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LABOR EFFORT OVER THE BUSINESS CYCLE

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Abstract

Unobservable labor utilization is recognized as a crucial feature of economic fluctuations. Yet very little is known on the behavior of work effort over the business cycle. By using firm-level panel data drawn from two high-quality sources, we obtain a microeconomic estimate of variable labor effort from a dynamic cost minimization set-up. We argue that, contrary to common assumptions, the relationship between effort and hours is not monotonic. During a recovery, if a critical level of hours per capita is reached (say, because of labor market rigidities), every additional hour is worked with decreasing effort, due to physical fatigue. We provide supporting evidence by estimating the structural parameters of a Taylor approximation of the effort function. Corroborating evidence has been obtained by estimating the elasticity of effort with respect to hours at different business cycle conditions.

JEL classification: D20, E32.

Keywords: labor effort, factor hoarding, business cycles.

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Contents

1. Introduction[1]

The pronounced cyclical variability of labor productivity is a well-known feature of business fluctuations. One of the major explanations proposed in the literature, which dates back at least to Solow (1964), is based on unobserved variations in labor utilization. It is argued that sizeable adjustment costs affect firms' hiring and firing decisions and induce labor hoarding. Hence, employment is a quasi-fixed factor and firms utilize labor more intensively in booms than in recessions. The reported measures of labor input do not properly consider movements in effective factor services, and this induces cyclical mismeasurement.[2]

Variation in the intensity of work effort may act as a powerful shock propagation mechanism in the economy, and for this reason its importance is broadly recognized in the theoretical literature on economic fluctuations. Indeed, while unobserved labor utilization has traditionally been a feature of demand-driven business cycle models, more recently it has also been assigned a prominent role in supply-driven models (see, *e.g.*, Burnside, Eichenbaum and Rebelo, 1993).

In the extensive empirical literature on labor hoarding, the unobservability of work effort is dealt with in a number of ways. Abbot, Griliches and Hausman (1988), for example, approximate labor utilization by the number of hours per employee, while Caballero and Lyons (1992) also use data on overtime hours and the ratio of production to non-production workers. Shea (1991) obtains information on the intensity of labor use by employing data on accident rates, and Basu (1996) uses materials input growth as an indicator of cyclical factor utilization. Other contributions take a different approach to this measurement problem, extracting information on work effort by imposing optimality conditions on the behavior of economic agents. For example, Burnside, Eichenbaum and Rebelo (1993) employ a general

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[2] Among the early contributions on this issue, see Oi (1960), Hultgren (1965), Fair (1969) and Sims (1974); recent contributions include Gordon (1990), Burnside, Eichembaum and Rebelo (1993), Bils and Cho (1994), Basu (1996), Sbordone (1996, 1997), Burnside and Eichembaum (1996) and Basu and Kimball (1997).

equilibrium model and obtain a time series estimate of labor effort by requiring that, in equilibrium, the return of the marginal unit of effort is equal to the disutility associated with it. Sbordone (1996) derives effort within a cost minimization set-up, where it is assumed that in the compensation scheme wages increase more than proportionally with effort. Basu and Kimball (1997) assume that the compensation paid by a cost-minimizing firm depends on both effort and hours and is governed by an implicit long-term contract.

This paper takes an approach to the measurement of labor effort which is similar in spirit to that of the latter works. However, unlike most contributions to the literature we make use of data at the firm level. In particular, we use panel information drawn from two high-quality sources (the Bank of Italy Survey of Investment and the Company Accounts Data Service) to investigate the behavior of effort exerted by the employee at work during different cyclical phases. We assume that firms face costs in adjusting labor and capital inputs but may vary the (unobserved) rate of utilization over time. By imposing the firm's optimality conditions in the empirical specification, we derive an estimate of labor effort and focus on its relationship with the number of hours actually worked.

The procyclicality of hours worked is a well known feature of economic fluctuations. Firms' cost-minimizing behavior implies that *effective* labor input (that is, hours worked weighted by the unobserved intensity of work effort) also moves positively with output. On the other hand, the relationship between hourly effort and the number of hours worked is less obvious. Indeed, in light of simple considerations on the physical fatigue associated with work, such relationship is likely to be non-monotonic, contrary to common assumptions.[3] In particular, we advance the following testable hypothesis, which is consistent with the underlying theoretical model. Below a certain number of hours per capita worked in a given period, the marginal hour is worked by the employee with an increasing hourly effort. In other words, when firms face increasing demand, they typically respond by increasing both hours per capita and the intensity of the work effort required from each employee. They may also increase the number of employees. However, if the number of hours worked per employee reaches a critical threshold value, for example because new hiring is difficult due to labor market rigidities or technological factors (i.e., the need for workers with very specific skills),

[3] It is customary in the literature to assume, either implicitely or explicitely, that labor effort is positively correlated with the number of worked hours. For example, Abbot, Griliches and Hausman (1988) and Caballero and Lyons (1992) approximate the rate of unobserved labor utilization with the amount of hours per employee.

then the marginal hour is worked with decreasing intensity of work effort. In other words, if the services of the firm's labor force requested by the firm rise very significantly through a sharp increase of the number of hours per worker, then physical fatigue is likely to be encountered, with a consequent decline of marginal effort. If hours per capita is below its critical value, the relationship between hours and hourly effort is positive; otherwise it is negative . Whether one observes one case or the other will depend on the state of the business cycle and on the features of the labor market. According to this view, the positive relationship between hours and effort which is typically assumed in the literature would be only a particular case. The hypothesis just described lends itself to empirical scrutiny, and this paper investigates the matter.

We formulate a dynamic cost-minimization model and estimate effort from a production function augmented with some optimal conditions stemming from the firm's problem. The theoretical framework that we employ was originally developed by Basu and Kimball (1997) to identify technology shocks; it accommodates possible departures from perfect competition and constant returns as well as variations in unobserved factor utilization. In addition, the use of microeconomic panel data is consistent with the requirement of the theoretical model and allows us to control for unobservable individual idiosyncracies that would otherwise wash out in the aggregation process, inducing a potential bias in the estimates. The regression analysis is conducted with the generalized method of moment (GMM) estimator for panel data developed by Arellano and Bond (1991). We provide evidence that supports our claim by estimating the structural parameters of a Taylor approximation of the effort function. Corroborating evidence has been obtained by estimating the elasticity of effort with respect to hours per capita in different phases of the business cycle.

Finally, in order to gauge if our measure of labor effort is sensible, we exploit the fact that, at cyclical frequencies, the rates of utilization of labor and capital are closely linked to each other. This suggests comparing our model-based estimates with sample information on capacity utilization, drawn from the Bank of Italy survey. The strong link between this indicator and our estimate of labor effort provides further evidence that variations in unobserved labor utilization are well captured by our data and model.

The remainder of the paper is organized as follows. The next section presents the underlying theoretical model. Section 3 illustrates the data and the methodology used for estimation. In Section 4 the empirical findings are presented. Section 5 contains some concluding remarks.

