Which firms work at night?
New evidence on the causes of shift work from the Italian metalworking sector*

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Abstract:

Shift work is one of the most common working time schedules in manufacturing firms and it is one of the first margins they use to adjust their production to changes in the demand.
However, so far few empirical work, often based on aggregated data, has been done on this topic, also for the lack of appropriate data sets at the establishment level.
Using micro data on a representative sample of Italian metalworking firms in 1995, in this paper I study which factors can influence the choice of using shift work, the percentage of shift workers in the workforce and the total number of shifts regularly used by firms.
My findings suggest that the incidence of shift work is influenced by factors related to both labor and product market. Among them, as predicted by economic theory, capital intensity and firm's size have a positive effect on the use of shift work.
Confirming the results of previous macroeconomic studies, I also found some evidence on a positive relation between the use of shift work and firms' economic conditions.
Furthermore, additional factors (such as the composition of the workforce by gender, the use of other working time schedules or particular production strategies) seem to influence the probability of working at night through the introduction of a third shift.

Key words: shift work, working time, labor demand, metalworking sector

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1. Introduction

The use of shift work has been traditionally considered, along with overtime, one of the ways in which firms can adjust to fluctuations in demand and use their capital stock more efficiently.

In the United States, at the beginning of the Nineties more than 30% of the total workforce usually worked on shift, even if evening and night work were less common than during the Seventies (Hamermesh, 1996 and 1999b).

In Italy, shift work still represents one of the most common forms of "functional" flexibility adopted by firms: according to recent estimates (Istat, 1999) in 1995-1996 47.8% of workers in firms with at least 10 employees usually worked on shifts, while almost 6% did that occasionally. In the same period, one firm out of five used some kind of shift or night work.

Even if the use of shift work is so widespread, little attention has been paid to the economic analysis of this phenomenon, both in terms of the causes determining its adoption and its effects on firms' performance.

In particular, due to the lack of appropriate data sets, empirical studies on the demand side are rare and often based on aggregated data.

The aim of this paper is to fill partly this gap, trying to shed more light on the factors determining the incidence of shift work using a representative sample of Italian metalworking firms in 1995.

In the next section, a simple economic model explaining why firms might use shift work is presented, while previous empirical work is discussed in section 3. In section 4 I shall present the main results of the empirical analysis, paying particular attention to specific features of the data set used (4.1), some selected descriptive statistics on the incidence of shift work (4.2), the specification and estimation of the empirical model (respectively, 4.3 and 4.4). A few concluding remarks are then outlined in section 5.

2. A theoretical framework

According to the theory of the firm, the choice to use more than one shift is essentially related, at least in the long run, to the problem of capital utilization[1]. For simplicity, consider a firm whose production process requires the simultaneous use of labor and capital, both employed according to different combinations of workday length and level

[1] The following theoretical model is based on Stafford (1980), Bosworth et al., (1980) and Mayshar and Halevy (1997).

of effort. Assume also that the firm decides both the length of the workday and the relative compensation of each factor and there exists a sort of compensating differential between these two elements[2]. If all workers have similar preferences, firms needing longer working days for reasons of capital utilization should offer higher wages to compensate people for the disutility of working more than their desired level of hours. Let's define as w(H) all the possible hourly wage–working hours combinations that the firm can offer. This function is generally U shaped[3] and its minimum level depends on both the substitution elasticity between effort and goods and the existence of search costs in presence of heterogeneous workers[4].

With respect to capital, let's define a similar cost function, r(H), which represents the hourly rental function for capital: if capital depreciation and obsolescence is independent of the number of working hours, the firm is interested only in the monetary return per 24-hour a day and will therefore incur in higher costs if capital is used less than that length of time[5]. This locus is then downward sloping and is truncated at 24 hours per day (i.e., in correspondence of the point of full utilization).

If the firm faces a cost minimization problem subject to an output constraint, in absence of shifts practice and assuming that wage is the only labor cost, the first order condition for the optimal utilization of capital is given by:

$$\frac{w'(H)}{r'(H)} = -\frac{K}{L} \qquad [1]$$

This condition implies that, in absence of shifts, more capital intensive firms should have a longer workday and pay a higher wage rate to reduce idle time of expensive capital.

In this context, the introduction of shifts is a way for dealing with high costs of capital idleness without incurring in a prohibitively high wage premium for long hours. If the firm can determine both the length of labor workday and the (integer) number of

[2] In presence of a competitive labor market, for example, workplaces characterized by longer or harder workdays have to offer higher wages to attract people and compensate them for such non pecuniary disadvantages (Rosen, 1974).
[3] The downward sloping part is determined by the existence of fixed labor costs (like a minimum weekly wage) which are independent from the number of hours worked.
[4] In particular, the lower is this substitution elasticity and the higher are search costs, the lower is the minimum. Note that, even if workers have different taste for working hours, the existence of search costs disincentives firms to perfectly identify only workers whose preferences can match the time schedule offered.
[5] From another perspective, the supplier of capital is interested only in the monetary return of its full utilization and therefore he will require a higher hourly payment if the capital is used less than 24 hours a day.

consecutive shifts during the day, the workday for capital is given by the number of shifts times the workday of labor.

The option of using a different number of shifts allows a number of possible solutions, characterized by different combinations of number of shifts and length of each shift. Furthermore, given the same mix, more capital intensive firms should pay higher wages and work longer hours: they will be then characterized by less flexible work schedules, with longer workdays, less opportunities for personalized working time or unscheduled breaks and more “mandatory” overtime hours.

Of course, capital intensity is not the only factor influencing the optimal level of capital utilization and, consequently, the use of shift work. In fact, any element affecting the shape and position of labor and capital costs may change the optimal level of capital utilization and the cost opportunity of using shifts or a certain amount of shift workers. These factors can be classified into two main groups: those influencing, respectively, labor costs (like the shift premium, the composition of the workforce, the presence of unions, regional or industry traditions in terms of shift work, etc.) and capital costs (other than capital intensity, technical obsolescence, technical reasons for continuous operations, plant and firm size, etc.).

In the next empirical session, I shall examine more deeply the role of some of these factors, paying particular attention to capital intensity and firm’s size.

3. Review of the empirical literature

Empirical work on shift work is scant and somewhat outdated. Even though the relation between the demand for workers and hours have been extensively studied in the empirical literature[6], little attention has been specifically paid to the use of shift work and its effects on both labor demand and supply.

Research on this topic was mainly prevented by the paucity of suitable (micro) data sets, in particular on the labor demand side (either firms or establishments).

