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DIRECT AND INDIRECT LABOR AND DEMAND FOR WORKERS AND WORKING HOURS

by
PAOLO PALAZZI * and PAOLO PIACENTINI *

Abstract

The main purpose of the paper is to estimate a function of demand for labor (both for production workers and working hours) for the U.S. Manufacturing Industry for the period 1956-84.

The proposed functional form includes, among explanatory variables, the stock of capital and its average age in addition to output and trend. Such a specification is aimed at capturing the incidence of the "indirect" component of labor input, whose behavior cannot be described in a flow-to-flow relationship with output, and is assumed to be complementary to the accumulation of capital.

The average age variable is aimed at partially capturing the effect of the embodied technical progress.

The results of the estimations appear to be encouraging for the basic hypotheses.

Introduction

In recent years "segmentation" theorists have increasingly challenged the positing of homogeneous labor as a feasible model. Different characteristics of two (or more) segments of the labor force are often expressed in terms of social, behavioral, racial factors, etc.; these elements are essentially extrinsic to the strictly technical features of the production process. This paper

* University of Rome.

explores the implications of a particular type of heterogeneity in the work force which stems from differences in the role and characteristics of labor utilization *inside* the production process. The most obvious example is the distinction between white collar and manual labor; but also within the aggregate which is normally classified in statistical sources as "production" or "operative" labor, it seems increasingly relevant to make a distinction between "directly" and "indirectly" productive components. This dichotomy is not expressly related to the personal characteristics of the labor force (such as sex or age referred to in segmentation theories); rather, it emerges from differences in the nature of the tasks performed, independently of these individual factors. In this paper various implications of this duality hypothesis will be developed in terms of a model of labor demand; major results of empirical estimates for manufacturing in the United States from 1956 to 1984 will also be outlined.

The Composition of Total Labor Input

The traditional approach to empirical analysis of demand for operative labor posits a homogeneous labor input whose relationship to the level of production (in terms of elasticity, lagged response, etc.) is explored using different behavioral hypotheses to explain demand for labor. Introducing a concept of "labor hoarding" and/or existence of lags in the adjustment of current input requirements to optimal demand does not contradict the core of the traditional vision of labor input as flow of productive services functionally related to the flow of production.

In partial contrast to this framework, it will be proposed that it is possible and useful to distinguish between "direct" and "indirect" components within the aggregate of "production" labor. This distinction is to a certain degree an extension of the traditional dichotomy between productive and "overhead" labor, the latter generally defined as clerical, administrative and a part of technical personnel. It is our belief that a significant sector exists, within the aggregate designated as "production" or "operative" labor, whose functional determination and dynamic behavior cannot be incorporated into the "flow against flow" theory; this sector's "quasi-fixed" nature in the face of short-run output fluctuation calls for further or alternative causal explanation. Unfortunately, the distinction between "directly productive" and "indirect" labor cannot be quantitatively ascertained with available statistics; rigorous investigation would require case studies of individual processes. Furthermore, over the course of a work year or even during a work day, the same personnel may perform both direct and indirect tasks; thus, a clear indentification of direct versus indirect workers and corresponding work-time may not be feasible. The introduction of this dichotomy into labor input theory, may, nevertheless, be useful in interpreting current behavior of aggregate work hours and employment.

In particular, this new aspect may bear upon the perennial controversy over the interpretation of empirical evidence of increasing returns to labor in the short-run, and possible ways of reconciling this evidence with orthodox models of factor demand by firms.

According to the theory of the influence of an "overhead" component upon behavior of aggregate labor input, this component's rigidity throughout the cycle would explain the procyclical behavior of measured (average) productivity; such a hypothesis has often been advanced as the most convincing explanation of the "increasing returns" paradox. As a rule, however, the "overhead" component has been wholly identified with nonproduction (clerical/administrative/certain technical) workers; while the empirical analysis restricted to the aggregate of production workers, still prevailingly showed evidence of SRIRL [1]. It is believed that this framework, to wit searching for a rationale for non-proportionalities between work hours and output variability within the production process itself, might represent a valid groundwork for interpreting these phenomena.

The Model

Let those work hours, functionally related to output on a flow-to-flow basis, be termed "directly productive (or more briefly, direct) hours". Any variation of production thus requires some variation of direct hour input.

