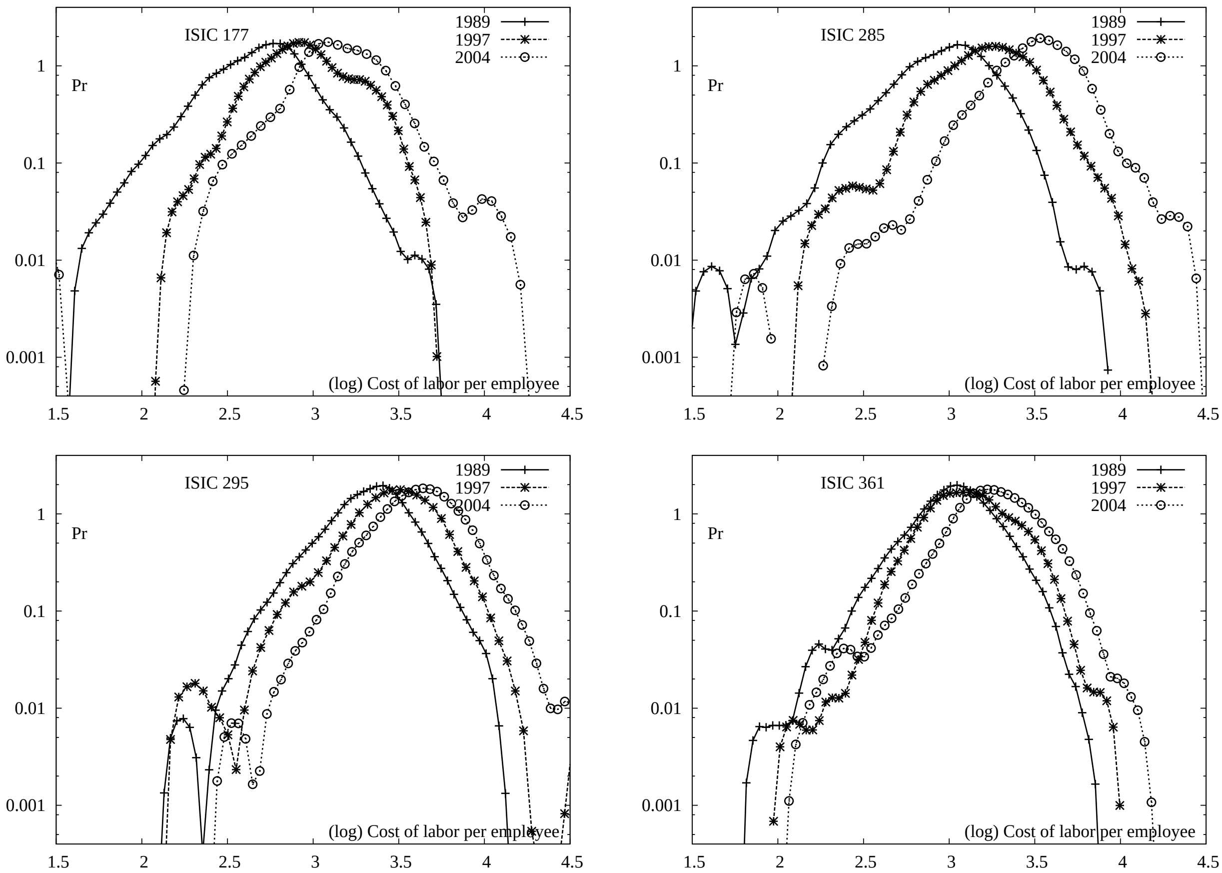

Figure 1: Kernel density estimate of (log) cost of labor per worker in crocheted articles, NACE 177; coating of metals, NACE 285; special purpose machinery, NACE 295 and manufacture of furniture, NACE 361. Data are deflated.

Finally, to ease the interpretation of results, we also report all variables in thousands of Euro, even though, at the beginning of the period of observation, these reports were filled in Lira currency.[6]

3 Univariate analysis: size-wage and size-output elasticities

Before analyzing the size-wage relationship it is instructive to look at the shape of the distributions of cost of labor as this variable will be at the core of our analysis. Whether there exists a large literature on size and productivity differences among firms (a comprehensive survey is that in Bartelsman and Doms, 2000, for Italy refer to Bottazzi et al., 2007, 2005) there is much less evidence documenting differences in the cost of labor of firms. In this respect, we begin by showing the degree of heterogeneity in the cost of labor for firms belonging to the same three-digit sector. Figure 1 displays the kernel density estimate of labor cost in four different industries, the knitting and crocheted articles (NACE 177), treatment and coating of metals (NACE 285), special purpose machinery (NACE 295) and Furniture (361). Density is computed in 64 equispaced points with an Epanenchnikov kernel and the bandwidth is set according to the 'optimal routine' described in Section 3.4 of (Silverman, 1986). Also notice

http://con.istat.it/default.asp

[6]At the beginning of the period, the Italian currency with legal tender status was the Italian Lira whose exchange rate with the Euro was later fixed at 1 € per 1936.27 Lira.

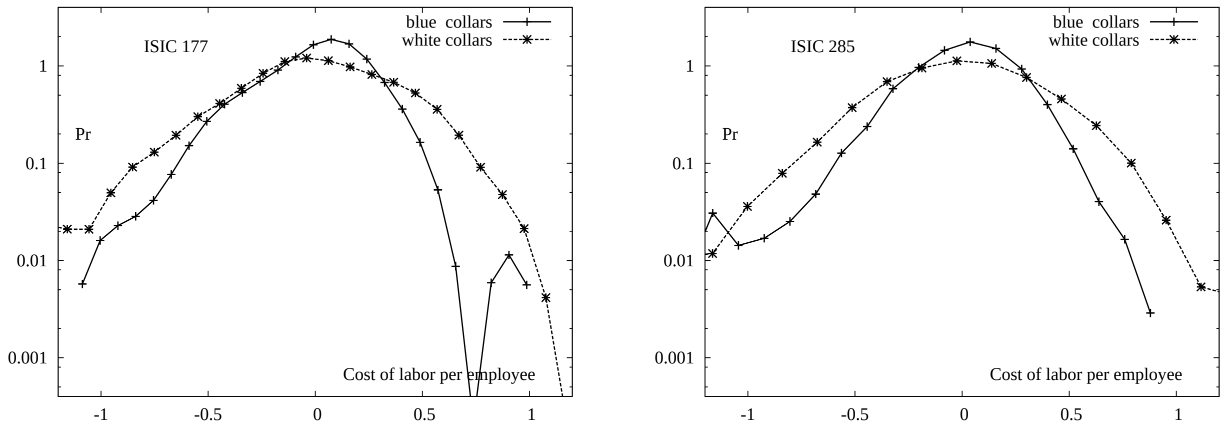

Figure 2: Kernel density estimate of (log) cost of labor per worker for blue and white collars in 1993, in deviation from the mean.