2. The model and the empirical specification

We consider the following production function:

$$(1) \qquad Y_{it} = F(\widetilde{L}_{it}, \widetilde{K}_{it}, M_{it}, Z_{it}),$$

where Y_{it} denotes gross output. $\widetilde{L}_{it}$ is effective labor services and has three dimensions: the number of employees, N_{it}, the number of hours per worker, H_{it}, and hourly effort, E_{it} ($\widetilde{L}_{it} = N_{it}H_{it}E_{it}$). Analogously, effective capital services ($\widetilde{K}_{it} = K_{it}U_{it}$) combines the installed capital stock (K_{it}) and its rate of utilization (U_{it}). M_{it} is the quantity of intermediate inputs and Z_{it} is an index of technology.

Taking logs of both sides of (1) and differentiating with respect to time yields:

$$(2) \qquad dy = \frac{\partial F}{\partial \widetilde{L}} \frac{\widetilde{L}}{Y} (dn + dh + de) + \frac{\partial F}{\partial \widetilde{K}} \frac{\widetilde{K}}{Y} (dk + du) + \frac{\partial F}{\partial M} \frac{M}{Y} dm + dz,$$

where lower-case letters represent logs, the rate of growth of each input is weighted by the output elasticity with respect to input and the elasticity to technology is assumed to equal one. To simplify, time subscripts and the index i are omitted.

In order to measure output elasticities, we recall the first order condition of a simple firm optimization problem, $P\frac{\partial F}{\partial X} = \mu P_X$, where X is one of the inputs of production with its price, P_X, and P is the product price charged as a mark-up, μ, over marginal costs. Using the above expression, each of the output elasticities can be formulated as $\frac{\partial F}{\partial X}\frac{X}{Y} = \mu \frac{P_x X}{PY} = \mu s_X$, where s_X is the revenue-based share of factor X. Similarly, the output elasticities can also be expressed in terms of the returns-to-scale parameter, γ.[4] In that case, they would be:

$$(3) \qquad \frac{\partial F}{\partial \widetilde{L}} \frac{\widetilde{L}}{Y} = \gamma c_L; \qquad \frac{\partial F}{\partial \widetilde{K}} \frac{\widetilde{K}}{Y} = \gamma c_K; \qquad \frac{\partial F}{\partial M} \frac{M}{Y} = \gamma c_M;$$

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[4] To see this, we first recall that γ, the measure of the local degree of returns to scale, can be viewed as the inverse of the cost elasticity to output: $\gamma = \frac{Costs}{Y}\frac{1}{MC}$, where MC is marginal cost (Fernald and Basu, 1999). In addition, the ratio of revenue-based and cost-based factor shares is equal to total costs over total revenues: $(Costs/PY)$. Using the definition of μ as P/MC, we have: $\gamma c_X = \mu s_X$. Of course, this holds true for all the inputs.

where c_L, c_K and c_M are the cost-based factor shares.

Inserting expressions (3) in (2) yields an equation that still contains two unobservable variables: the time variation of labor and capital utilization (respectively, de and du). As extensive evidence suggests (see for example Shapiro, 1995), inputs are used more intensively in booms than in recessions. The explanation for this pattern points to the sizeable adjustment costs that prevent firms from instantaneously hiring (laying-off) workers or increasing (decreasing) capital when more (less) of these inputs is required. This induces a form of factor-hoarding, with employment (N) and capital (K) being quasi-fixed factors and the intensity of their use varying over the cycle. Clearly, the increase in factor utilization is also costly for the firm and, thus, the "optimal" degree of input use is set by balancing benefits and costs at the margin.

These considerations suggest adding more structure to the theoretical framework. Following Basu and Kimball (1997), we consider a dynamic cost minimization problem with adjustment costs in hiring and investing. The optimization set-up is the following:

(4) $$\underset{H,E,A,I,U,M}{Min} \int_0^\infty \left[NWG(H,E) + NW\Psi\left(\frac{A}{N}\right) + P_I K J \left(\frac{I}{K}\right) + P_M M \right] e^{-rt} dt$$

$subject \quad to$

$$Y = F(NHE, UK, M, Z)$$
$$\overset{\circ}{K} = I - \delta(U)K \quad and \quad \overset{\circ}{N} = A$$

The above expressions introduce some new variables in addition to those defined before. W is the base wage; $WG(H,E)$ is the total compensation to each worker and depends both on the number of hours and on the effort supplied. As is argued convincingly by Basu and Kimball (1997), one can assume that the wage payments are governed by implicit contracts, so that the actual variation of this compensation is not observed. A denotes net hiring and $NW\Psi\left(\frac{A}{N}\right)$ measures the adjustment cost of varying the number of workers. The investment activity, also, encounters adjustment costs, which are captured by the function $J\left(\frac{I}{K}\right)$; the product of this term and $P_I K$ gives the expenditure for capital, where P_I is the price of investment goods. δ

is the rate of capital depreciation which varies with the utilization, U: more intensive capital utilization causes depreciation to be faster. P_M is the price of intermediate inputs.

The first order conditions of the problem are derived in Appendix I. Manipulating these equilibrium relations and combining them with the expressions for marginal products stemming from equation (3) yields an expression for changes in capital utilization:

$$du = \frac{1}{1+\Delta}\left(dp_M + dm - dp_I - dk\right) - \frac{\xi}{1+\Delta}(di - dk), \tag{5}$$

where we have used the fact that in steady-state $(\frac{I}{K})^* = \delta^*$. Two new parameters are introduced in (5). The first represents the elasticity of marginal depreciation with respect to utilization, $\Delta = \frac{U\delta^{''}}{\delta^{'}}$, and captures the degree of convexity of depreciation as a function of capital utilization. The second denotes the elasticity of marginal costs of adjustment with respect to the accumulation rate, $\xi = \frac{\delta J^{''}}{J^{'}}$, and measures the degree of convexity of adjustment costs. As in Basu and Kimball (1997), it is useful to define these elasticities in terms of steady-state variables and treat them as constant.[5]

With regard to effective labor input, the following relation holds:

$$d\widetilde{l} = dn + dh + de = dn + (1+\zeta)\,dh \tag{6}$$

where ζ defines the elasticity of hourly effort with respect to hours per worker: $\zeta = \frac{de}{dh}$. Thus, the unobserved change in work effort, de, can be expressed in terms of change in hours per worker, dh.