For this reason, with the exemption of some work in the Eighties (Bosworth et al., 1980; Hart, 1988), most of the recent analysis on this topic was aimed at studying either the relative use of shift work over the business cycle (Mayshar and Solon, 1993; Shapiro, 1993) or the relation between compensating wage differentials for shift work and labor supply (Kostiuk, 1990; Schumacher and Hirsch, 1997).

[6] See, for example, Ehrenberg and Schumann (1982) and Hart (1988). For an extensive review of this literature see Hamermesh (1993).

All the macroeconomic studies pointed out the extreme cyclical sensitivity of shift work to the business cycle: according to Mayshar and Solon's estimates based on the BLS "Area Wage Survey" from 1951 to 1990, the cyclical elasticity for overall manufacturing production employment is 1.80, but it goes up to 3.35 considering only late shift employment[7]. Firms seem to react to downturn periods eliminating the second shift an when full time employment decline during a recession, about one half of the decline for manufacturing production workers and one third of the overall economy occur on late shifts. In general, however, the proportional decline in output is greater than the corresponding reduction in employment.

On the labor supply side, analysis has been focused on estimating a shift wage premium after correcting for the existence of self selection into shift work determined by heterogeneous individual preferences in terms of working hours. For example, Kostiuk (1990) uses a two stages - three equations model, in which probit estimates on the choice of shift work in the first stage are used to correct wage equations parameters in the second stage. In the latter, wage equations are allowed to structurally differ between regular daytime and shift workers. Estimating this model for two samples of manufacturing workers in the 1979 and 1985 Current Population Survey (CPS), he finds a sizable shift premium that varies substantially with union membership and race[8]. Furthermore, probit estimates point out the crucial role of self selection, since workers with lower potential daytime earnings (like the youngest and the least educated) are more likely to choose night work. In general, taking into account the existence of a shift premium reduces the wage premium associated to both union membership and firm size in traditional cross-section wage equations.

Also Shapiro (1995) estimates a marginal shift premium using both a OLS estimator and a two stage procedure on two cross-sections of manufacturing workers from the 1985 (as Kostiuk) and 1991 CPS. The OLS estimates give a marginal shift premium of about 25%, but it reaches almost 90% when self-selection is taken into account[9].

In his paper, he extends his attention also to the labor demand side, trying to estimate a marginal shift premium using a sample of 1894 establishments from the 1977 Industry Wage Survey (IWS). Shift premium (i.e., the parameter associated to the fraction of workers on night shift) is estimated in a traditional wage equation including controls for unionization, plant size, location in a city, industry and the occupational mix of the workers at the establishment. To take into account possible self-selection biases of the

[7] They define as "late shifts" the evening and the night ones, excluding then the day shift.

[8] The estimated shift differential is about 8% for all workers, but it increases to 12 and 18% among, respectively, non white and unionized workers.

[9] As the author himself points out, the two stage least square estimates are likely biased upwards because the instruments used (industry dummies) are positive correlated with the error term of the wage equation.

same kind discussed by Kostiuk, he performs both OLS and IV estimates, where the instruments used in the last model are the establishment size and capital intensity. The IV estimate of the marginal shift premium is around 70% of the base wage, a value much higher than the 10% obtained using OLS[10].

For the purpose of the present paper, it is worth underling that Shapiro's OLS estimates in the first stage of the IV procedure show a strong, positive effect of both plant size and capital-labor ratio on the percentage of shift workers in the workforce. On the contrary, union and skill-mix variables don't seem to play a significant role in explaining its variation among firms[11].

4. The empirical analysis

4.1. Data source

The empirical analysis is based on a representative sample of 2738 Italian metalworking firms in 1995. This is part of the survey yearly conducted by the national employers' association of this industry (Federmeccanica), mainly for wage bargaining purposes[12].

The data set gives detailed information on firms, both at the corporate and establishment level. For example, it contains data on the composition of the workforce by sex, occupation, type of shift[13]. Wage levels and their composition are available by occupation. The data set contains information also on the sector of activity (75 sub-sectors in the metalworking industry), location (city), rate of unionization (in terms of both unionized workers and local union representatives among the employees), presence and feature of a firm contract.

Even if the data set doesn't provide explicit data on the stock of capital, it contains information on eventual new investments made in the year of the survey.

Some information referred to 1990 is available for almost 50% of the firms. This data was partially used to study the evolution of the use of shift work in the Nineties.

4.2. Descriptive statistics

Before presenting the econometric model estimated and the main results obtained, it is worth looking at the incidence of the use of shift work, its evolution in the Nineties and

[10] The presence of few controls for workers' characteristics in the establishments sample can explain this lower value with respect to the estimates on CPS samples.
[11] The first stage contains also location and industry dummies among the regressors.
[12] For more details on the survey, see Federmeccanica (1996)
[13] Partial information is also available on the incidence of non EU workers.

its correlation with other firms' characteristics. Table 1 reports the percentage of firms regularly using any kind of shift and the average quota of shift workers per firm in 1990 and 1995[14].

On average, in 1995 30.6% of the firms in the sample uses some kind of shift work, while the percentage of shift workers per firm is 10.5[15].

Both measures vary notably with industry, size, location and firms' workforce composition.

Shift work is particularly widespread in the primary metals and transportation industries (where it is adopted by, respectively, 59% and 56% of the firms), while it is used by less than 20% of the repair shops.

The distribution of firms using shift work by percentage of shift workers (figure 1) confirms the existence of relevant differences among sectors not only at the mean, but also in the shape and skewness of the overall distribution. For example, the distribution is more concentrated around low percentages of shift workers in sectors producing electronic instruments and industrial machinery, while it is skew to the right in the case of the primary metals sector. The same distribution is approximately normal for the fabricated metals sector and repair shops. In the case of transportation, the distribution is "M-shaped", with two peaks, respectively, at 14% and 59%.

Considering firms' location, shift work is used by more than a half of the firms located in the South, a quota 20 percentage points higher than in the North.

A larger divide emerges once firms' size is taken into account: only 12% of the firms with less than 50 employees uses shift work, while at least two shifts are adopted by almost three quarters of the largest firms.

Shift work seems more common in firms where unions are present (40%) or in those adopting also a local labor contract other than the national one (48%)[16].

Looking at the workforce composition, the use of shift work appears positively correlated with the incidence of blue collar workers, but negatively correlated with the presence of

[14] To allow a more precise comparison between the 2 years, for 1995 I calculated also the same averages using only the firms presented in the 1990 sample. My panel contains then exactly the same firms in both years.

[15] Note that this average was calculated using all the firms in the sample. The percentage of shift workers in total employment is much higher, equal to 33%. I reported the first measure because it is the one actually used as dependent variable in most of the estimates discussed in the next sections. In general, the two measures present the same variation by firms' characteristics.