that probability, on the y-axis, is on a log scale to enhance the representation of the tails of the distribution. For the same reason, cost of labor per employee, on the x-axis, is in logarithm so that it is possible to plot in the same graph firms with very different levels of cost of labor. Note that even if observations are deflated with production price index, the distributions display a noticeable shift to the right as we get to more recent years, suggesting an increase in the cost of labor in real terms. Figure 1 displays the remarkable coexistence of firms within the same sectors that are facing conspicuous differences in their cost of labor, with most spending firms facing an average labor cost which is seven time larger then the one of less spending firms. The sectors reported in Figure 1 are exemplary as the distributions display the same features in all other industries under analysis. Note also that there is no evidence of a shrinking of the support of the distribution over time, which suggests that the observed differences are persistent (more on this in Dosi et al., 2012). Further, the span of the support cannot even be exclusively attributed to the contemporaneous presence of different categories of workers. By way of an example, in Figure 2 we display, in deviation from the mean, the distribution of the firm average cost of labor per category of employment, blue collars and white collars.[7] As can be seen, the huge differences in labor cost persist within the same category and the width of the original distribution cannot be exclusively ascribed to differences in workforce composition (on this issue, also refer to Bottazzi and Grazzi, 2010).

In order to investigate the source of this heterogeneity we start by analyzing the relation between total cost of labor, W, and size of the firm as proxied by number of employees, L. If the cost of labor does not depend on the size of the firm, the labor total expenditure, W, grows proportionally with the number of employees, L. Consider the following scaling relation

$$W \sim L^{1+\beta} \ . \tag{1}$$

If $\beta > 0$ then larger firms incur, in general, in increased labor costs, while if $\beta < 0$ the opposite happens. In order to capture these effects we fit a log-linear relation between the labor cost per employee $C = W/L$ and the number of employees, L, with the model

$$c_i(t) = \alpha + \beta l_i(t) + \epsilon_i(t) \ , \tag{2}$$

where subscript t identifies the year of interest and lowercase symbols denote the logarithm of

[7] Unfortunately, we cannot replicate this evidence for the latest years of the sample as in that period labor costs by employment categories is available only for firms with more than 100 employees, a rather small proportion of the sample. On the other hand, there is no reason to believe that the shape and, more importantly, the width of the two distributions significantly changed in more recent years.

NACE SECTOR	1989 α (stderr)	1989 β (stderr)	1989 R^2 Obs	2004 α (stderr)	2004 β (stderr)	2004 R^2 Obs
151 - Production, processing of meat	**2.811**	**0.081**	0.964	**3.160**	**0.062**	0.963
	(0.004)	(0.001)	293	(0.006)	(0.002)	360
177 - Knitted, crocheted articles	**2.229**	**0.125**	0.957	**2.844**	**0.071**	0.956
	(0.005)	(0.001)	450	(0.009)	(0.002)	181
182 - Wearing apparel, accessories	**1.962**	**0.174**	0.955	**2.546**	**0.130**	0.945
	(0.002)	(0.001)	1357	(0.005)	(0.001)	798
193 - Footwear	**2.162**	**0.145**	0.960	**2.707**	**0.103**	0.961
	(0.005)	(0.001)	753	(0.008)	(0.002)	487
212 - Articles of paper, paperboard	**2.640**	**0.122**	0.967	**2.967**	**0.117**	0.963
	(0.005)	(0.001)	334	(0.005)	(0.001)	437
222 - Printing, related services	**2.794**	**0.150**	0.973	**3.128**	**0.088**	0.969
	(0.005)	(0.001)	521	(0.004)	(0.001)	493
252 - Plastic products	**2.652**	**0.120**	0.969	**3.039**	**0.100**	0.975
	(0.003)	(0.001)	831	(0.002)	(0.001)	1129.00
266 - Concrete, plaster, cement	**2.839**	**0.085**	0.954	**3.071**	**0.077**	0.959
	(0.007)	(0.002)	388	(0.008)	(0.002)	447
281 - Metal products	**2.531**	**0.143**	0.964	**3.150**	**0.058**	0.962
	(0.004)	(0.001)	562	(0.007)	(0.002)	619
285 - Treatment & coating of metals	**2.490**	**0.137**	0.958	**3.519**	0	0.968
	(0.007)	(0.002)	608	(0.004)	(0.001)	849
295 - Special purpose machinery	**2.968**	**0.092**	0.968	**3.408**	**0.054**	0.965
	(0.003)	(0.001)	853	(0.003)	(0.001)	884
361 - Furniture	**2.446**	**0.146**	0.962	**3.014**	**0.052**	0.963
	(0.004)	(0.001)	1047	(0.004)	(0.001)	921

Table 2: Relation between size (as number of employees) and labor cost per employee in 1989 and 2004. LAD estimates and bootstrapped standard errors in brackets. Constant price log variables; coefficients significant at the 0.05 level are in bold. See also Fig. 3, left panel.

the original variables, that is $c = \log C$ and $l = \log L$.[8]

Figure 3 exhibits binned scatter plots of c vs l for the same sectors analyzed in the previous figures, namely knitting and crocheted articles (NACE 177) and treatment and coating of metals (NACE 285) together with the estimated relation. Table 2 reports coefficients for all sectors in the analysis. Since the residuals of OLS estimation display a Laplacian shape, the use of least absolute deviation (LAD) as a robust estimation technique (Huber, 1981) appears particularly suited. In general, a positive relation appears between labor cost per employee and size. Due to the small magnitude of standard errors, the relation is significant in almost all sectors considered.[9] As such, this evidence suggests that labor cost per employee is increasing more than proportionally with size. Moreover, we also notice that the positive relation between size and wage is persistent over time, as the estimated coefficients are positive and significant both in 1989 and in 2004. In this respect we observe a tendency towards a relative reduction of the β coefficient between the beginning and the end of the period. It would be of course much interesting to verify if this trend has continued up to a point in which the relation is not anymore significant. Notice that eq. 2 is the same as that used in Idson and Oi (1999) in which the authors also find evidence of a positive relation. Even if they do not run separate regressions for each industry as we do, the magnitude of the relation that they found is very close to ours.