Indirectly productive (indirect) hours are those work hours that, *although technologically necessary for the realization of the production process, do not depend on output flow.*

All production processes, even the most primitive, require a quota of total labor time for overseeing the instrumental inputs and the goods involved in the production process (maintenance and repair, storage, etc.).

Apart form specifying indirect tasks, however, it is more important to point out that advances in technological sophistication have a tendency to raise the degree of separation of the worker from the production process in its narrower sense. The cutoff point is automation, where the entire process

[1] For a recent discussion, see COSTRELL (1982). For evidence of increasing returns when production workers alone are considered, see HULTGREN (1965), FÁIR (1969).

of transformation of material inputs is accomplished by automata; residual hours of operative workers may be considered a complement to machinery, necessary for its proper operation and control.

A simple formalization of an empirically testable model will now be attempted on the basis of these definitions.

a) "Direct" hours imply a flow-to-flow relation with output; an elasticity coefficient specifies the required proportionality. At this point what interests us is a theoretical formulation of an optimal hours requirement; therefore, specifications for lagged response or "labor excess" with respect to an optimal level, due to the existence of "labor hoarding" margins, will not be introduced.

The relationship between hours and output will be altered over time by technical progress. Without imposing unneccessary restrictions, one may imagine technical progress operating through both a "disembodied" trend and an "embodied" component; this advancement necessitates prior investment to incorporate new technology and to improve average efficiency of capital stock.

Thus the functional relationship for direct hours may be specified in the following form:

$$HP_t = \frac{e^{-\delta t} Y_t^{\alpha}}{\mu (K_t)}$$

where HP = direct hours, δ is the exogeneous rate of disembodied technical progress and $\mu (K_t)$ is an efficiency index, to be specified, associated with capital stock in operation during period t.

b) Detailed specification of the indirect hours requirement would call for an investigation of the technical structure of each particular process. No such information is available at the level of aggregate data; thus, a plausible approximation must be determined. If indirect hours are chiefly devoted to servicing productive equipment rather than to manufacturing of materials, then the capital stock in use could be considered an indicator of productive capacity; the indirect hours requirement is derived from this reasoning. In such a simple hypothesis, the level of these hours is related to the capital stock in operation and is "fixed" in the short-run with respect to variations in output. It should be noted that the relationship implied between labor and capital is reversed with respect to a traditional two-factor production function; this is so because an assumption of complementarity is introduced between indirect components of labor input and capital stock.

The following is a quote from A.M. Okun:

"For example, labor may be needed to maintain overhead capital: a worker may be needed merely to lubricate an idle machine. In that case, the employment of such a worker is necessary in a slump, although the reason he is needed stems not from any fixity in the labor factor, but rather from a production function in which capital and labor are complementary (and not substitutive) in the short-run" (Okun, 1981, p. 17).

In the hypothesis set forth in this paper short-run complementarity concerns a section of the total work force; it is agreed that the requirement for indirect labor to service capital stock should be mainly related to the stock of the latter, rather than to its rate of utilization [2].

Labor saving through technical progress should also occur with respect to indirect hours through disembodied and embodied (e.g., new machinery requiring less servicing) components. Hence, the equation would be as follows:

$$HF_t = \frac{e^{-\delta' t} K_t^{\beta}}{\mu' (K_t)}$$

where HF = indirect hours, and K = capital stock.

An appropriate operational model for empirical estimates must be specified in order to test the hypothesis of a dual structure of labor input.

The dependent variable in the equation shall be represented by the sum of HP and HF, to wit total labor input (number of hours worked by "production" workers, or the number of production workers employed); the dependent variable is specified in this way given the impossibility, as noted earlier, of making separate estimates of "directly" and "indirectly" productive labor input.

Formulation of the function $\mu (K_t)$, indicating the degree of efficiency embodied in capital stock, is surely the most difficult task. An "efficiency index" should include the rate of "embodied" technical progress and some indicator of the vintage structure of the stock in use. From the obvious consideration that recent investment in all likelihood incorporate more efficient technologies, a higher share of newer to total capital stock should increase efficiency, coeteris paribus. For the rate of embodied technical progress, we are here only able to add a further trend element, while we assume that the temporal structure of the stock in use can be adequately described by the average age of the stock; i.e. greater average age is a proxy for lower efficiency. Thus the formulation is as follows:

[2] Complementarity between total labor input and capital stock also emerges from estimations in pluri-factor (KLEM) input demand models. (See Morrison and Berndt, 1981).

$$\mu(K_t) = \mu'(K_t) = \lambda_0 e^{\lambda t} A_t^{-\gamma}$$

where λ = rate of "embodied" technical progress; A_t = average age of capital stock at time t.