[16] In Italy collective bargaining can take place at two levels: industry and firm/local level. While the first is mandatory for all the firms belonging to a certain industry, the second is optional. An additional contract is usually bargained in large or unionized firms.

immigrants from non-EU Countries. In any case, it doesn't vary drastically with the incidence of females.

It also exists a sort of correlation between shift work and other working time schedules, such as overtime and the use of a flexible time over the year. However, this relation, mainly in the case of flexible time, is not clear-cut.

The same is true, at least in terms of workers, when firms are divided according to the use of temporary lay-offs. In this case, it is worth underling that 43% of the firms apparently in bad economic conditions adopts nonetheless at least two shifts.

As expected by the economic theory, the percentage of firms using shift work increases, at least to a certain extent, with the capital-labor ratio. Shift work is in fact used by less than 20% of the firms whose investment per worker is less than 500$, while the same percentage is at least as twice as high in firms with higher capital investment.

The distribution of firms by percentage of shift workers and capital intensity depicted in figure 2 confirms this result. The distribution is in fact concentrated around a percentage of shift workers equal to 10-15% in the case of firms with low level of capital intensity, while it reaches its maximum around a percentage of shift workers equal to 60% in the case of more capitalized firms.

The comparison between 1990 and 1995 reveals on average a slight increase in the use of shift work, in terms of both firms and workers. Despite the average increase, shift work decreases in some sectors (such as the electric industrial machinery) and in small firms.

Figures 3a and 3b confirm this result. In each panel, I plotted the percentage of shift workers in 1990 (horizontal axis) and 1995 (vertical axis) by, respectively, firm and sector. The distribution of the points along the main diagonal shows how the relative position of each firm/sector changed from 1990 to 1995. In particular, the percentage of shift workers increased for all the points above the diagonal, while it decreased for those below it. Even if the relation is less clear-cut in the case of firms, the scattered diagrams show a quite stable ranking of both firms and sectors by incidence of shift work. However, the relative concentration of the points above the diagonal indicates a slight increase in the use of shift work. For example, 6% of the firms used shift work in 1995 but not in 1990, while the opposite is true in 4% of the cases. Furthermore, among the firms using shift work in both years, 64% increased their percentage of shift workers from 1990 to 1995, and only 30% reduced it.

The highest increase was experienced by firms in the automotive sector, while the greatest reduction occurred in firms producing computers and office equipment.

The correlation indexes reported in table 2 show that the incidence of shift workers increases with the size of the firms, the rate of unionization of the workforce, the average productivity level, the percentage of manual workers and the capital-labor ratio. On the contrary, the same variable is negative correlated with the incidence of exports on sales, the percentage of production made by contract manufacturers (outsourcing), the incidence of temporary lay-offs and the use of flexible time over the year. The relation appears less clear-cut when wages, overtime and alternative measures of unions' power (i.e., the percentage of local unions representatives in the workforce) are considered.

If, on one hand, it is important to study if firms using shift work differ significantly from those which don't use it, on the other hand it might be interesting to look whether or not firms using a different number of shifts share the same characteristics. This is particularly important in this sample, where firms using shift work are almost equally distributed on two and three shifts, even if, as shown in figure 4, there are noticeable differences in the distribution of both firms (panel a) and workers (panel b) by number of shift among sectors[17].

Table 3 presents some information on the sampled firms by number of shifts used. It clearly shows that firms working at night (i.e., using three shifts) are larger, more unionized, more productive and more capital intensive than firms with a lower number of shifts. There is a also monotonic positive relation between the number of shifts and the percentage of manual workers, the annual wage paid and the percentage of sales exported. Moreover, firms without shifts present the same growth rate (both in terms of employees and productivity) of firms working at night (respectively, 8% and 18%), but the highest employment growth (over 26%) is experienced by firms with at most two shifts.

4.3. The econometric model

The empirical analysis is aimed at estimating which factors can influence the choice of using shifts, the incidence of shift workers in the total workforce and the number of shifts adopted.

Referring initially to the first two aspects (i.e., use of shift work and relative number of shift workers), we can assume that a certain firm decides to adopt shift work after

[17] Note also that sectors presenting the same distribution of firms by number of shifts may have quite different distribution of workers. For example, both the primary metals and the transportation sector are characterized by roughly 40% of firms with one shift, 25% with two shifts and the remaining part with three shifts. Though, the incidence of employees working two shifts is lower in the primary metals sector than in the transportation one (respectively, 15% and 42%), while the opposite is true for the percentage of employees regularly working at night (respectively, 38% and 12%).

calculating the net benefits deriving from that choice. Given the choice of using shift work, this firm then determines the number of shift workers. This decision process can be described by the following two equations model:

$$W_i^* = X_i\beta + \varepsilon_i \qquad [1]$$

$$E(Y_i/W^*_i>0) = Z_i\gamma + u_i \qquad [2]$$

where W_i^* is a measure of the net benefits of using shifts in the i-th firm, X_i a vector of factors influencing this choice, $E(Y_i/W_i>0)$ the (expected poditive) number of shift workers in the workforce conditioning on the existence of positive net benefits in adopting shifts and Z_i a vector of factors influencing the incidence of shift workers. β and γ are the coefficients to be estimated and εi and u_i the usual error terms.

In practice, we hardly observe any accurate measures of the net benefits that the firm might gain from using shift work: what we observe is the actual choice, that we assume to be correlated with the unknown net benefits in the following manner:

$$\begin{cases} Wi = 1 \quad \text{iff} \quad Wi^* \geq 0 \\ Wi = 0 \quad \text{iff} \quad Wi^* < 0 \end{cases}$$

where Wi is equal to 1 if the i-th firm uses shift work, 0 otherwise.

This assumption allows us to revise the previous model as follows:

$$W_i = X_i\beta + \varepsilon_i \qquad [1']$$

$$E(Y_i/W_i = 1) = Z_i\gamma + u_i \qquad [2']$$

With the further assumption that the choice of using shift work is independent from the choice of the relative number of shift workers (i.e., the unobservables in [1'] and [2'] are uncorrelated), the two equations can be separately estimated using a probit (or logit) estimator for the first equation, followed by a traditional linear regression considering only the firms adopting shift work.

Even if the no-correlation assumption is probably too strong and an Heckman's two-step procedure might appear as the unbiased estimator of this model, the absence of factors influencing the choice of using shift work but not the incidence of shift workers (i.e., variables entering X_i but not Z_i) prevents to correctly identify the model[18].