[8]In this work we employ linear or log-linear functional forms for regressions. In principle, this is not an innocuous assumption, and need to be tested. We have done so in previous works on similar data and such assumption is supported by empirical evidence, refer to Bottazzi et al. (2005); Bottazzi and Grazzi (2010); Bottazzi et al. (2010).

[9]In this and in the following regression standard errors are obtained through bootstrap using 200 independent replications.

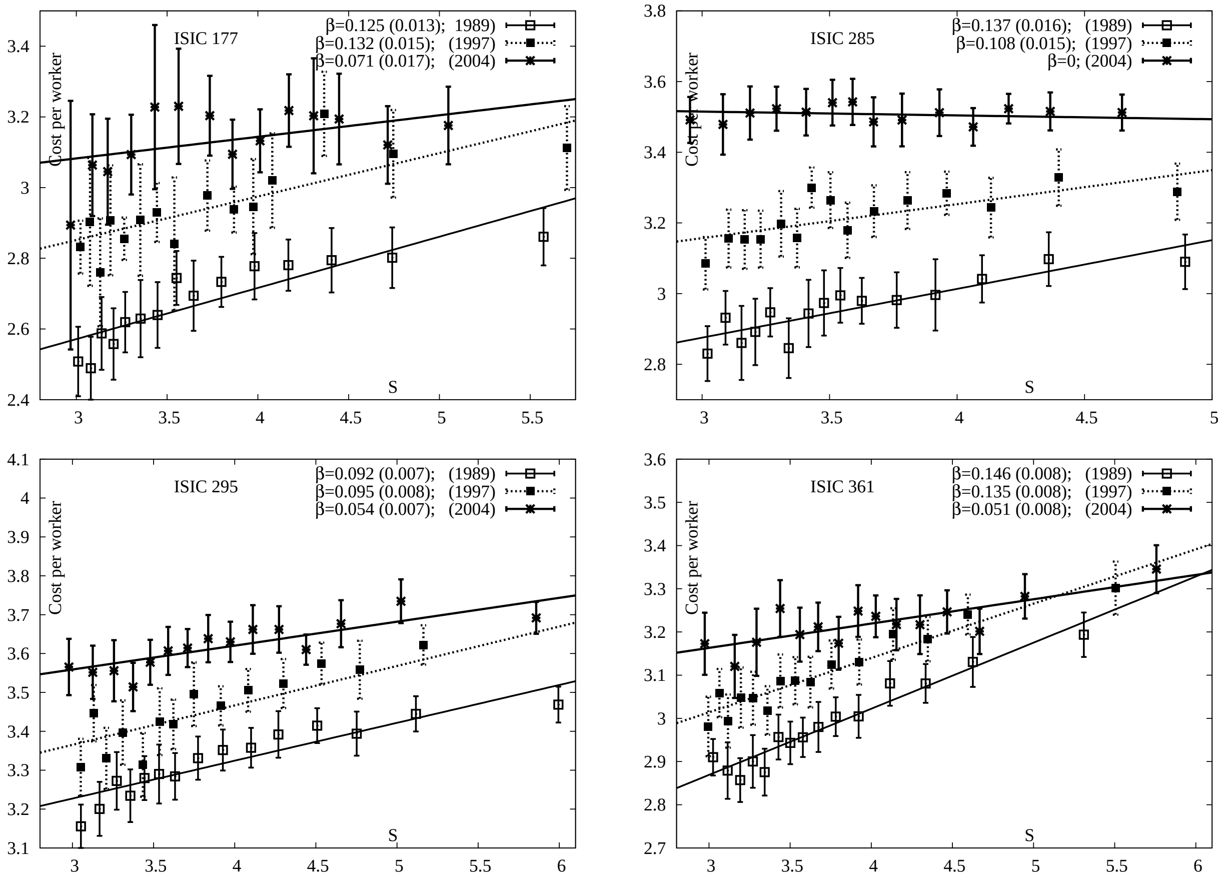

Figure 3: Relation between size (as number of employees) and cost of labor in 1989 and 2004. Variables are in logs and deflated.

While the slope of the fitted lines has only marginally diminished from 1989 to 2004, the intercepts display an outward shift. This is also apparent in the plots of Fig. 3. Since the monetary variables in the analysis are already inflation-adjusted, such a shift is proportional to the sectoral average increase in the cost of labor in real terms. The assessment of such a trend, which goes beyond the scope of the present work, might shed some light on the sources of Italian often claimed competitiveness loss in recent years (Malgarini and Piga, 2006; Dosi et al., 2012).

The last column for each year of Table 2 reports the number of observations and the value of the coefficient of determination R^2 (McKean and Sievers, 1987) defined as

$$R^2 = \frac{\hat{L}}{\hat{L} + s_{95}(N - K - 1)} \tag{3}$$

where $\hat{L}$ is the estimated (minimal) log-likelihood of the model, N is the number of observations, K the number of estimated parameters and s_{95} the 95% confidence interval of the median of the distribution of residuals. The latter is computed using the distribution free range of variation described in Hollander and Wolfe (1999) (see McKean and Schrader (1984) for a discussion about the efficiency of this method). We also computed the confidence level with which the hypothesis of no relationship (in this case β=0) can be rejected. This level is obtained by comparing s_{95} with the asymptotic distribution of the ratio between the likelihood gain of the fully specified model and the model with only the constant. Since the null hypothesis was always rejected with confidence higher than 1% - in this and in all the following regressions - in the interest of space we decided not to report such statistics, which is however available upon request.