The complete function for total labor input requirement thus becomes:

$$H_t = HP_t + HF_t = (e^{-\delta t} Y_t^{\alpha} + e^{-\delta' t} K_t^{\beta})\, \lambda_0 e^{-\lambda t} A_t^{\gamma} \tag{1}$$

The following log linear expression for the empirical estimation may be derived from this function:

$$\lg H_t = C + \alpha(1-f)\cdot \lg Y_t + \beta f \lg K_t + \\ + \gamma \lg A_t - [\lambda + \delta' f + \delta(1-f)]t \tag{1'}$$

where C = constant term; $f = \frac{HF}{H}$ (the share of indirect labor to total labor)[3].

It is clear from the above equation that the coefficients of output and capital stock are determined by the elasticities of direct and indirect labor weighted by their respective share of total labor input. Hence, the empirical estimate of labor elasticity with respect to output will be decisively influenced by labor input structure.

Constant or decreasing returns on directly productive labor input become compatible with apparent evidence of increasing returns when total labor input is considered.

Empirical Results

Equation (1′) and a modified version were tested on U.S. manufactur-

[3] The linear function expressed in logarithms may be considered to be approximately hold, given the expression in terms of variation rates:

$$\mathring{H} = \frac{HP}{H}\mathring{HP} + \frac{HF}{H}\mathring{HF} = -[\lambda + \delta' f + \delta(1-f)] + \alpha(1-f)\mathring{Y} + \\ + \beta f \mathring{K} + \gamma \mathring{A}$$

Unfortunately, some "external" information would be required for the purpose of knowing the share "f" and thus identifying elasticity parameters. Patterns of technical progress leading to changing proportions of direct and indirect labor inputs may in the longer run imply instability of the estimated elasticities.

ing data for the period 1956-1984, for both total work hours and number of production workers [4].

The modified version of equation (1) is derived from a simple algebraic operation which allowed introduction of the capital/output ratio as a variable (K_t/Y_t). Equation (1) can be rewritten in the following way:

$$(2) \qquad H_t = \left[e^{-\delta t} Y_t^{\alpha} + e^{-\delta' t} \left(\frac{K_t}{Y_t} \right)^{\beta} Y_t^{\beta} \right] \cdot A_t^{\gamma} e^{\lambda t}$$

And the following logarithmic expression may be derived from the above equation:

$$(2') \qquad \lg H_t = C + [\alpha(1-f) + \beta f] \lg Y_t + \\ + f\beta \lg \left(\frac{K_t}{Y_t} \right) - [\lambda + \delta f + \delta' (1-f)]\, t + \gamma \lg A_t$$

The only difference between equations (1′) and (2′) lies in the value of the production coefficient; in equation (2′) the value is determined by the sum of the production and capital stock coefficients of equation (1′).

The two equations have been formulated utilizing both the number of hours worked by production workers and, directly, the number of production workers in the manufacturing sector, to determine labor input. Manufacturing production data was used to determine the value of output. With regard to capital stock for absolute accuracy only net capital data should be used, in view of the fact that this data more accurately represents the make-up and technological structure of machinery actually in use; as is well-known, however, the depreciation computation in the available data is based on very elementary (straight line) depreciation hypotheses; for this reason, both series of net capital and gross capital stock were used.

Estimates were formulated utilizing annual data; in this way structural components of labor demand, independent of the short-run cycle, may be more accurately determined. The estimates are expressed in both a logarithmic base and in terms of variation rates; the latter are suitable for verifying the stability of the relationships and for reducing possible phenomena of multicollinearity. The results of our estimates are indicated in Table 1 and

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[4] Sources: Average weekly hours and production indexes – *Economic Report of the President*, February 1985 - Tables B-38 and B-42.

Production and related workers. U.S. Dept. of Labor. *Emloyment and Earnings*, 1984.