Also in light of the limitations of the data set used, I then estimated the two equations separately (using a sort of two-part model approach; see Manning, Duan and Rogers, 1987).

The explanatory variables included in both X and Z can be divided into four main groups:

a) *Labor demand factors or firms' characteristics*: among these variables, I used the size of the firm (measured as the logarithm of the number of employees), its location (North, Center or South of Italy[19]), the sector of activity (up to 75 metalworking sub-sectors), the quota of production made by contract manufacturers (% outsourcing), the percentage of exported sales, the presence of a firm contract and the capital-labor ratio[20].

b) *Labor supply factors*: its influence is captured by the composition of the workforce in terms of skills (% manual workers), occupation, gender (% females), race (presence of non-EU workers) and unionization (either % unionized workers or % union's representatives within the firm).

c) *Product demand or business cycle factors*: its role is measured by the incidence of temporary lay-offs and overtime (in terms of number of hours per worker), use of flexible working time during the week or the year, opening of new plants or closing of some of the existing ones by three years after the survey.

d) *Other factors*, related to more than one of the above groups. Among them, I used productivity levels (measured as sales per workers) and local unemployment rates (measured for 95 administrative provinces).

To further test the robustness of the results obtained, I then treated the incidence of shift workers as a censored variable (recoding this variable as zero in the case of firms not adopting shifts) and I estimated a tobit model using all the valid observations in the sample.

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[18] In theory those identifying variables are not necessary as long as you can make assumptions on the functional form to identify the model. However, this kind of assumptions are at least as strong as that of no correlation between the two errors. This problem will be anyway better addressed in future research, when more detailed information, including longitudinal data, will be likely available.

[19] In the case of firms with more than one plant, I used the percentage distribution of those plants by area.

[20] As already mentioned, the data set doesn't contain any information on the capital stock of each firm, but it has detailed information on the new investments in capital made in the year of the survey. The capital-labor ratio is then measured as the investment per worker made by each firm in 1995. Note that, in a steady state, this variable is a good proxy of the actual stock of capital. Furthermore, in the regressions I also control for technology, business cycle and incidence of export, making the approximation even more reliable.

Finally, I used an ordered probit model to estimate the determinants of the probability to adopt a certain number of shifts, given that the variable measuring the number of shifts is discrete and naturally ordered.

4.4. Main results

Table 4 and 5 report the estimates of the determinants of the choice of using shift work (tab. 4) and the relative number of shift workers (tab. 5) obtained using different specifications. The specification in column 1 doesn't control for the occupational mix, local unemployment rate, and other working time schedules (overtime and flexible time)[21]. The set of occupational variables is added in column 2, while in columns 3 I added also an alternative measure of union's power. The variables capturing other working time schedules are included in column 4. In the last two columns I control for local labor market conditions, also allowing for different effects of local unemployment by area.

All the models contain also a set of industry dummies (at the most disaggregated level).

According to these estimates, both the use of shifts and the incidence of shift workers are determined by variables belonging to all the four groups of factors outlined above and in general the coefficients estimated present the expected sign.

The empirical analysis strongly confirms the predictions of the economic model: the use and the incidence of shift work is positively influenced by both capital intensity and firm's size. As suggested by the economic theory discussed in section 2, firms with higher capital-labor ratios are more likely to use shift work to avoid higher opportunity costs of idle capital. My estimates suggest also that not only the probability of using shift work, but also its incidence in terms of regular shift workers among the employees progressively increases with firms' capital intensity[22].

Among firms' characteristics, also the location of the firm plays an important role in influencing the incidence of shift work: the latter is in fact higher in the South than in the Center-North of Italy. This result is somewhat puzzling, given the noticeable gap in terms of economic competitiveness and productivity levels between the two areas. One plausible explanation involves the characteristics of local labor supply: critical local labor market conditions could in fact induce people to accept either less paid jobs or more disadvantaged working time conditions, such as night and shift work. To test this hypothesis, I tried to control for local unemployment rate, also allowing for different

[21] Note that the variables related to both productivity and working time patterns may be endogenous, given that these factors are usually co-determined with the use of shift work.
[22] According to my estimates, the marginal effect is between 6-8%..

effects between the three areas. The introduction of these variables actually increases the "South" effect. Furthermore, just in the South the local unemployment rate has a significant negative effect on the incidence of shift workers. The "supply side" explanation is then rejected by the data and firms' location seems to be a factor determining the intensity of shift work *per se* [23].

Considering the role of unions, the results obtained show that the unionization rate significantly increases the probability of using shift work, while it doesn't have any influence on the relative number of shift workers actually employed.

On the labor supply side, the use and the incidence of shift work seems determined solely by the composition of the workforce by skills and partially by its occupational mix: the percentage of shift workers increases with the percentage of blue collars and, among them, with the incidence of workers belonging to middle-low occupations [24] (2^{nd} level). The composition of the workforce by sex or race doesn't play any relevant role in determining the use and the incidence of shift work.

The factors capturing the product market and business cycle conditions present generally the expected sign, even if not all the coefficient are statistically robust. An overall interpretation of the effect of these variables confirms the results of earlier macroeconomic studies on the pro-cyclical use of shift work, but the significance of the estimates seems to reveal that the use of shift work is more sensitive to bad economic conditions (captured by the variables related to future shutdowns and the incidence of temporary lay-offs) rather than good ones (the coefficient estimated for the opening of new plants is never statistically significant).

Considering other working time schedules, the incidence of overtime increases the probability of using shifts, but decreases the relative number of shift workers within the firm. It is then likely that firm use shift work and overtime together, with a certain degree of substitutability between the two time schedules. The last result emerges also when the use of flexible working time schedules (over the week or the year) are considered, even if the latter doesn't seem to influence the choice of using shift work.

[23] An alternative explanation of the location effect might rely on the existence of a long tradition of shiftworking in certain areas (Bosworth et al., 1980). However, this doesn't really seem the case of the South of Italy.

[24] I used the traditional definition of occupations (the so called "livelli di inquadramento") described in the labor national contract of this sector. This classification is influenced by both workers' age-experience and education. It's then difficult to clearly interpret which specific factor is captured by the coefficients estimated.

The estimates obtained using the tobit model confirm most of the results already discussed (see table 6). In particular, also in this case it clearly emerges the crucial role of firm's size and capital intensity in determining the incidence of shift work.

4.4.1. The probability of using a different number of shifts

At this point of our analysis it is also interesting to study if there are some factors influencing specifically the use of a particular number of shifts (from one to three).

The results obtained using an ordered probit estimator and different specifications are reported in table 7.