NACE SECTOR	1989 α (stderr)	1989 δ (stderr)	1989 R^2 Obs	2004 α (stderr)	2004 δ (stderr)	2004 R^2 Obs
151 - Production, processing of meat	**3.244**	**0.086**	0.939	**4.010**	**-0.033**	0.937
	(0.009)	(0.002)	292	(0.014)	(0.004)	356
177 - Knitted, crocheted articles	**2.315**	**0.180**	0.939	**3.221**	**0.060**	0.924
	(0.009)	(0.002)	449	(0.019)	(0.004)	177
182 - Wearing apparel, accessories	**2.050**	**0.203**	0.934	**3.019**	**0.088**	0.901
	(0.004)	(0.001)	1351	(0.009)	(0.002)	780
193 - Footwear	**2.454**	**0.133**	0.932	**2.987**	**0.110**	0.931
	(0.008)	(0.002)	753	(0.012)	(0.003)	480
212 - Articles of paper, paperboard	**3.162**	**0.110**	0.951	**3.349**	**0.130**	0.937
	(0.009)	(0.002)	334	(0.007)	(0.002)	432
222 - Printing, related services	**3.336**	**0.112**	0.960	**3.371**	**0.108**	0.951
	(0.009)	(0.002)	521	(0.005)	(0.001)	493
252 - Plastic products	**3.220**	**0.095**	0.942	**3.608**	**0.058**	0.957
	(0.006)	(0.001)	829	(0.005)	(0.001)	1119
266 - Concrete, plaster, cement	**3.375**	**0.068**	0.942	**3.776**	**0.024**	0.936
	(0.010)	(0.003)	388	(0.011)	(0.003)	445
281 - Metal products	**3.183**	**0.069**	0.949	**3.375**	**0.082**	0.946
	(0.009)	(0.003)	560	(0.009)	(0.002)	614
285 - Treatment & coating of metals	**3.172**	**0.065**	0.937	**4.012**	**0.962**	0.950
	(0.009)	(0.002)	607	(0.005)	(0.001)	849
295 - Special purpose machinery	**3.478**	**0.060**	0.952	**3.766**	**0.032**	0.948
	(0.005)	(0.001)	852	(0.006)	(0.001)	878
361 - Furniture	**2.733**	**0.167**	0.951	**3.294**	**0.063**	0.949
	(0.005)	(0.001)	1044	(0.006)	(0.001)	913

Table 3: Relation between size (as number of employees) and labor productivity in 1989 and 2004. LAD estimates and bootstrapped standard errors in brackets. Constant price log variables; coefficients significant at the 0.05 level are in bold. See also Fig. 4, left panel.

The width of the support for cost of labor in Figure 1 already informed us about the broad differences existing within three-digit sectors. Then, the estimates of the β coefficients from equation 2 already provides a first account of such intra-industry heterogeneity. In particular, notice that, for instance in the knitted and crocheted sector (NACE 177) in 1997 (top left plot of Figure 3) firms of smallest size benefit of a labor cost per employee, in per capita terms, which is roughly one third smaller than the one of largest firms. This "spread" in the cost of labor might appear modest at first, but one has to bear in mind that most employment contracts in Italy are set according to nation-wide agreements in the various industrial sectors. If one considers the plausible flattening effect of these regulations on the pay of employees, then such wage spreads are substantial. On the other hand, the fact that firms face rather different wage rates is well in tune with the evidence reported in Bottazzi et al. (2005) and Bottazzi et al. (2007) on the heterogeneity in the mix of inputs and in the level of labor productivity (on the persistency over time of such phenomena see also Dosi and Grazzi 2006). This result contributes to lend empirical support to a picture of pervasive and persistent heterogeneities characterizing business firms. At the same time, however, this implies that a careful investigation on the sources of the remarkable differences in labor cost at the sectoral level and of the size-wage relation has to encompass an analogous analysis of firms' productivity. Indeed, it could be the case that such a variability in the cost of labor finds its counterpart and it is entirely explained by correspondingly different levels in the productivity of firms (in this respect see also Idson and Oi 1999; Oi and Idson 1999 and for more recent empirical evidence on UK, Faggio et al. 2007).

To investigate possible productivity differentials, we analyze the relation between the total value added produced by a firm, VA, and the number of its employees, L. If the productivity of labor does not depend on the size of the firms, we expect to find a proportional relation between these two variables. We try to capture possible deviations from the proportionality