Constant cost valuation of fixed nonresidential private capital (gross and net) and average age (gross and net) – U.S. Dept. of Commerce. Bureau of Economic Analysis. *Fixed Reproducible Tangible Wealth in the U.S. 1925-84* - Table A-1.

2. It seems feasible to state in general that the results tend to confirm the initial hypotheses with respect to labor input expressed in work hours as well as to the number of production workers [5].

TABLE 1.

DEPENDENT VARIABLE: TOTAL HOURS WORKED BY PRODUCTION WORKERS

Trasformations	C	t	Y	KN	KG	KN/Y	KG/Y	A_{t-1}	R^2C	DW
lg	− 1.63 (2.27)	− 0.05 (16.21)	0.84 (39.9)	0.70 (6.76)				0.57 (5.00)	0.986	1.182
lg - *CO*	− 1.59 (1.68)	− 0.05 (12.10)	0.86 (32.9)	0.68 (4.75)				0.55 (3.76)	0.999	1.831
lg	− 4.85 (4.07)	− 0.05 (16.21)	1.54 (14.27)			0.70 (6.76)		0.57 (5.00)	0.986	1.182
lg - *CO*	− 4.73 (2.95)	− 0.05 (12.10)	1.54 (10.78)			0.68 (4.65)		0.55 (3.76)	0.999	1.931
lg	− 4.03 (4.16)	− 0.06 (16.37)	0.91 (45.26)		0.94 (7.89)			0.63 (4.7)	0.990	1.258
lg	− 8.34 (5.52)	− 0.06 (16.37)	1.85 (14.37)				0.94 (7.89)	0.63 (4.7)	0.990	1.258
RV	− 4.49 (11.16)		0.87 (25.37)	0.52 (3.36)				0.37 (2.09)	0.976	2.408
RV	− 4.91 (10.33)		1.46 (9.82)			0.60 (3.65)		0.40 (2.31)	0.977	2.182
RV	− 5.6 (9.15)		0.88 (28.79)		0.90 (3.85)			0.63 (2.29)	0.978	2.535
RV	− 6.05 (8.35)		1.79 (7.86)				0.90 (3.82)	0.55 (2.11)	0.978	2.079

Legenda: C = Constant; t = Trend; Y = Production index; KN = Capital stock net; KG = Capital stock gross; A = Average age of capital stock (net or gross); *lg* = Natural logarithm; *RV* = Yearly rate of variation; *CO* = Cochrane-Orcutt transformation.

[5] For logorithmic estimates where the D.W. index indicated the presence of first order autocorrelation, estimates on variables, transformed in accordance with the Cochrane-Orcutt method, are also included. (Note how the coefficient values show good stability).

TABLE 2.

DEPENDENT VARIABLE: NUMBER OF PRODUCTION WORKERS

Trasformations	C	t	Y	KN	KG	KN/Y	KG/Y	A_{t-1}	R^2C	DW
lg	− 4.8 (6.12)	− 0.05 (14.36)	0.71 (31.09)	0.76 (6.76)				0.41 (3.31)	0.980	1.377
lg - CO	− 5.33 (5.4)	− 0.05 (11.63)	0.71 (27.8)	0.85 (5.74)				0.47 (3.17)	0.992	1.820
lg	− 8.31 (6.4)	− 0.05 (14.36)	1.47 (12.55)			0.76 (6.76)		0.41 (3.31)	0.980	1.377
lg - CO	− 9.22 (5.56)	− 0.05 (11.63)	1.56 (10.41)			0.85 (5.74)		0.47 (3.17)	0.992	1.820
lg	− 4.8 (3.3)	− 0.05 (9.58)	0.79 (26.4)		0.73 (4.11)			0.07 (.36)	0.972	1.237
lg	− 8.16 (3.61)	− 0.05 (9.58)	1.52 (7.93)				0.73 (4.11)	0.07 (.36)	0.972	1.237
RV	− 4.85 (9.86)		0.66 (15.85)	0.89 (4.67)				0.53 (2.45)	0.948	2.307
RV	− 5.22 (8.09)		1.55 (7.68)			0.88 (3.97)		0.46 (1.97)	0.940	1.988
RV	− 6.38 (7.76)		0.70 (16.99)		1.36 (4.33)			0.74 (2.02)	0.944	2.125
RV	− 6.19 (5.6)		1.78 (5.14)				1.07 (2.96)	0.38 (.96)	0.927	1.92

Legenda: C = Constant; t = Trend; Y = Production index; KN = Capital stock net; KG = Capital stock gross; A = Average age of capital stock (net or gross); lg = Natural logarithm; RV = Yearly rate of variation; CO = Cochrane-Orcutt transformation.