Inserting equations (5) and (6) in (2) and using the expressions in (3) for output elasticities yield our main regression equation:

$$\begin{aligned} dy_{it} &= \alpha dx_{it} + \beta(c_{L,it}dh_{it}) + \varepsilon\left[c_{K,it}\left(dp_{M,it} + dm_{it} - dp_{I,it} - dk_{it}\right)\right] \\ &\quad +\theta\left[c_{K,it}(di_{it} - dk_{it})\right] + b^{'}W_{it} + dv_{it}, \end{aligned} \tag{7}$$

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[5] A feature of equation (5) is that capital utilization is negatively related to investment spending. Intuitively, this traces back to the first order condition with respect to capital utilization, U (see eq. A.3), setting the marginal benefit of increased utilization equal to its marginal user cost. Building on this relationship, eq. A.9 in the appendix states that the marginal cost in terms of increased capital depreciation, $\frac{\partial\delta}{\partial U}$, depends upon the ratio between the *current* marginal value product of capital, $\lambda\frac{\partial F}{\partial \widetilde{K}}$, and the *future* marginal products of capital, q. Thus, whenever q and, consequently, investment, I, decline, $\frac{\partial\delta}{\partial U}$ increases; in turn, due to convexity of the depreciation function, an increase of $\frac{\partial\delta}{\partial U}$ mirrors a rise in capital utilization.

where dx_{it} represents the weighted average of changes in the observed component of inputs $(dx_{it} = c_{L,it}(dn_{it}+dh_{it})+c_{K,it}dk_{it}+c_{M,it}dm_{it})$, with $c_{L,it}$, $c_{K,it}$ and $c_{M,it}$ being the cost-based input shares. The terms in brackets are measurable entities and, as illustrated earlier, they are part of the definition of de_{it} and du_{it}. W_{it} is a vector of dummy variables referring to the sector of manufacturing industry, the year, the firm's size and the occurrence of a corporate operation such as a merger, an acquisition or a break-up.[6] The specification in level also contained a firm-specific effect, which was eliminated by taking first differences. The error terms in the level equation, v_{it}, are assumed to have finite moments with $E(v_{it}) = E(v_{it}v_{is}) = 0$, for all $t \neq s$.

The unknown parameters to estimate in (7) are $\alpha,\ \beta,\ \varepsilon,\ \theta$ and b'. α represents the degree of internal returns to scale $(\alpha = \gamma)$. The second parameter allows us to trace back the elasticity of effort with respect to hours, ζ $(\beta = \gamma\zeta)$; the third parameter, ε, depends on Δ according to the relationship $\epsilon = \frac{\gamma}{1+\Delta}$, while the parameter θ is linked to the elasticity ξ through the relationship: $\theta = -\frac{\gamma\xi}{1+\Delta}$.

3. Data and estimation

We use firm-level data drawn from two main sources: the Bank of Italy's Survey of Investment in Italian Manufacturing (henceforth, SIM) and the Company Accounts Data Service reports (henceforth, CADS). The SIM has been carried out at the beginning of each year since 1984. The data are of unusually high quality, thanks to the representativeness of the sample, appropriately stratified by industry, firm size and location, and to the professional expertise of the interviewers. The number of firms surveyed is about 1,000, and the data have a panel structure; however, because of attrition, the balanced panel consists of fewer than 300 firms. The survey collects both quantitative and qualitative information.

The SIM survey leaves out a few variables needed for our analysis, such as gross production and purchases of intermediate goods and raw materials. Hence, we also employ data from CADS. The latter dataset, maintained by a consortium of the Bank of Italy and a very large number of Italian banks, is the primary source of information on balance sheets and income statements of Italian firms. It collects detailed information drawn from the

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[6] The sectoral classification used roughly corresponds to the SIC two-digit level; for details, see Appendix II.

annual accounts of more than 30,000 firms. Merging the information from the two sources produced an unbalanced panel of slightly fewer than 1,000 firms, which was used in the estimation process. Data range from 1984 to 1997 and include about 8,000 observations. The variability of industrial output during the fourteen-year period considered, which includes the 1993 recession and 1996 slowdown plus branch-specific and firm-specific output fluctuations, appears enough to convey plenty of microeconomic evidence on the cyclical behavior of the variables.

In the estimation, output is measured as gross output at constant prices and purchases of intermediate goods and raw materials are included among inputs, in addition to man-hours and capital stock services. In order to compute the cost-based capital share, c_K, and the other cost-shares, the series for the required payment to capital, rP_KK, is constructed. We use data on the firm-level capital stock at constant prices, $K,$ on the sectoral deflator of capital stock, P_K, and on firm-level estimates of the user cost of capital, r, as computed by the Hall-Jorgenson approach (see Appendix II for details).

Equation (7) in the previous section represents our empirical specification. In estimating it, one has to take into account that unobservable technology variation is likely to be correlated with changes in effective labor and capital services and materials input. This would yield a specification error inducing inconsistency of the parameter estimates. In order to account for this endogeneity of regressors, we adopt the generalized method of moments (GMM) estimation procedure developed by Arellano and Bond (1991) for panel data. This method has been shown to be efficient within the class of instrumental variable procedures, as it optimally exploits all linear moment restrictions descending from the assumptions made on the error terms, v_{it}. In our estimation the lagged values of the endogenous explanatory variables dated t-2 and earlier are utilized as instruments. In particular, we truncate the set of these instruments at the third lag because, as was shown in Ziliak (1997), using fewer instruments allows one to attenuate the bias that arises in the optimal GMM estimator when all the available linear orthogonality conditions are exploited. We also employ external instruments, presumably uncorrelated with technology variation, that are commonly used in production function regressions (see for example for Hall, 1988, Burnside, 1996, and Basu, Fernald and Kimball, 1998). These instruments are the contemporaneous growth rate of material input price and the real exchange rate, the variation in sectoral order-book levels (drawn from the business surveys of Institute for Studies and Economic Analyses (ISAE), a public body providing technical support to the Italian Treasury) and a measure of unanticipated monetary shock based on a vector autoregression (VAR) model.[7] Throughout the paper, we present estimates obtained by using all the instruments listed above. However, results turned out to be very robust to the choice of instruments. In particular, evidence very similar to that presented in the next section was obtained by excluding, both together and singly, the demand-side instruments.

The optimal method of Arellano and Bond allows us to compute standard errors that are asymptotically robust with respect to heteroschedasticity. Also, a set of diagnostic tests can be derived to assess the validity of both the instruments used and the empirical specification (see Burnside, 1996). In particular, we considered the Sargan test of over-identifying restrictions, which verifies the lack of correlation between errors and instruments, and the statistic developed by Arellano and Bond (1991), testing for the absence of second-order serial correlation in the differenced residuals. Moreover, the relevance of our instruments was assessed by examining the correlation with each endogenous regressor (see Ziliak, 1997). Since the estimation is conducted on firm-level data, our results are not affected by the aggregation bias and composition effects that generally arise in aggregate data regressions, inducing potentially misleading inference.[8]

4. Results

4.1 *Evidence from the baseline model*

The estimation results are reported in Table 1. The first four rows of Table 1 refer to the reduced form parameters (α, β, ε and θ) and the last four report the implied values of the structural parameters (γ, Δ, ξ and ζ). We are mostly interested in the latter, which provide some insights into the functioning of the production process. The estimate of the returns-to-scale parameter (α is exactly equal to γ) is close to one, and the hypothesis of constant returns

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[7] The measure of monetary shock is obtained from a monthly recursive VAR model estimated at the Bank of Italy over the period 1975-1997 (Dedola and Lippi, 2000). The specification includes the following variables: the industrial production index, the CPI, an index of commodity prices, the three-month interbank rate, the nominal effective exchange rate and M2. The three-month interbank rate is assumed to be the policy variable, determined according to contemporaneous information on the first three series only and to lagged information on all the six series. The error term from the fitted policy rule provides our measure of monetary impulse.