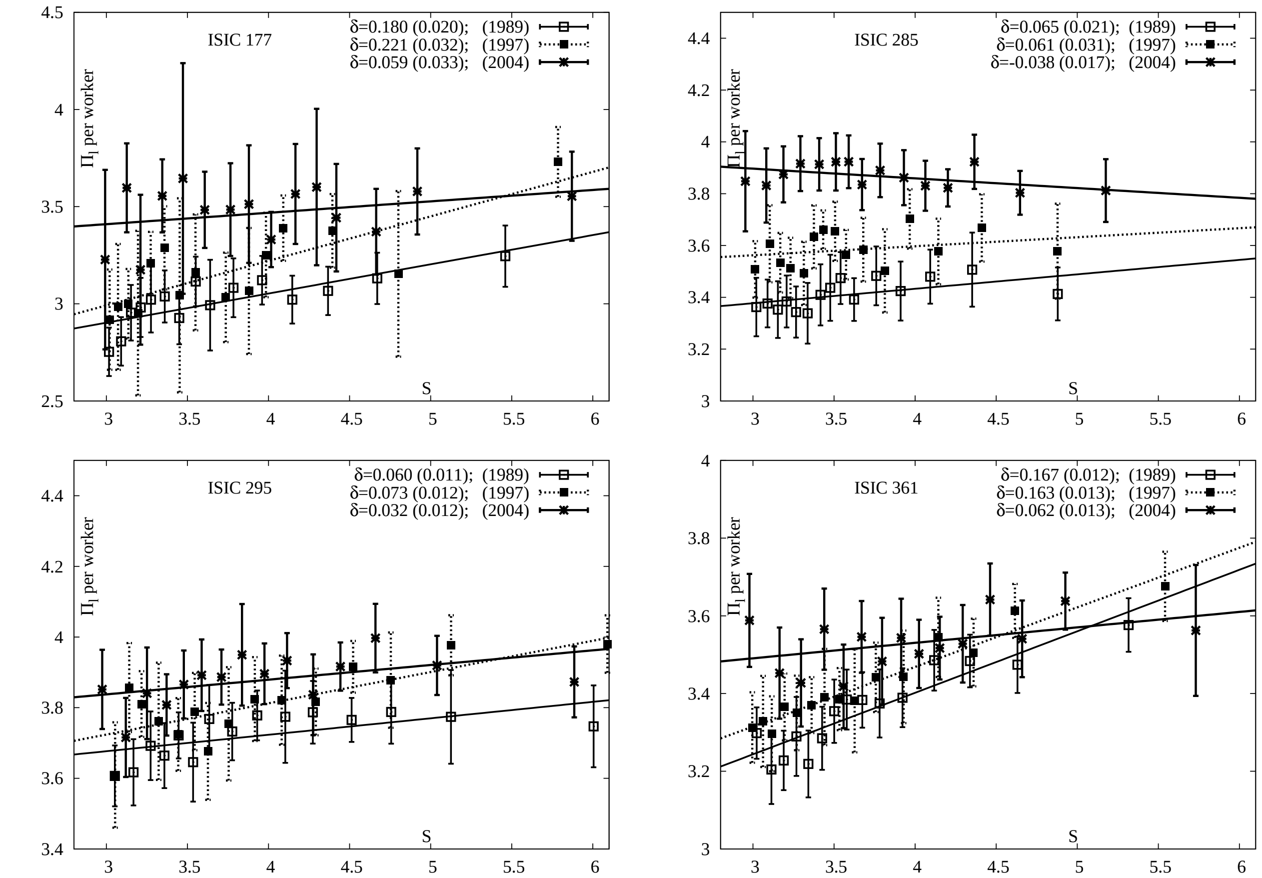

Figure 4: Relation between size (as number of employees) and labor productivity, Π_l, as value added per worker for years 1989 and 2004. Variables are in logs and deflated.

assumption by fitting a double log relation between labor productivity, $\Pi = VA/L$, and the number of employees, L

$$\pi_i(t) = \alpha + \delta l_i(t) + \epsilon_i(t) \ , \tag{4}$$

where $\pi = \log \Pi$. If $\delta = 0$, then the amount of value added produced per worker does not depend on the size of the firm. As shown by plots in Fig. 4, this is not the case, and labor productivity does indeed depend on firm size through an increasing relation. The statistical significance of coefficients in Table 3 supports the hypothesis that bigger firms enjoy higher levels of labor productivity. As for the elasticity of wage to size, we notice that δ, although positive and significant from the beginning to the end of the sample period, displays a relative decrease over time.

While we were able to find a positive relationship between the size of the firm and both its labor productivity, captured by coefficients δ in Table 3, and the cost of labor per worker, captured by coefficients β in Table 2, the separate inspection of these coefficients does not allow to discern if one of the two effects is overwhelming the other. That is, one cannot ascertain if the positive relation between size and productivity is sufficient to compensate a similar trend in the cost of labor, as it was the case in Idson and Oi (1999). There a simple comparison of the coefficients revealed a higher elasticity for labor productivity than for labor cost. In our case, it is then necessary to build a measure that provides a succinct picture of the relation between cost of labor and productivity at different levels of firm size. The simplest approach is to consider as a proxy for unit labor cost the ratio between total labor cost and value added (see also Kravis and Lipsey, 1982), $UC = W/VA$. Given the very likely occurrence of value added that are positive and bigger than labor cost, most of the times unit labor cost takes values in the interval $(0, 1]$ (and its logarithm in $(-\infty, 0]$). Quite obviously, a value of the ratio

NACE SECTOR	1989 α (stderr)	γ (stderr)	R^2 Obs	2004 α (stderr)	γ (stderr)	R^2 Obs
151 - Production, processing of meat	**-0.583**	**0.030**	0.449	**-0.877**	**0.104**	0.443
	(0.070)	(0.002)	292	(0.006)	(0.001)	356
177 - Knitted, crocheted articles	**-0.224**	**-0.023**	0.310	**-0.173**	**-0.040**	0.407
	(0.059)	(0.002)	449	(0.008)	(0.002)	177
182 - Wearing apparel, accessories	**-0.227**	-0.001	0.276	**-0.374**	**0.018**	0.262
	(0.029)	(0.001)	1351	(0.005)	(0.001)	780
193 - Footwear	**-0.239**	**-0.004**	0.394	**-0.376**	**0.020**	0.306
	(0.037)	(0.001)	753	(0.007)	(0.002)	480
212 - Articles of paper, paperboard	**-0.522**	**0.012**	0.522	**-0.390**	**-0.011**	0.403
	(0.056)	(0.002)	334	(0.006)	(0.002)	432
222 - Printing, related services	**-0.526**	**0.038**	0.446	**-0.308**	**-0.003**	0.412
	(0.046)	(0.001)	521	(0.004)	(0.001)	493
252 - Plastic products	**-0.644**	**0.043**	0.451	**-0.533**	**0.033**	0.475
	(0.042)	(0.001)	829	(0.003)	(0.001)	1119
266 - Concrete, plaster, cement	**-0.589**	**0.032**	0.542	**-0.567**	**0.025**	0.422
	(0.062)	(0.001)	388	(0.009)	(0.002)	445
281 - Metal products	**-0.569**	**0.056**	0.409	**-0.277**	**-0.007**	0.457
	(0.046)	(0.001)	560	(0.003)	(0.001)	614
285 - Treatment & coating of metals	**-0.742**	**0.090**	0.510	**-0.462**	**0.035**	0.401
	(0.054)	(0.002)	607	(0.006)	(0.002)	849
295 - Special purpose machinery	**-0.526**	**0.038**	0.411	**0.318**	**0.013**	0.357
	(0.036)	(0.001)	852	(0.003)	(0.001)	878
361 - Furniture	**-0.352**	-0.001	0.510	**-0.222**	**-0.023**	0.403
	(0.034)	(0.001)	1044	(0.003)	(0.001)	913

Table 4: Relation between size (as number of employees) and unit labor cost in 1989 and 2004. LAD estimates and bootstrapped standard errors in brackets. Constant price log variables; coefficients significant at the 0.05 level are in bold.

close to zero (one) suggests a very low (high) incidence of labor cost on value added, so that, unit labor cost also provides a first account of distributive shares.