In general, most of the factors influencing the use and the incidence of shift work are important in determining also the number of shifts used. An important role is still played by firm's size and capital intensity: both factors significantly increases the probability of adopting a higher number of shifts. Also the unionization rate and the incidence of blue collar workers have a positive effect on the number of shifts while, as obtained in the previous models, future plant closing have a strong significant negative effect.

In contrast with the previous models, the number of shifts seems negatively (and significantly) related with the incidence of women in the workforce. Even if the last result can be interpreted in light of the traditional trade-off between job career and family care[25], in the Italian case it is more likely due to a national law which prevented women from working at night until February 1999, when a 1993 EU Directive against this kind of discrimination was finally applied.

5. Concluding remarks

The empirical analysis on a cross section of Italian metalworking firms showed that the incidence of shift work is influenced by both labor and product markets factors.

A crucial role is in particular played by firm's size, unionization rate, composition of the workforce by skills and capital-labor ratio: the percentage of shift workers increases with all these factors.

As suggested by the economic theory and by previous empirical work, firms with higher capital intensity are more likely to use shift work to avoid higher opportunity costs of idle capital. According to my estimates, not only the probability of using shift work, but also its incidence (in terms of percentage of shift workers) progressively increases with firms' capital-labor ratio.

[25] In other words, women may be generally favorable to flexible working time, such as shift work, but their role within the family doesn't allow them to accept any working time schedule, such as night shifts.

Confirming the results of previous macroeconomic studies, I also found some evidence on a positive relation between the use of shift work and firms' economic conditions.

Furthermore, specific factors seem to influence the use of a certain number of shifts. For example, the composition of the workforce by gender, which doesn't have a relevant impact on the percentage of shift workers, has a negative (robust) effect on the probability of working at night (i.e., using three shifts), also because of a national law which prevented firms from employing women on night shifts until 1999.

Looking at the relation between shift work and other working time schedules, I found a certain degree of substitutability between the first and both overtime and the use of flexible working time over the year, but further research is necessary to fully understand how these working time patterns are used in both the short and the long run to adjust production to demand changes.

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Table 1 – The use and the incidence of shift work by firms' characteristics

	Cross section 1995		Panel 1995		Panel 1990	
	% firms using shifts	% shift workers per firm	% firms using shifts	% shift workers per firm	% firms using shifts	% shift workers per firm
TOTAL	30.6	10.5	34.4	11.4	32.3	9.2
By sector:						
Primary metal	59.3	28.9	65.9	31.2	64.7	25.9
Fabricated metals	22.6	8.8	23.8	9.3	19.3	6.9
Non electric ind. machinery	35.7	11.9	38.9	14.9	48.1	11.1
Electric industrial machinery	27.5	5.9	28.8	5.9	29.9	5.5
Instruments	33.4	10.9	38.1	12.0	33.1	10.2
Electronic equipment	30.3	8.4	42.0	11.1	36.1	9.4
Transportation	55.7	22.2	60.8	23.2	54.6	16.2
Repair shops	17.5	6.6	16.7	5.3	15.1	4.4
By area:						
North	30.1	10.0	33.7	10.9	32.1	3.8
Center	35.2	13.4	47.8	16.5	40.6	12.2
South	52.0	23.7	64.7	28.7	50.7	18.5
By size (# workers):						
< 50	12.2	5.0	11.8	4.9	12.7	4.4
50 –100	40.3	12.9	34.0	9.0	26.6	7.4
> 100	71.9	23.6	73.1	23.7	67.7	18.1
By union. status:						
non union	8.4	3.3	9.1	3.8	7.4	2.7
union	40.4	13.7	40.8	13.3	40.6	11.3
w/o firm contract	15.6	5.5	17.2	5.9	14.7	4.7
with firm contract	48.0	16.4	46.6	15.3	43.4	12.0
By workforce characteristics:						
blue collars< 50%	15.5	1.5	18.4	2.0	19.8	3.2
blue collars> 50%	33.1	12.0	36.9	12.8	33.9	9.9
women<50%	30.9	10.6	34.7	11.6	32.0	9.1
women>50%	27.6	10.1	30.0	8.9	37.5	10.6
w/o no EU immigrants	26.3	9.1	29.2	9.7	-	-
with no EU immigrants	43.4	14.9	47.9	15.9	-	-
*By K/L intensity**						
low (<500$)	18.5	6.1	20.0	6.2	-	-
medium (500-25,000$)	47.8	16.4	50.2	16.6	-	-
high (>25,000$)	40.4	19.6	54.5	24.7	-	-
By other working time schedules:						
overtime:						
no	10.5	4.4	11.9	4.5	11.3	3.8
yes	33.6	11.4	37.2	12.2	35.3	10.0
flexible time over the year:						
no	30.3	10.6	33.8	11.5	-	-
yes	39.8	9.5	47.9	9.9	-	-
By economic conditions (temporary lay-offs):						
no	29.5	10.2	33.4	11.3	30.3	8.5
yes	43.0	14.5	44.7	12.2	54.1	16.7

\- not available

Table 2 - The relation between the percentage of shift workers and other firms' characteristics:

	Cross section 1995	
Correlation: % shift workers and:	pairwise	partial
ln(# workers)	0.41 *	0.35 *
% blue collars	0.24 *	0.08 *
Composition by occupation:		
- apprentices	-0.06 *	-0.04
- 1st level	0.01	0.01
- 2nd level	0.20 *	0.09 *
- 3rd level	0.16 *	0.02
- 4th level	0.14 *	0.02
- 5th level	-0.05 *	-0.01
% females	-0.03	0.01
% unionized workers	0.30 *	0.12 *
% local unions representatives	0.09 *	-0.04 *
annual wage	-0.05 *	0.02
productivity (sales/workers)	0.09 *	0.10 *
overtime hours per worker	0.05 *	-0.01
hours temporary lay-offs per worker	-0.03	-0.06 *
use of flexible time over the year	-0.01	-0.06 *
outsearching/production	-0.06 *	-0.06 *
exports/sales	0.05 *	-0.09 *
K intensity (new investment per worker)	0.09 *	0.08 *

* statistically significant at 5%

Table 3 – Firms' characteristics by type of shift work, 1995

	Firms with at most:			
	1 shift	2 shifts	3shifts	TOTAL
# workers	54	149	825	166
% blue collars	67.1	72.5	73.2	68.8
% females	19.7	20.3	16.5	19.4
annual Δworkforce (%)	8.1	26.3	8.0	11.4
hires/workers (%)	19.2	19.2	17.1	18.9
fires/workers (%)	14.9	12.4	11.8	14.1
% unionized workers	20.8	36.4	43.0	26.3
% local unions representatives	2.1	3.1	2.7	2.4
hours on strike per worker	0.4	1.0	2.4	0.8
annual wage ($)	15,968	16,227	16,546	16,089
prod (sales/workers, $)	131,274	138,619	161,518	136,390
yearly Δprod (%)	17.8	16.5	17.9	17.8
overtime hours per worker	93	109	103	97
hours of temp lay-offs per worker	0.01	0.01	0.01	0.01
outsourcing/production (%)	12.3	13.1	9.9	12.2
exports/sales (%)	21.6	30.8	32.3	24.6
K intensity (new investment per worker, $)	3,753	5,542	7,405	4,524
# observations	1908	494	36	2738