[8] For an insightful discussion on the effect of aggregation bias in production function regressions, see Basu and Fernald (1997a).

to scale is not rejected by our micro-data. Indeed, the γ coefficient is estimated at 1.05, with a standard error of about .05. This finding is in line with most microeconomic evidence reported in the literature (see, for example, Baily, Hulten and Campbell, 1992, for U.S. firms).

Among the parameters related to the intensity of factor utilization, we focus on ζ, representing the elasticity of effort that an employee exerts in one hour of work in response to a change in the number of hours worked. In other words, it is the variation of hourly effort (de) when a unit percentage change in hours per capita (dh) takes place. Consistent with this, change in total effective work per employee is measured by $(dh + de)$.

The estimated value of ζ is -.38, with a standard error of .20. That is, if the number of hours worked by an employee increases by 10 per cent, then his/her hourly effort declines by about 4 per cent, while total effective work per employee increases by roughly 6 per cent $(1 + \zeta)$. In other words, if hours per employee is a pro-cyclical indicator, total effective work per employee is also pro-cyclical, but hourly effort is not. Thus, increasing hours at the margin would lead to a reduction in the effort exerted during the marginal hour.

Using the information on ζ, it is possible to trace the information on the change in hourly effort: $de_{it} = \zeta dh_{it}$. In order to appraise whether our model-based estimate of effort is sensible, we compare it with independent information drawn from the Bank of Italy's survey on the degree of capacity utilization appraised by each firm. We estimated a panel regression of effective work per employee, $dh_{it} + de_{it}$, on the firm-level capacity utilization rate plus a number of dummy variables as control factors (year, sector, size, type of ownership, location, and occurrence of corporate operations). The coefficient associated with capacity utilization is positive and statistically significant (.037 with a standard error of .003). Conversely, if we use labor effort, de_{it}, as dependent variable, the coefficient becomes negative (-.037) and remains strongly significant.

With regard to the other parameters, the elasticity Δ is informative on the shape of the depreciation function $\delta(U)$. Our evidence lends only weak support to the hypothesis that δ is convex, as is generally assumed in the literature, since the estimate for this elasticity is positive but rather imprecise (.81 with a standard error of .66). The elasticity ξ is informative on the degree of convexity of adjustment costs on capital. A positive value of this parameter indicates that the marginal installment cost of capital, $J^{'}$, is increasing in the rate of investment, $\frac{I}{K}$. Our results point to the convexity of capital adjustment costs, since our estimate of the elasticity ξ is positive and statistically different from zero (.12 with a t-statistic of 1.79).

4.2 *Labor effort and hours*

Although the evidence presented in Table 1 indicates that the relationship between effort and the number of hours is negative, this result may not hold in general because, for example, the relationship can be non-monotonic. Indeed, it seems reasonable to assume that, at least initially, an increase in the number of hours is accompanied by an increase in work effort. This is consistent with the broadly recognized fact that, due to adjustment costs in hiring and firing, firms hoard labor during cyclical slowdowns and recessions. When the recovery begins, firms face the increasing demand by augmenting both the number of hours worked and the effort required. In this case, a positive relationship emerges between hours worked and effort. However, simple considerations on the physical fatigue associated with the work effort suggest that there should exist a critical value of hours per capita beyond which every additional hour is worked with decreasing intensity. If this threshold value is reached - for example because new hiring is difficult due to labor market rigidities or technological factors (the need for specific skills) or because of a very fast acceleration in demand - a negative relationship emerges at the margin between hours worked and effort. On the contrary, if this threshold value is not reached, for example because firms increase the number of employees, then the relationship between hours and effort remains positive. Whether one observes one case or the other will depend on both cyclical conditions and the features of the labor market. For example, the positive elasticity estimated by Basu, Fernald and Kimball (1998) with data for U.S. sectors may ultimately be due to the lesser rigidity of the U.S. labor market vis-à-vis the Italian. If this interpretation is correct, U.S. firms resort to new hiring more easily and more often than Italian ones, and are therefore less likely to over-step the critical threshold value of hours per capita.

In graphical terms, we argue that the equilibrium relationship between effort and hours is well captured by a hump-shaped function such as the one depicted in the top panel of Figure 1, where point A corresponds to the critical value of hours per capita. A formal derivation of this equilibrium relationship can be obtained from a simple theoretical model of cost minimization, where the firm rewards both hours and effort (such a model, which is consistent with the one presented in Section 2, is described in Appendix III). The implications for total effective work

$(h+e)$ are the following. If for values of h greater than A the elasticity ζ is negative but less than one in absolute value, then total effective work is positively related to the number of hours for any value of h. In particular, change in total effective work would be more than proportional to change in hours per capita for low values of h and less than proportional for high values of h. The bottom panel of Figure 1 graphically illustrates this situation.

The hypothesis that we have just discussed lends itself to empirical scrutiny. In particular, we need to test whether the relationship between e and h is hump-shaped and, consequently, the relationship between total effective work, $(h+e)$, and hours per employee, $h,$ is "S-shaped". To this purpose, we pursue two different approaches. The first considers a Taylor approximation of the effort function $e(h)$ and, in particular, of its time variation, $de = e_t - e_{t-1}$.[9] Let h^* be the average value of h in manufacturing overall and consider the following second-order approximation around this value:

$$e(h_t) \approx e(h^*) + e^{'}(h^*)(h_t - h^*) + e^{''}(h^*)\frac{(h_t - h^*)^2}{2!}. \tag{8}$$

If we compute the same approximation for $e(h_{t-1})$ and subtract its expression from equation (8), we obtain

$$de \approx e^{'}(h^*)dh + e^{''}(h^*)\frac{1}{2!}[h_t^2 - h_{t-1}^2 - 2h^*(h_t - h_{t-1})], \tag{9}$$

where $e^{'}(h^*) = \frac{de}{dh}|_{h=h^*}$ is equal to ζ. In the regression framework of equation (7), instead of inserting ζdh alone to represent de, we use the above approximation for it (recall that $\beta dh = \gamma\zeta dh = \gamma de$). As a result, the basic specification is augmented with another variable, namely the term $\frac{1}{2}[h_t^2 - h_{t-1}^2 - 2h^*(h_t - h_{t-1})]$, which appears in the right-hand side of (9), pre-multiplied by the labor share c_L. The empirical specification is therefore the following:

$$\begin{aligned} dy_{it} &= \alpha dx_{it} + \beta_0(c_{L,it}dh_{it}) + \beta_1\left[c_{L,it}\frac{1}{2}[h_t^2 - h_{t-1}^2 - 2h^*(h_t - h_{t-1})]\right] + \\ & \varepsilon\left[c_{K,it}\left(dp_{M,it} + dm_{it} - dp_{I,it} - dk_{it}\right)\right] + \theta\left[c_{K,it}(di_{it} - dk_{it})\right] \\ & + b^{'}W_{it} + dv_{it}. \end{aligned} \tag{10}$$

[9] We thank Miles Kimball who suggested us this approach.