We investigate the relation between unit labor cost, as defined above, and firm size, fitting the log linear model

$$\frac{c_i(t)}{\pi_i(t)} = \alpha + \gamma l_i(t) + \varepsilon_i(t) \ . \tag{5}$$

Coefficients for all sectors are reported in Table 4. It does not appear that a clear relation exists between the variables of interest. Indeed, the estimated slopes for γ do not display an unambiguous pattern across sectors. Coefficients of the three-digit sectors for γ are both positive and negative, also changing sign over time. Overall, there is a relative higher proportion of positive coefficients, suggesting that at first, bigger firms have to bear, on average, a higher unit cost of labor, but this univariate approach is clearly weak in detecting this kind of relation. In order to identify robust relations one has to switch to more structured specifications.

4 A multivariate parametric approach

In the previous paragraph we showed that the size of the activity affects both cost of labor and productivity. However, it is not possible to understand if any of the two effects is dominating by means of univariate analysis. To this purpose, we consider a multivariate linear framework in which the impact of size on the cost of labor can be measured controlling, at the same time, for labor productivity. We express cost of labor per worker as depending on labor productivity and size,

$$\ln(\frac{W_i}{L_i}) = \alpha_1 + \alpha_2 \ln(\frac{VA_i}{L_i}) + \alpha_3 \ln(L_i) + \varepsilon_i, \tag{6}$$

NACE SECTOR	1989 α_1 (stderr)	α_2 (stderr)	α_3 (stderr)	R^2 Obs	2004 α_1 (stderr)	α_2 (stderr)	α_3 (stderr)	R^2 Obs
151 - Production, processing of meat	**1.752**	**0.320**	**0.059**	0.933	**1.815**	**0.339**	**0.067**	0.941
	(0.012)	(0.003)	(0.001)	292	(0.013)	(0.004)	(0.001)	356
177 - Knitted, crocheted articles	**1.199**	**0.399**	**0.073**	0.928	**1.702**	**0.365**	**0.040**	0.938
	(0.006)	(0.002)	(0.001)	449	(0.012)	(0.002)	(0.001)	177
182 - Wearing apparel, accessories	**0.795**	**0.531**	**0.076**	0.933	**1.337**	**0.425**	**0.069**	0.931
	(0.003)	(0.001)	(0.001)	1351	(0.007)	(0.002)	(0.001)	780
193 - Footwear	**0.711**	**0.609**	**0.048**	0.929	**1.542**	**0.405**	**0.043**	0.932
	(0.007)	(0.003)	(0.001)	753	(0.008)	(0.002)	(0.001)	480
212 - Articles of paper, paperboard	**1.401**	**0.394**	**0.080**	0.943	**1.913**	**0.318**	**0.074**	0.953
	(0.011)	(0.003)	(0.001)	334	(0.009)	(0.002)	(0.001)	432
222 - Printing, related services	**1.140**	**0.496**	**0.099**	0.939	**1.682**	**0.426**	**0.042**	0.955
	(0.010)	(0.003)	(0.001)	521	(0.009)	(0.002)	(0.001)	493
252 - Plastic products	**1.219**	**0.428**	**0.091**	0.946	**1.978**	**0.298**	**0.078**	0.936
	(0.006)	(0.001)	(0.001)	829	(0.008)	(0.002)	(0.001)	1119
266 - Concrete, plaster, cement	**1.408**	**0.421**	**0.060**	0.939	**1.843**	**0.328**	**0.063**	0.931
	(0.010)	(0.002)	(0.001)	388	(0.010)	(0.002)	(0.001)	445
281 - Metal products	**0.816**	**0.546**	**0.099**	0.931	**1.186**	**0.543**	**0.046**	0.960
	(0.008)	(0.002)	(0.001)	560	(0.009)	(0.003)	(0.001)	614
285 - Treatment & coating of metals	**0.761**	**0.520**	**0.122**	0.926	**1.811**	**0.421**	**0.021**	0.937
	(0.010)	(0.003)	(0.001)	607	(0.010)	(0.002)	(0.001)	849
295 - Special purpose machinery	**1.861**	**0.313**	**0.076**	0.939	**2.103**	**0.362**	**0.029**	0.931
	(0.010)	(0.003)	(0.001)	852	(0.011)	(0.003)	(0.001)	878
361 - Furniture	**1.189**	**0.446**	**0.079**	0.950	**1.749**	**0.374**	**0.037**	0.946
	(0.006)	(0.002)	(0.001)	1044	(0.007)	(0.002)	(0.001)	913

Table 5: Estimates of the size-wage effect controlling for labor productivity in 1989 and 2004. LAD estimates for equation 7 and bootstrapped standard errors in brackets. Constant price log variables; coefficients significant at the 0.05 level are in bold.

where α_2 and α_3 capture the effect of productivity and size of the firm, respectively. The previous specification, with L on both sides of the equation, implies that errors in labor input measures will automatically create biases in the estimated coefficients. For this reason we choose the following alternative specification

$$\ln(W_i) = \alpha_1 + \alpha_2 \ln(VA_i) + \phi \ln(L_i) + \varepsilon_i \ , \tag{7}$$

where $\phi = (\alpha_3 - \alpha_2 + 1)$.

Given our interest in the residual effect of size on cost of labor, α_3, we first estimate ϕ from equation 7 and then compute α_3 as a difference.

Table 5, as for the previous regressions, reports estimated (LAD) coefficients for 1989 and 2004. The coefficient α_2 which accounts for the effect of total value added on total labor cost has the expected positive sign. On average, an increase in value added per worker bears a corresponding higher cost of labor for the firm. More interesting to the purpose of our analysis is the role of α_3, the coefficient accounting for the residual impact of firm size on cost of labor. This coefficient is positive and significant for all sectors. We can conclude that a size-wage relation appears even when controlling for productivity differences among firms. Notice that our model contains log on both dependent and independent variables, so that the reported coefficients should be interpreted as elasticities. For instance, in sector 151 (production and process of meat) a difference of 20% in labor productivity between firms of the same size is associated to a difference in labor cost of about 7%. If the labor cost is the same, but sizes differ by 20%, the difference in wages is around 1%. This seems a tiny number, but considering that firm size spans several order of magnitude, it could still generate important effects. A firm with 1000 employees faces, on average, a cost of labor which is 14% larger than the one faced by a firm of 100 employees and with the same productivity level. Moreover notice that the estimates reported in Table 5 are relatively stable over time, so that there is no evidence that