Table 4 – Factors determining the use of shift work, 1995: different specifications

Estimator: Probit; Dependent variable: use of any number of shifts (1=yes)						
	(1)	(2)	(3)	(4)	(5)	(6)
ln(# workers)	27.03	27.87	28.08	27.75	27.81	27.83
	(19.8)	(19.0)	(18.7)	(19.0)	(19.0)	(19.0)
Center	4.91	5.48	5.38	6.75	7.32	7.05
	(1.3)	(1.3)	(1.3)	(1.6)	(1.7)	(0.5)
South	9.44	9.85	9.49	10.54	13.33	41.64
	(1.6)	(1.5)	(1.5)	(1.7)	(1.7)	(2.0)
% outsourcing	-0.02	-0.01	-0.01	-0.02	-0.02	-0.02
	(0.4)	(0.2)	(0.2)	(0.4)	(0.4)	(0.4)
% export	-0.04	-0.05	-0.05	-0.05	-0.05	-0.05
	(1.0)	(1.2)	(1.1)	(1.3)	(1.3)	(1.3)
K intensity	0.11	0.11	0.11	0.11	0.10	0.11
	(4.5)	(4.0)	(4.0)	(3.9)	(3.9)	(4.0)
firm contract	1.48	1.88	1.39	2.02	1.88	1.90
	(0.6)	(0.8)	(0.6)	(0.8)	(0.8)	(0.8)
% unionized workers	0.19	0.23	0.20	0.24	0.24	0.24
	(4.4)	(4.8)	(3.8)	(5.0)	(5.0)	(4.9)
% local representatives	-	-	37.98	-	-	-
			(1.1)			
% blue collars	0.59	0.56	0.56	0.53	0.53	0.53
	(8.4)	(7.0)	(7.0)	(6.7)	(6.7)	(6.8)
apprentices	-	-0.003	-0.01	0.01	-0.02	-0.02
		(0.01)	(0.04)	(0.03)	(0.1)	(0.1)
1st level	-	0.16	0.17	0.17	0.17	0.16
		(0.7)	(0.7)	(0.7)	(0.7)	(0.7)
2nd level	-	0.28	0.28	0.29	0.28	0.28
		(3.2)	(3.2)	(3.2)	(3.2)	(3.2)
3rd level	-	0.01	0.02	0.03	0.02	0.02
		(0.2)	(0.2)	(0.4)	(0.3)	(0.4)
4th level	-	0.06	0.06	0.07	0.07	0.07
		(0.9)	(0.8)	(1.1)	(1.0)	(1.1)
% females	-0.11	-0.13	-0.12	-0.10	-0.10	-0.10
	(1.5)	(1.5)	(1.5)	(1.2)	(1.1)	(1.2)
non EU workers	0.27	-0.99	-1.03	-1.08	-1.24	-0.99
	(0.1)	(0.4)	(0.5)	(0.5)	(0.6)	(0.4)
open new plants	7.63	8.88	8.74	8.89	8.80	8.79
	(1.3)	(1.4)	(1.4)	(1.4)	(1.4)	(1.4)
close plants	-16.13	-17.16	-17.08	-17.37	-17.31	-16.98
	(2.4)	(2.5)	(2.5)	(2.6)	(2.6)	(2.5)
temp. lay-off per worker	-23.25	-20.80	-19.90	-16.85	-16.28	-16.68
	(1.6)	(1.3)	(1.3)	(1.1)	(1.0)	(1.0)
overtime per worker	-	-	-	0.04	0.04	0.04
				(2.7)	(2.7)	(2.6)
flexible time	-	-	-	-6.08	-6.12	-6.22
				(1.2)	(1.2)	(1.2)
U. rate	-	-	-	-	-0.23	0.02
					(0.6)	(0.1)
U. rate*center	-	-	-	-	-	-0.04
						(0.03)
U. rate *south	-	-	-	-	-	-1.64
						(1.6)
Dummies sectors (#)	yes (75)	yes (75)	yes (75)	yes (75)	yes (75)	yes (75)
# observations	2684	2531	2531	2531	2531	2531
pseudo R^2	45.6	46.02	46.06	46.29	46.30	46.38
LogL	-906.54	-856.84	-856.28	-852.67	-852.48	-851.17