The coefficient associated with this new variable, β_1, corresponds to $\gamma e^{''}(h^*)$. If this coefficient is estimated to be negative, then the data do not reject the hypothesis of a hump-shaped effort function. The results of this regression are reported in Table 2. The explanatory variables are those of Table 1 plus the quadratic term that allows for estimating the shape of the effort function. The results lend support to a non-monotonic effort function since the coefficient of the new variable is negative (-.322 with a t-statistic of -2.83); it is important to note that the parameter estimate associated with $c_L dh$ remains negative and statistically significant (-.604 with a t-statistic of -5.79). The parameter estimates for the other variables are also qualitatively invariant.

We also devised an alternative procedure for testing the hypothesis that the effort function, $e(h)$, is non-monotonic. This second approach hinges on the fact that the effort-hours relationship depends on the business cycle conditions in which the firm is operating. In general, situations where effort is increasing in hours per capita (*i.e.*, where firms are located to the left of point A in Fig. 1) should presumably satisfy two conditions. First, they are likely to occur in the aftermath of a demand slowdown or a recession, when firms utilize the hoarded labor more intensively, increasing both hours and effort required. Second, in order to maintain a positive relationship between effort and hours per capita, the latter variable must not increase excessively (otherwise, hours per capita, h, would reach its critical value). These two conditions can be characterized in terms of the behavior of hours per capita. In particular, in order to capture the first condition, we considered observations where the *level* of hours per capita in the previous period is below a "normal" amount, as measured by the firm-specific average (or median) of h_{it} over time. Among such observations, in order to capture the second condition, we selected the subset of data where the *variation* of hours per capita is positive but not unusually great, i.e. not exceeding the firm-specific 75-th percentile. Accordingly, we constructed two dummy variables: the first, $DLEFT$, takes the value of one if: (i) the number of hours per capita in the previous period does not exceed the firm mean or, alternatively, the firm median ($h_{it-1} \leqslant h_i^{mean}$or $h_{it-1} \leqslant h_i^{median}$) *and* (ii) the contemporaneous variation of hours per capita is positive but does not exceed the firm's 75-th percentile $(0 < dh_{it} \leqslant pctile75(dh_i))$. Otherwise, $DLEFT$ is equal to zero.[10] The second

[10] In the second half of the eighties, the reshape of industrial relations in Italian manufacturing has induced a remarkable and largely persistent increase of hours per capita (see Casadio and D'Aurizio, 1999). In principle, the mean-change that has arguably occurred in the latter variable may challenge the view that h_i^{mean} represents a "normal" level of h_{it}. This would imply a disproportionate concentration of unit values of $DLEFT$ in the first

dummy, $DELSE$, takes the value of one when at least one of the above conditions does not hold. In Table 3 we report the estimates obtained by including among regressors the interaction between each of the two dummies and the variable $c_L dh_{it}$. The first and second columns refer to the case where the first condition is captured, respectively, by $h_{it-1} \leqslant h_i^{mean}$ and $h_{it-1} \leqslant h_i^{median}$. The evidence provides support to the hypothesis that work effort is first increasing and then decreasing in hours per capita. Indeed, the elasticity ζ is estimated to be positive in situations where the firm is presumably operating to the left of point A in Figure 1 and to be negative elsewhere. Focusing on the results reported in the first column, the parameter estimates are equal to, respectively, 2.63 (with a standard error of .83) and -.52 (with a standard error of .20). We also experimented with alternative cut-off values for the construction of the dummies, and the results remained substantially unchanged.[11]

As already emphasized, the hypothesis of a hump-shaped relationship between effort and hours stems from physical fatigue considerations. However, effort responds not only to physical conditions but also to other factors, including economic incentives. For example, if the firm and the workers agree upon a wage premium scheme based on performance, this may induce workers to provide, *ceteris paribus*, a greater effort, possibly altering the effort-hours nexus. The availability of data from the SIM survey on wage premia allows us to investigate this issue. In particular, the 2000 survey provides information on whether firms pay wage premia and on the extent to which these premia are linked to the firm's performance. Thus, we focused on the firms included in the 2000 survey and split the sample into two groups: firms that pay labor premia entirely related to performance and all the others (respectively, 40 and 60 per cent of the sample). On the one hand, we found that the provision of performance-related wage incentives affects the relationship under investigation to a statistically significant extent. On the other hand, the payment of these wage premia does not suffice to induce a positive relationship between effort and hours per capita. Indeed, for this group of firms the estimated elasticity of effort to hours per capita, ζ, remains slightly negative but is not statistically significant. [12]

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years of the sample. However, the distribution of $DLEFT$ varies over time only to a very limited extent. Indeed, the annual frequency of unit values of this dummy variables averages .22 in the second half of the eigthies and .17 in the period 1990-1997.

[11] For example, we expressed the first condition as ($h_{it-1} \leqslant pctile25(h_i)$) and the second condition as ($0 < dh_{it} \leqslant dh_i^{mean}$) or, alternatively, ($0 < dh_{it} \leqslant dh_i^{median}$).

[12] The elasticity ζ is estimated to be .01 with a standard error of .14 in situations where wage premia are

5. Conclusion

Cyclical variations in unobserved labor utilization are commonly recognized as a crucial feature of economic fluctuations. They are due to the existence of adjustment costs in hiring and firing, which induce firms to hoard labor, and represent an important shock transmission mechanism in the economy. While variable labor effort is a typical element of demand-driven models, in recent years it has also been successfully incorporated in real business cycle (RBC) models. Empirically, unobserved labor utilization is estimated to account for a sizeable portion of the cyclical fluctuations of standard measures of labor and multifactor productivity.

In spite of its central role for economic fluctuations, very little is known about the behavior of labor effort over the business cycle, in part because of its intrinsic unobservability and because of the complexity of the interrelations to be investigated. Moreover, very few contributions have investigated the matter using microeconomic data, as required by the theory. In this paper we compute a measure of variable labor effort from a dynamic cost minimization set-up that takes into account potential deviations from constant returns and perfect competition as well as cyclical variation in labor and capital utilization. Our empirical framework is estimated on panel data at the firm level, thus avoiding the potentially serious problems induced by aggregation.

While effective labor input per employee is positively correlated with hours per capita, the relationship between hours and work effort is less obvious. In particular, we show that the positive relationship between hours and effort, which is commonly assumed in the literature, is only a particular case of a non-monotonic relationship between the two variables. During an economic recovery, if the number of hours per capita reaches a critical level, possibly because new hiring is discouraged by labor market rigidities, every additional hour is worked with decreasing effort due to physical fatigue. We provide evidence that supports our claim by estimating the structural parameters of a Taylor approximation of the effort function. Moreover, corroborating results have been obtained by estimating the elasticity of effort with respect to hours at different business cycle conditions.

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entirely linked to performance. Conversely, it is estimated to be -.782 with a standard error of .20 in situations where wage premia are not paid or are not entirely linked to performance. We thank Andrea Brandolini who suggested us to investigate this issue and Leandro D'Aurizio who provided crucial data on the matter.