NACE sector	1989 Tot	20-49	50-99	100-249	250+	2004 Tot	20-49	50-99	100-249	250+
1513 - Production of meat, poultrymeat products	100	16.6	15.8	35.3	32.3	211	27.2	20.0	29.4	23.4
1772 - Knitted, crocheted pullovers, cardigans	117	24.8	31.6	24.4	19.2	160	33.5	24.7	21.5	20.3
1822 - Manufacture of other outerwear	307	10.7	13.9	25.0	50.4	864	27.9	18.5	19.9	33.4
1930 - Manufacture of footwear	332	24.9	23.4	29.6	22.0	868	40.1	22.6	20.2	16.9
2121 - Household, sanitary goods, toilet requisites	109	20.6	23.9	25.3	30.3	251	24.1	17.2	28.2	30.0
2222 - Printing n.e.c	213	18.8	15.5	18.4	47.3	515	33.5	20.6	19.3	26.5
2524 - Manufacture of other plastic products	310	34.4	28.3	27.5	9.7	877	38.9	25.9	24.3	10.4
2663 - Manufacture of ready-mixed concrete	59	45.3	26.2	28.4	0.0	175	42.4	23.4	9.8	24.4
2812 - Builders carpentry and joinery of metal	50	55.6	32.2	12.2	0.0	236	55.0	21.6	19.2	4.2
2852 - General mechanical engineering	268	54.0	25.4	18.1	2.5	1283	57.3	24.2	15.1	2.8
2954 - Machinery for textile, apparel, leather prod.	133	19.4	27.5	28.7	24.4	226	28.2	23.5	20.1	28.2
3611 - Manufacture of chairs and seats	99	33.3	21.1	31.9	13.7	365	30.0	19.1	13.1	37.4

Table 6: Total number of firms per sector and employment share (percentages) per size class measured in terms of number of employees. Selected 4 digit sectors in the Manufacturing, 1989 and 2004

this residual size-wage effect is vanishing over time.

In the multivariate specification of equations 6 and 7 we do not control for different production inputs, as, for instance, different capital productivities, and we are not making any statement on some generic measures of productivity, i.e. TFP, or on the relation between such proxy of productivity and size. This investigation would indeed lay well beyond the scope of this work.[10] Thus it is still possible that the increased cost of labor at larger firms is somehow compensated by a lower cost of capital - or other inputs of production - and higher capital intensities, as for instance reported in Idson and Oi (1999). In any case, however, this effect, even if present, does not translate into an increase of value added per worker large enough to account for the increased cost of labor. As such our point remains valid.

Notice also that, although we do not condition here on employee characteristics, such as education, experience and the like, we do control for the relation between productivity and labor cost, that is exactly the assumed economic outcome ultimately resulting from the cumulative effect of the heterogeneous skills in the workforce. As such, the evidence emerging from Table 5 has to be interpreted as supportive of the hypothesis of a relative advantage of smaller firms over bigger ones in terms of the average cost of labor. These findings appear promising for a better understanding of the causes of constraints to growth of business firms especially when jointly addressed with the troubles hindering firm growth and stemming from the limited access to the credit market of many SME firms (in this respect see also Bottazzi et al., 2011).

4.1 Analyses on four-digit sectors

The analyses above documents the existence of a size-wage effect for Italian firms in three-digit sectors. In this respect an obvious concern is that these sectors might be composed of firms that are not involved in the same production activity. If this were the case, differences in productivity levels among firms would not point to "real" differences in technical efficiencies, but they would be the result of a rather approximate comparison of firms that are not producing the same products. In order to account for such a possibility, we replicate the analyses previously performed at three on a selection of four-digit industrial sectors. To this purpose we pick, for every three-digit sector employed, the nested four-digit industry with the largest number of observations. This is the first work presenting results at the four-digit level of sectoral

[10] For these and other issues, see Bottazzi et al. (2005).

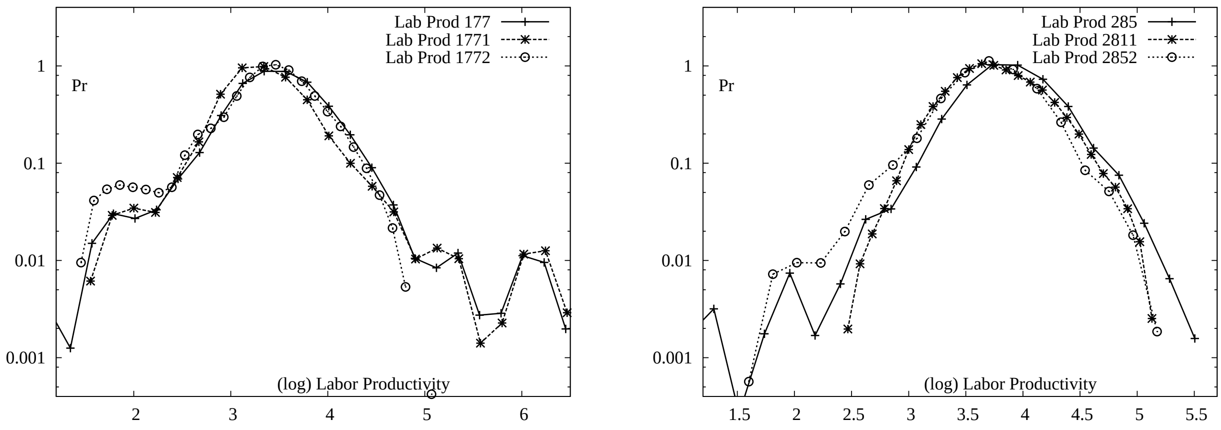

Figure 5: Distribution of labor productivity for 3 digit and two nested 4 digit industries, year 2004.

disaggregation for Italy. Table 6 reports the NACE code, the name of the sectors, the total number of observations in 1989 and 2004, and the size distributions of firms in those two years. Comparison with Table 1, reporting the same statistics for three-digit sectors, shows that the number of observations is significantly smaller once that we pick the nested four-digit sector with the biggest number of observations. Also the size distribution of firms is affected. Take for instance the sector of Production of meat and poultrymeat products (NACE 1513). In this industry there are only 100 (211) firms in 1989 (2004) and there is a much smaller share of large firms (250 employees or more) than in the corresponding three-digit sector.