marginal effects*100; absolute t-values in parenthesis

Table 5 – The determinants of the incidence of shift work, 1995

Estimator: OLS; Dependent variable: % of shift workers in total workforce (conditioning on the use of shift work)						
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-21.53	-22.21	-20.63	-17.63	-19.89	-21.99
	(2.9)	(2.8)	(2.6)	(2.3)	(2.5)	(2.8)
ln(# workers)	3.32	3.16	2.95	3.19	3.07	2.87
	(4.7)	(4.3)	(3.9)	(4.4)	(4.3)	(4.0)
Center	4.18	3.16	3.31	2.12	1.16	-0.10
	(1.3)	(1.0)	(1.0)	(0.7)	(0.4)	(0.1)
South	8.32	6.87	6.94	6.60	2.89	28.32
	(1.9)	(1.6)	(1.6)	(1.5)	(0.6)	(2.9)
% outsourcing	-0.02	-0.03	-0.03	-0.02	-0.02	-0.02
	(0.6)	(0.6)	(0.7)	(0.4)	(0.4)	(0.6)
% export	-0.04	-0.05	-0.06	-0.05	-0.04	-0.04
	(1.5)	(2.0)	(2.0)	(1.7)	(1.5)	(1.3)
K intensity	0.06	0.07	0.07	0.07	0.07	0.08
	(1.7)	(1.8)	(1.8)	(2.0)	(2.1)	(2.3)
firm contract	1.30	0.42	0.75	0.48	0.66	0.87
	(0.7)	(0.2)	(0.4)	(0.2)	(0.3)	(0.4)
% unionized workers	-0.02	0.01	0.02	-0.01	-0.01	-0.05
	(0.6)	(0.2)	(0.5)	(0.2)	(0.1)	(0.1)
% local representatives	-	-	-25.09	-	-	-
			(1.1)			
% blue collars	0.78	0.72	0.72	0.75	0.75	0.75
	(13.8)	(11.2)	(11.1)	(11.8)	(11.8)	(11.9)
apprentices	-	-0.08	-0.06	-0.04	-0.01	-0.02
		(0.3)	(0.02)	(0.1)	(0.01)	(0.1)
1st level	-	0.13	0.11	0.07	0.07	0.03
		(0.8)	(0.7)	(0.4)	(0.4)	(0.2)
2nd level	-	0.28	0.28	0.27	0.28	0.27
		(3.9)	(3.9)	(3.9)	(4.1)	(3.9)
3rd level	-	0.08	0.08	0.06	0.07	0.06
		(1.5)	(1.5)	(1.2)	(1.4)	(1.1)
4th level	-	0.10	0.10	0.07	0.07	0.08
		(1.7)	(1.7)	(1.3)	(1.3)	(1.3)
% females	-0.02	-0.04	-0.04	-0.08	-0.08	-0.08
	(0.4)	(0.6)	(0.7)	(1.1)	(1.2)	(1.2)
non EU workers	-1.68	-2.43	-2.53	-2.48	-2.18	-1.67
	(1.1)	(1.6)	(1.6)	(1.6)	(1.4)	(1.1)
open new plants	-2.26	-1.81	-1.89	-1.70	-1.69	-1.57
	(0.5)	(0.4)	(0.4)	(1.4)	(0.4)	(0.3)
close plants	-2.51	-2.74	-2.82	-2.84	-3.33	-2.61
	(0.5)	(0.6)	(0.6)	(0.6)	(0.7)	(0.6)
temp. lay-off per worker	-16.62	-15.93	-15.98	-19.70	-23.32	-18.81
	(1.1)	(1.0)	(1.0)	(1.4)	(1.6)	(1.4)
overtime per worker	-	-	-	-0.04	-0.05	-0.05
				(3.5)	(3.7)	(3.8)
flexible time	-	-	-	-6.20	-6.07	-6.46
				(2.1)	(2.0)	(2.2)
U. rate	-	-	-	-	0.36	0.76
					(1.5)	(2.8)
U. rate*center	-	-	-	-	-	0.04
						(0.03)
U. rate *south	-	-	-	-	-	-1.72
						(3.1)
Dummies sectors (#)	yes (75)	yes (75)	yes (75)	yes (75)	yes (75)	yes (75)
# observations	838	811	811	811	811	811
R^2	44.32	46.97	47.03	48.25	48.42	49.20
F test	111.62	112.14	106.40	1453.52	65.51	66.47
(k-1, n-k)	(68, 758)	(73, 726)	(74, 725)	(75, 724)	(76, 723)	(77, 721)

absolute t-values in parenthesis

Table 6 – The determinants of the incidence of shift work, 1995: an alternative estimator

Estimator: Tobit; Dependent variable: % of shift workers in total workforce								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	-124.66	-122.32	-125.18	-123.93	-124.66	-126.83	-123.44	-125.87
	(12.8)	(12.4)	(12.5)	(12.4)	(12.6)	(11.6)	(12.2)	(12.2)
ln(# workers)	19.35	18.66	20.04	18.94	18.77	18.75	18.81	18.61
	(20.1)	(19.3)	(20.2)	(18.9)	(19.3)	(18.8)	(19.3)	(19.2)
Center	5.99	5.38	7.06	5.27	6.07	6.71	6.47	8.22
	(1.8)	(1.6)	(2.1)	(1.5)	(1.8)	(1.9)	(1.8)	(0.8)
South	13.10	11.75	12.96	11.54	11.78	16.88	13.65	47.11
	(2.7)	(2.4)	(2.6)	(2.4)	(2.4)	(3.4)	(2.3)	(3.7)
% outsourcing	-0.04	-0.04	-0.03	-0.04	-0.04	-0.05	-0.04	-0.04
	(0.8)	(0.7)	(0.6)	(0.7)	(0.7)	(0.3)	(0.7)	(0.8)
% export	-0.04	-0.05	-0.05	-0.05	-0.05	-0.06	-0.05	-0.05
	(1.2)	(1.5)	(1.4)	(1.5)	(1.5)	(1.7)	(1.6)	(1.5)
K intensity	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09
	(3.7)	(3.3)	(3.2)	(3.3)	(3.3)	(2.9)	(3.2)	(3.3)
firm contract	4.91	4.83	6.37	4.36	4.97	4.94	4.87	4.98
	(2.3)	(2.2)	(2.9)	(2.0)	(2.3)	(2.2)	(2.2)	(2.3)
% unionized workers	0.20	0.24	-	0.22	0.25	0.22	0.25	0.25
	(5.1)	(5.8)		(4.8)	(6.0)	(5.2)	(6.0)	(5.9)
% local representatives	-	-	98.38	37.26	-	-	-	-
			(3.5)	(1.2)				
% blue collars	0.77	0.69	0.76	0.69	0.67	0.68	0.67	0.68
	(11.9)	(10.1)	(11.3)	(10.2)	(9.9)	(9.4)	(9.8)	(10.0)
apprentices	-	0.04	-0.08	0.03	0.05	-0.18	0.67	0.02
		(0.2)	(0.4)	(0.1)	(0.2)	(0.7)	(0.1)	(0.1)
1^{st} level	-	0.23	0.17	0.23	0.23	0.32	0.23	0.21
		(1.1)	(0.9)	(1.1)	(1.1)	(1.5)	(1.2)	(1.0)
2^{nd} level	-	0.40	0.34	0.40	0.40	0.47	0.40	0.39
		(5.2)	(4.4)	(5.1)	(5.2)	(5.7)	(5.1)	(5.0)
3^{rd} level	-	0.08	0.05	0.08	0.09	0.10	0.09	0.08
		(1.4)	(0.9)	(1.4)	(1.5)	(1.7)	(1.5)	(1.4)
4^{th} level	-	0.12	0.12	0.12	0.13	0.11	0.13	0.13
		(1.9)	(1.9)	(1.9)	(2.1)	(1.7)	(2.1)	(2.1)
% females	-0.04	-0.08	-0.08	-0.07	-0.06	-0.05	-0.06	-0.06
	(0.7)	(1.1)	(1.1)	(1.1)	(0.9)	(0.9)	(0.8)	(0.9)
non EU workers	-0.02	-1.51	-1.39	-1.51	-1.65	-1.81	-1.77	-1.32
	(0.1)	(0.8)	(0.7)	(0.8)	(0.8)	(0.9)	(0.9)	(0.7)
open new plants	5.94	6.54	4.94	6.52	6.78	3.37	6.72	6.84
	(1.2)	(1.3)	(1.0)	(1.3)	(1.4)	(0.7)	(1.4)	(1.4)
close plants	-23.05	-22.66	-22.18	-22.66	-23.50	-24.29	-23.31	-22.58
	(3.2)	(3.2)	(3.1)	(3.2)	(3.3)	(3.4)	(3.3)	(3.2)
temp. lay-off per worker	-31.81	-26.49	-20.36	-25.97	-24.14	-23.52	-23.39	-21.23
	(2.0)	(1.7)	(1.3)	(1.6)	(1.5)	(1.4)	(1.5)	(1.4)
overtime per worker	-	-	-	-	0.02	0.01	0.02	0.02
					(1.7)	(0.8)	(1.7)	(1.7)
flexible time	-	-	-	-	-9.44	-9.20	-9.48	-9.82
					(2.1)	(2.0)	(2.1)	(2.2)
prod. (sales per worker)	-	-	-	-		0.01	-	-
						(1.5)		
U. rate	-	-	-	-	-	-	-0.16	0.29
							(0.5)	(0.9)
U. rate*center	-	-	-	-	-	-	-	-0.32
								(0.3)
U. rate *south	-	-	-	-	-	-	-	-2.13
								(3.0)
Dummies sectors (#)	yes (75)	yes (75)	yes (75)	yes (75)	yes (75)	yes (75)	yes (75)	yes (75)
# observations	2738	2583	2583	2583	2583	2337	2583	2583
pseudo R^2	14.68	14.85	14.65	14.87	14.93	14.98	14.93	15.02
LogL	-4641.60	-4462.64	-4473.45	-4461.91	-4458.68	-4095.98	-4458.53	-4454.10