Appendix I: Optimality conditions

The first order conditions of the constrained optimization problem (4) in the text are the following (see Basu and Kimball, 1997):

$$H: \quad \lambda \frac{\partial F}{\partial \widetilde{L}} EL = WL \frac{\partial G}{\partial H} \tag{A.1}$$

$$E: \quad \lambda \frac{\partial F}{\partial \widetilde{L}} HL = WL \frac{\partial G}{\partial E} \tag{A.2}$$

$$U: \quad \lambda \frac{\partial F}{\partial \widetilde{K}} K = qK \frac{\partial \delta}{\partial U} \tag{A.3}$$

$$M: \quad \lambda \frac{\partial F}{\partial M} = P_M \tag{A.4}$$

$$A: \quad \phi = W\Psi' \tag{A.5}$$

$$I: \quad q = P_I J' \tag{A.6}$$

where λ, ϕ, and q are the Lagrange multipliers associated, respectively, with the first, second and third constraints. The Euler equations for the quasi-fixed factors are:

$$N: \quad \overset{\circ}{\phi} = r\phi - \lambda \frac{\partial F}{\partial \widetilde{L}} EL + WG + W(\Psi - \frac{A}{L}\Psi') \tag{A.7}$$

$$K: \quad \overset{\circ}{q} = (r+\delta)q - \lambda \frac{\partial F}{\partial \widetilde{K}} U + P_I(J - \frac{I}{K}J') \tag{A.8}$$

Combining condition (A.3) with the expression for marginal product of capital stemming from equation (3) in the text ($\frac{\partial F}{\partial \widetilde{K}} = \mu s_K \frac{Y}{UK}$) yields

$$U\frac{\partial \delta}{\partial U} = \frac{\lambda}{q}\mu s_K \frac{Y}{K}; \tag{A.9}$$

similarly, the joint consideration of condition (A.4) and of the expression for marginal product of intermediate inputs gives

$$\lambda\mu = \frac{P_M M}{s_M Y}; \tag{A.10}$$

if we combine the expression for marginal productivity of capital with (A.10), the following relation holds:

$$\lambda \frac{\partial F}{\partial \widetilde{K}} = \frac{s_K}{s_M} \frac{P_M M}{UK}; \tag{A.11}$$

putting together (A.9), (A.10) and condition (A.6) yields

$$U \frac{\partial \delta}{\partial U} = \frac{s_K}{s_M} \frac{P_M M}{P_I J' K}. \tag{A.12}$$

If we differentiate the above equation with respect to time and divide both sides by $U \frac{\partial \delta}{\partial U}$, we obtain equation (5) in the text for percentage changes in capital utilization.

If we insert (5) and (6) into equation (2) in the text and use the expressions (3) for output elasticities, we obtain the estimating equation (7).

Appendix II: Data description

Sources. The two main sources used in the paper, both at the firm level, are the Bank of Italy Survey of Investment in Manufacturing (SIM) and the Company Accounts Data Service (CADS). The SIM database goes back to 1984. The questionnaire is sent to each enterprise at the beginning of each year; the questions refer to the year just past and the previous year (this allows data consistency to be checked over time). Interviewers are officers of the Bank of Italy, who tend to establish long-run relationships with firms' managers and are also responsible for verifying the accuracy of the information collected. The sample is stratified according to three criteria: sector of economic activity, size and geographical location. With regard to the first, the three-digit Ateco-91 classification of the National Institute of Statistics (ISTAT) is used (fully consistent with the international Standard Industrial Classification). Size refers to the number of employees; four classes are considered: 50-99, 100-199, 200-999 and 1000+. Due to difficulties in ensuring high quality in the data collection, firms with fewer than 50 employees are excluded. Firm location refers to the regions (nineteen). The presence of outliers and missing data within the sample is dealt with by appropriate statistical techniques.

The company accounts report is a data service provided by an institution (*Centrale dei Bilanci*) established by the Bank of Italy and a pool of banks. Information on the annual accounts of around 30,000 Italian firms has been collected since 1982 and data are reclassified to ensure comparability across firms.

Panel structure. Merging the information from the two sources resulted in an unbalanced panel of around 1,000 firms. After taking rates of growth, there are a total of 6,811 observations. The structure of the sample by number of observations per firm is reported in Table A.1.

Table A.1

Sample structure by number of observations per firm

Number of annual observations	3	4	5	6	7	8	9	10	11	12	13
Number of firms	136	130	103	88	80	73	80	96	37	42	85

Source: SIM and CADS.

Sectoral classification. The sectors of economic activity in manufacturing industry are: 1) Food and tobacco products; 2) Textiles and Clothing; 3) Leather and footwear; 4) Wood and furniture; 5) Paper and publishing; 6) Chemicals; 7) Rubber and plastic products; 8) Transformation of non-metalliferous minerals; 9) Metals and Metallurgy; 10) Machinery for industry and agriculture; 11) Electrical machinery (including computers and office equipment); 12) Transport equipment (automobiles, railway trains, ships, aircraft and other motor vehicles) and 13) Other manufactures.

Variable definitions and sources. Gross output is measured as firm-level production (source: SIM) deflated by the sectoral output deflator computed by ISTAT. Employment is firm-level average employment over the year (source: SIM). Man-hours are also firm-level and include overtime hours (source: SIM). Information on hours effectively worked is available after 1989, while that on hours paid is available from 1984 to 1995. To ensure data coherence, we used a correction coefficient equal to the firm-specific time average of the ratios of hours paid to hours worked computed over the period for which data on both variables are available. The use of intermediate inputs is measured as firm-level net purchases of intermediate goods of energy, materials and business services (source: SIM), deflated by the corresponding sectoral deflator computed by ISTAT. Investment is firm-level total fixed investment in buildings, machinery and equipment and vehicles (source: SIM), deflated by the sectoral investment deflator published by ISTAT. Capital stock is measured as the beginning-of-period stock of capital in equipment and non-residential buildings at 1997 prices. It was computed by applying backwards a procedure based on the perpetual inventory method (using firm-level investment figures from SIM and sectoral depreciation rates from ISTAT), using as a benchmark the information on the capital stock in 1997 (valued at replacement cost), collected by a special section of the Bank of Italy Survey conducted for that year. The capital deflator is the sectoral capital deflator computed by ISTAT.