The distributional effect of disaggregation is much less significant when the production efficiency is concerned. Plots in Figure 5 display the distribution of labor productivity for a three-digit sector and two nested four-digit industries in 2004. Remarkably, the support of the distribution does not shrink much when going from three to four-digit of industrial classification. As discussed in Dosi and Grazzi (2006), this is a general phenomenon, which suggest that the observed heterogeneity is rather an intrinsic property of industries, no matter of what is the chosen level of disaggregation. To say with Griliches and Mairesse (1999): "There is a sense in which different bakeries are just as much different from each others as the steel industry is from the machinery industry."

We replicate regressions of equations 2, 4 and 5 on the selection of four-digit sectors, and since they do not display relevant differences with the previous evidence at at the three-digit, we do not include those tables, which are however available upon request.

The estimation of equation 7 is more crucial for the point we make in this work about the size-wage relation, hence we report results at the four-digit level in Table 7. Notice that both the sign and the magnitude of all coefficients (α_1, α_2, α_3) is much similar to those in Table 5. In particular, α_3, the coefficient accounting for the residual impact of firm size on cost of labor, is positive and significant for all sectors, with the only exception of Manufacture of builders carpentry and joinery of metal (NACE 2812). As a result, also at a higher level of sectoral disaggregation it is possible to confirm the finding of a positive relation between the size of the firm, as proxied by the number of employees, and cost of labor per employee. Such relation is robust also when controlling for productivity differences among firms.

5 Conclusions

In this paper we have shown the existence of a size-wage effect for Italian manufacturing firms (cf. Figure 3 and Table 5). This is a robust regularity as it holds both over time - almost two decades - and across all sectors of analysis. As such our results contribute both to the size-

NACE SECTOR	1989				2004			
	α_1 (stderr)	α_2 (stderr)	α_3 (stderr)	R^2 Obs	α_1 (stderr)	α_2 (stderr)	α_3 (stderr)	R^2 Obs
1513 - Meat & poultrymeat prod	**1.837**	**0.307**	**0.058**	0.968	**1.970**	**0.264**	**0.104**	0.953
	(0.015)	(0.005)	(0.002)	100	(0.019)	(0.005)	(0.001)	208
1772 - Knitted & crocheted pullovers	**1.398**	**0.308**	**0.097**	0.937	**1.598**	**0.377**	**0.057**	0.934
	(0.012)	(0.002)	(0.002)	117	(0.016)	(0.004)	(0.002)	154
1822 - Manufacture of other outerwear	**1.085**	**0.393**	**0.103**	0.946	**1.039**	**0.525**	**0.058**	0.923
	(0.005)	(0.002)	(0.001)	307	(0.004)	(0.002)	(0.001)	849
1930 - Footwear	**1.039**	**0.502**	**0.047**	0.938	**1.405**	**0.429**	**0.053**	0.946
	(0.009)	(0.004)	(0.001)	332	(0.005)	(0.002)	(0.001)	846
2122 - Household, sanitary goods, etc	**0.950**	**0.477**	**0.113**	0.958	**1.759**	**0.320**	**0.106**	0.965
	(0.015)	(0.004)	(0.002)	109	(0.011)	(0.003)	(0.001)	250
2222 - Printing n.e.c	**1.265**	**0.462**	**0.095**	0.951	**1.681**	**0.401**	**0.061**	0.939
	(0.015)	(0.004)	(0.001)	213	(0.009)	(0.003)	(0.001)	515
2524 - Manuf. of other plastic prod	**1.162**	**0.436**	**0.093**	0.937	**1.760**	**0.344**	**0.081**	0.946
	(0.013)	(0.004)	(0.001)	309	(0.005)	(0.002)	(0.001)	868
2663 - Ready-mixed concrete	**1.025**	**0.528**	**0.046**	0.938	**1.831**	**0.352**	**0.052**	0.954
	(0.032)	(0.007)	(0.004)	59	(0.014)	(0.004)	(0.002)	174
2812 - Builders carpentry, metal joinery	**-0.091**	**0.636**	**0.262**	0.960	**1.084**	**0.598**	0.001	0.947
	(0.035)	(0.008)	(0.005)	50	(0.021)	(0.007)	(0.002)	234
2852 - General mechanical engineering	**0.922**	**0.476**	**0.121**	0.942	**1.177**	**0.570**	**0.038**	0.949
	(0.013)	(0.004)	(0.001)	268	(0.008)	(0.002)	(0.001)	1283
2954 - Machinery for textile, apparel	**2.092**	**0.219**	**0.093**	0.938	**2.176**	**0.304**	**0.057**	0.939
	(0.022)	(0.005)	(0.002)	133	(0.019)	(0.005)	(0.002)	221
3611 - Manufacture of chairs and seats	**1.555**	**0.328**	**0.087**	0.947	**1.293**	**0.445**	**0.078**	0.940
	(0.029)	(0.011)	(0.003)	99	(0.009)	(0.003)	(0.001)	361

Table 7: Estimates of the size-wage effect controlling for labor productivity in 1989 and 2004 in selected 4 digit sectors. LAD estimates and bootstrapped standard errors in brackets. Constant price log variables; coefficients significant at the 0.05 level are in bold.

wage literature (Brown and Medoff, 1989; Idson and Oi, 1999) and also to the investigation of inter-industry wage differentials (Thaler, 1989). Further and probably also more relevant for the understanding of the size-wage effect, we show that such relation still exists once we explicitly account for the different levels of labor productivity that characterize firms operating at different scales. That is, the size-wage effect does not vanish when controlling for different productivities among firms. Also it does not appear that such relation is fading away, as the estimated coefficients are pretty stable over time.

Overall, our results are supportive of the size-wage "puzzle" as found also in other empirical works, as for instance in Brown and Medoff (1989); Troske (1999); Belfield and Wei (2004). In particular, we are able to test for this relation without having to resort to proxies capturing the capabilities and skills of workers, but directly including labor productivity in our analysis. This, we believe, further strengthen our findings which hold both at three and four-digit level of sectoral disaggregation.

Finally, the empirical evidence we provide in the paper is coherent with the theoretical explanation put forward by Idson and Oi (1999) according to whom employees at larger firms are more productive and hence command higher wages in a competitive labor market. In this respect, we are able to show that, at least for Italy, controlling for different levels of labor productivity does not completely extinguish the size-wage effect. The higher cost of employment in larger companies is not fully explained by the increased efficiency in the use of labor.

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