absolute t-values in parenthesis

Table 7 – The factors determining the use of a different number of shifts

Estimator:	Ordered Probit					
Dependent variable:	# of shifts (0=1 shift, 1=2 shifts, 2=3 shifts)					
	(1)		(2)		(3)	
ln(# workers)	0.784	(23.4)	0.927	(22.9)	0.933	(22.9)
Center	0.164	(0.5)	0.025	(0.1)	0.051	(0.1)
South	1.124	(2.4)	0.721	(1.4)	0.724	(1.5)
% outsourcing	-0.005	(2.9)	-0.003	(1.8)	-0.004	(1.9)
% export	-0.001	(1.0)	-0.001	(1.1)	-0.001	(1.2)
K intensity	0.005	(5.7)	0.004	(4.1)	0.004	(4.0)
firm contract	0.090	(1.3)	0.053	(0.7)	0.057	(0.7)
% unionized workers	0.007	(4.9)	0.007	(4.5)	0.007	(4.8)
% blue collars	0.020	(9.8)	0.017	(7.1)	0.016	(6.8)
apprentices	-0.005	(0.8)	0.006	(0.7)	0.006	(0.8)
1^{st} level	0.006	(0.9)	0.007	(0.9)	0.007	(0.9)
2^{nd} level	0.009	(3.4)	0.009	(3.1)	0.009	(3.1)
3^{rd} level	-0.001	(0.4)	-0.001	(0.6)	-0.001	(0.5)
4^{th} level	0.003	(1.5)	0.002	(1.0)	0.003	(1.2)
% females	-0.002	(0.9)	-0.006	(2.1)	-0.005	(1.8)
non EU workers	-0.006	(0.1)	-0.057	(0.8)	-0.060	(0.8)
open new plants	0.105	(0.7)	0.166	(0.9)	0.172	(1.0)
close plants	-0.665	(2.8)	-0.762	(2.9)	-0.798	(3.1)
temporary lay-off per worker	-1.325	(2.4)	-0.824	(1.5)	-0.731	(1.3)
overtime per worker	-		-		0.001	(2.1)
flexible time	-		-		-0.244	(1.5)
U. rate	0.019	(1.7)	0.008	(0.6)	0.008	(0.6)
U. rate*center	-0.007	(0.2)	0.030	(0.7)	0.031	(0.7)
U. rate*south	-0.057	(2.3)	-0.025	(0.9)	-0.025	(0.9)
Dummies sectors (#)	NO		75		75	
# observations	2583		2583		2583	
LR χ^2 (d.f.)	1327.46	(22)	1730.15	(96)	1737.44	(98)
pseudo R^2	30.95		40.33		40.50	
LogL	-1481.01		-1279.67		-1276.03	

Absolute z-values in parenthesis

Figure 4a
Percentage of firms by number of shifts and sector, 1995

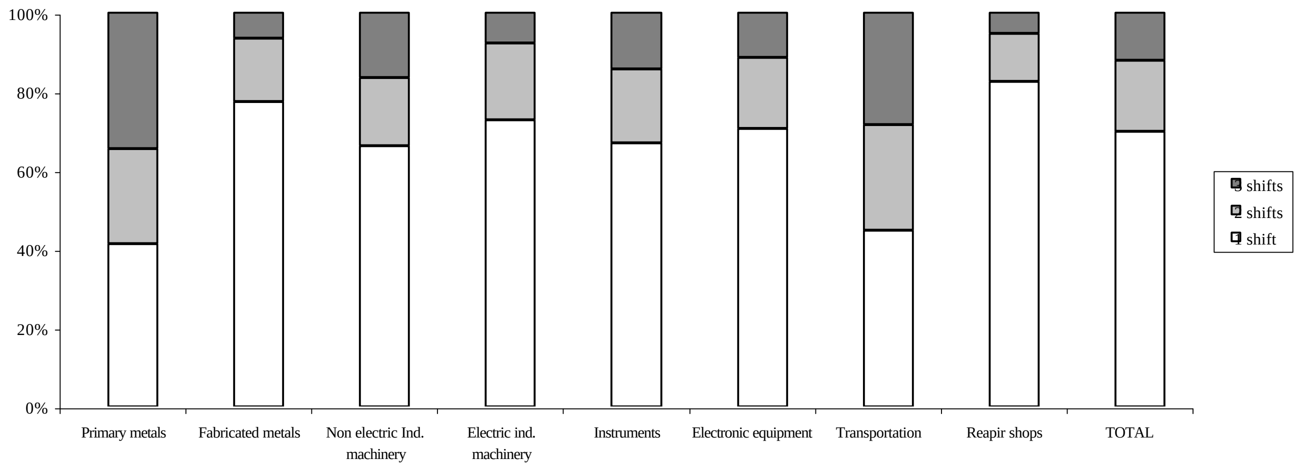

Figure 4b
Percentage of workers in each shift by sector, 1995