In order to construct the series of the required payment to capital, $rP_K K$, we used the firm-level, time-varying estimates of the user cost of capital computed at the Bank of Italy by De Mitri, Marchetti and Staderini (1998) on the basis of the SIM and CADS datasets. A further source is the Credit Register (CR) data, which are collected by a special unit of the

Bank of Italy (*Centrale dei Rischi*) and include detailed information on bank-firm contracts. De Mitri *et al.* (1998) followed the well-known Hall-Jorgenson approach, as developed by Auerbach (1983) for firms that use both equity and debt finance. Thus, the user cost of capital is expressed as follows:

$$r = \frac{(1-S)}{(1-\tau)}\left[gi(1-\tau)+(1-g)e-\pi+\delta\right] \qquad \text{(A. 13)}$$

where τ is the corporate tax rate and S reflects corporate tax rates, investment tax credits, depreciation allowances and any relevant subsidy, all of which are set to the appropriate firm-specific value according to Italian law in the given year and to a number of firm characteristics; g is the firm-specific ratio of financial debt to total liabilities (source: CR); i is the average borrowing rate payed by the firm (source: CR); e is the nominal return to equity (i.e., the opportunity cost associated with holding part of the firm's equity), approximated by the average yield of Italian Treasury bonds (BTP), on the ground that the equity premium on the Italian stock market is usually estimated to have been negligible, or even negative, during most of the period considered; π is the sector-specific expected increase of capital good prices (source: SIM) and δ is the sectoral rate of capital depreciation (source: ISTAT).

Descriptive statistics of key variables. See Table A.2.

Table A.2

Descriptive statistics of selected variables (percent)

Variable	*25th perc.*	*50th perc.*	*75th perc.*	*Mean*
Gross output growth, dy	-6.4	3.0	12.4	2.9
Total hours growth, $(dn + dh)$	-3.3	.2	4.3	.7
Capital stock growth, dk	-3.0	-.5	2.9	.8
Materials growth, dm	-7.6	3.0	13.8	3.0
Labor cost-share, c_L	15.0	20.5	26.9	21.9
Capital cost-share, c_K	7.6	13.1	20.8	15.5
Materials cost-share, c_M	53.4	64.5	73.4	62.9

Source: SIM and CADS.

Appendix III: The equilibrium relationship between hours and effort

In the theoretical framework illustrated in Section 2 a compensation function, $G(H, E)$, is introduced, reflecting how the firm rewards hours and effort. Combining the first order conditions with respect to H and E (see equations A.1 and A.2 in Appendix I), we get that at the optimum the elasticity of cost with respect to hours has to be equal to the elasticity of cost with respect to effort, $\frac{G_H H}{G} = \frac{G_E E}{G}$. If it is actually true that the higher the number of hours, the lower is the effort spent in the marginal hour, then the compensation (cost) function would take this into account. Thus, compensations would be such that the greater the firm demands E and H, and the higher the cost to compensate them, the more advantageous it is for the firm to increase hours relatively to effort. A simple way to rationalize this is by considering the following cost-minimization problem of the firm:

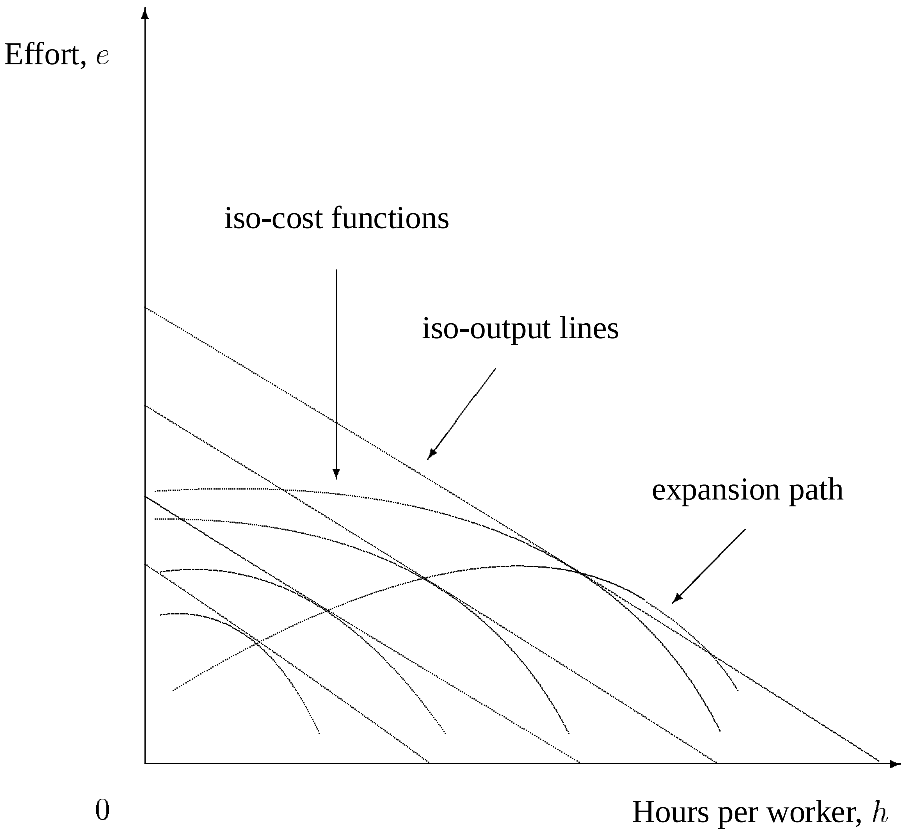
$$\begin{aligned} \underset{H,E}{Min} \quad \log[G(H,E)] &= \underset{h,e}{Min} \quad g(h,e) \\ s.t. \quad y &= c_L(h+e) \end{aligned} \qquad \text{(A. 14)}$$

where, for simplicity, we abstract from considering all inputs except labor and normalize the number of employees to one.[13] Following Basu and Kimball (1997), we assume convexity of the g function. The iso-cost *loci* and the iso-output *loci* are illustrated in Figure A.1 for different amounts of the expenditure for compensation and for different output levels. The compensation scheme underlying the function g is devised so as to satisfy the hypothesis advanced earlier. Therefore, g is formulated so that the resulting expansion path for h and e is hump-shaped, as in the figure.

[13] In the objective function we define $g(h, e)$ as $\log[G(H, E)]$. Moreover, without loss of generality, we consider a very simple Cobb-Douglas production function: $Y = (HE)^{c_L}$; taking the logarithmic transformation, it becomes $y = c_L(h + e)$.

Figure A.1

Hours and effort: The equilibrium relationship



Tables and figures

Table 1

Baseline model - Equation (7)

GMM estimates on firm-level panel data

Dependent variable: dy_{it}	
dx_{it}	1.054 (.056)
$c_{L,it}dh_{it}$	-.404 (.210)
$c_{K,it}(dp_{M,it} + dm_{it} - dp_{I,it} - dk_{it})$	.582 (.190)
$c_{K,it}(di_{it} - dk_{it})$	-.069 (.033)
Wald tests of joint significance:	
year dummies	40.2 (12; .001)
sectoral dummies	33.6 (12; .001)
firm size dummies	8.4 (4; .079)
corporate operat. dummies	11.0 (6; .088)
Sargan test of over-identifying restrictions	62.4 (68; .67)
Test of 2^{nd} order serial correlation	-.64 (.52)
Wald tests for weak instruments:	
dx_{it}	420.9 (106; .00)
$c_{L,it}dh_{it}$	290.0 (106; .00)
$c_{K,it}(dp_{M,it} + dm_{it} - dp_{I,it} - dk_{it})$	492.8 (106; .00)
$c_{K,it}(di_{it} - dk_{it})$	287.0 (106; .00)
Implied estimates of structural parameters	
$\gamma = \alpha$	1.054 (.056)
$\zeta = \frac{\beta}{\gamma}$	-.384 (.20)
$\Delta = \frac{\gamma - \varepsilon}{\varepsilon}$	.811 (.657)
$\xi = -\frac{(1+\Delta)\theta}{\gamma}$	.118 (.066)

Legend: the sample period is 1984-1997. Variables and parameters are defined in the text. Heteroschedasticity-consistent standard errors for parameter estimates are shown in brackets. For each test, degrees of freedom and p-values are reported in brackets; the test for second-order serial correlation is distributed asymptotically as a standard normal. The instrument set comprises: lagged values of the endogenous explanatory variables at time t-2 and t-3; contemporaneous growth rate of material input prices and of the real exchange rate; variation of sectoral order-book levels drawn from the ISAE business survey; a VAR-based measure of monetary shock. In the Wald tests for weak instruments the null hypothesis is that instruments jointly explain none of the variation in the endogenous variable. S.e. of structural parameters are not heteroschedasticity-consistent.

Table 2

The shape of the effort function - Equation (10)

GMM estimates on firm-level panel data

Dependent variable: dy_{it}	
dx_{it}	.959 (.024)
$c_{L,it} dh_{it}$	-.517 (.084)
$c_{L,it} \frac{1}{2}[h_{it}^2 - h_{it-1}^2 - 2h^*(h_{it} - h_{it-1})]$	-.237 (.111)
$c_{K,it}(dp_{M,it} + dm_{it} - dp_{I,it} - dk_{it})$	.958 (.084)
$c_{K,it}(di_{it} - dk_{it})$	-.020 (.015)
Sargan test of over-identifying restrictions	170.22 (166; .40)
Test of 2^{nd} order serial correlation	-2.21 (.03)

Legend: see Table 1. The sample period is 1984-1997. The specification comprises all the control dummy variables of the specification in Table 1. Values of Wald tests for the joint significance of these control variables are not reported. The instrument set is the one of the regressions of Table 1. In addition, lagged values of the new variable dated t-2 and earlier are included.

Table 3

The elasticity of effort with respect to hours

at different business cycle conditions

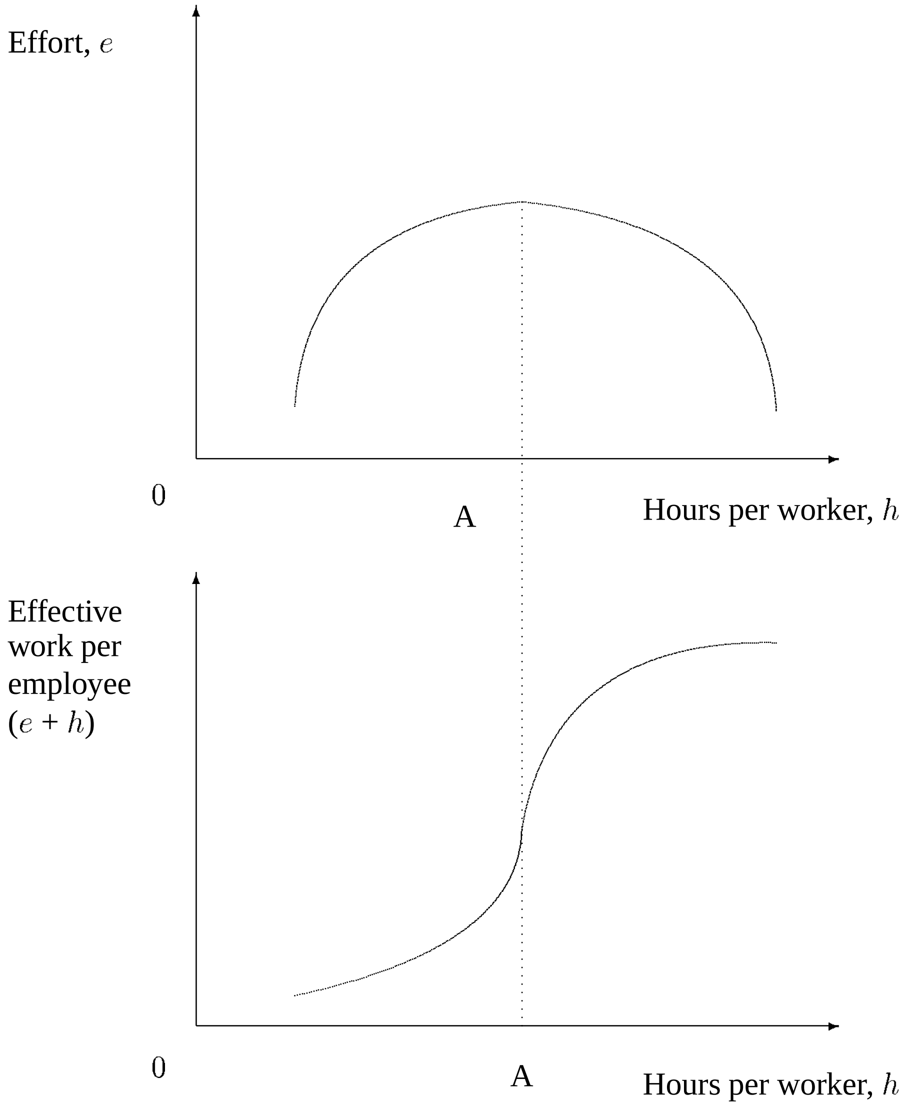
GMM estimates on firm-level panel data

Dependent variable: dy_{it}	(1)	(2)
dx_{it}	1.003 (.045)	.986 (.044)
$DLEFT * c_{L,it}dh_{it}$	1.660 (.932)	1.499 (.669)
$DELSE * c_{L,it}dh_{it}$	-.688 (.141)	-.762 (.154)
$c_{K,it}(dp_{M,it} + dm_{it} - dp_{I,it} - dk_{it})$	.901 (.123)	.854 (.118)
$c_{K,it}(di_{it} - dk_{it})$	-.009 (.022)	.011 (.022)
Sargan test of over-identifying restrictions	83.66 (88; 0.61)	83.53 (88; .62)
Test of 2^{nd} order serial correlation	-.68 (.49)	-.68 (.50)

Legend: See Table 1. The sample period is 1984-1997. In column (1), $DLEFT = 1$ if $h_{it-1} \leqslant h_i^{mean}$ and $0 < dh_{it} \leqslant pctile75(dh_i)$; $DLEFT$ is equal to zero otherwise. $DELSE = 1$ if $DLEFT = 0$. In column (2), $DLEFT = 1$ if $h_{it-1} \leqslant h_i^{median}$ and $0 < dh_{it} \leqslant pctile75(dh_i)$. The specification comprises all the control dummy variables of the specification in Table 1, plus two geographical dummies (North and South), which were found to be significant. Values of Wald tests for the joint significance of these control variables are not reported. The instrument set is described in Table 1.

Figure 1

Effort and effective work per employee



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