In particular, the confirmation of the existence of a direct relationship between labor demand for production workers and hours and industrial productive capacity, indicated by (net or gross) capital stock and by the capital/income ratio, seems significant. This demonstrates how the theory of indirect labor also existing within the aggregate of production workers can be tested using variables representing technological structure. Accepting this framework, one can draw interesting inferences regarding labor elasticity coefficients with respect to production. In all our estimates, the coefficients were found to be less than unity, demonstrating increasing returns. As shown earlier, however, this coefficient is the product of directly productive labor elasticity and its weight in aggregate labor input. For example, these results can be considered compatible with a coefficient of actual elasticity of direct work hours with respect to output equal to or greater than one, where the share of indirect work hours is greater than a value of 12-13%.

As was to be expected, the production coefficient in the employment equations is considerably lower. With regard to labor demand expressed in number of workers, institutional rigidity factors (adjustment costs, etc.) should be considered greater here than in the case of work hours; hence, elasticity coefficients equal to or greater than unity, also with regard to directly productive workers only, are extremely unlikely. Finally, it should be noted how the logarithmic estimates of labor demand, in which the capital/income ratio variable is clearly stated, demonstrate that the coefficients correspond almost exactly to the algebraic sum of the production and capital coefficients in equation (1′) [6]; in coherence with the algebraic transformation implied.

All coefficients of labor elasticity demonstrate a significant direct relationship to capital stock variation. Coefficient values are considerably lower for estimates in which net capital is used; a reasonable explanation, however, may be found for this systematic divergence [7].

It should be noted that elasticity coefficients, with respect to capital, are higher for labor input in terms of workers than in terms of work hours; this is in contrast with what occurred for production. As could be predicted, however, the value vary only slightly, as they refer to fixed labor input in which work hours and employment should have the same dynamic.

Average age coefficients are positive and above significance levels, with a time lag of one year in all cases, with the exception of the equations

[6] In the variation rate estimates, the production coefficient in equation with the capital/product ratio also has values close to the sum of the Y and K coefficients in the base equation; in this case, however, the algebraic construction does not entail an exact relationship.

[7] Defining labor input elasticity in relation to net and gross capital as ε_N and ε_G respectively, one can easily demonstrate the following equation, approximating in terms of finite variation:

$$\varepsilon_G/\varepsilon_N = \frac{1 - \Delta D/\Delta K_G}{1 - D/K_G}$$

where D = cumulative depreciation ($K_G = K_N + D$)

If investments are prevalently increasing over time, the marginal incidence of D is less than the average incidence; thus $\varepsilon_G/\varepsilon_N$ will be greater than one. This is also confirmed by the regression coefficients for variation rates of K_G over K_N.

using gross capital stock in employment equations. The existence of lag in the significance of the age variable should reflect, in our opinion, a lag in full activation of current investments, for which the structure of the capital stock one-period before is more effective as indicator of the capacity in use. The hypothesis that the efficiency component can be incorporated through a sinthetic indicator of the time structure of investiments is thus confirmed.

The value of the trend variable summarizes the labor saving effects of both embodied and disembodied technical progress; these are highly negative, indicating that demand for labor input is reduced, coeteris paribus, by approximately 5% annually in terms of hours and by slightly less in terms of number of workers [8].

Further study may lead to a better specification of the characteristics of the technology in the model. The "average age of capital" variable, apart from its dependence on conventional hypothesis of the lifespan of equipment and plant, obviously covers only a "moment" in the time distribution of productive machinery. The high values and significance of the trend reflect formulation limits of the model, i.e. the inability of introducing a specification of further variables and factors influencing the pace and the shape of technical progress [9].

It seems possible to affirm, nonetheless, that, overall, the results are encouraging for our basic hypothesis. In our opinion, the functional distinction in labor input between directly and indirectly productive components with respect to production workers can constitute a useful approach to the debate around the problem of the dynamic of labor returns. In particular, it is our belief that the introduction of this distinction – for labor input expressed both in terms of number of workers and in terms of work hours – can represent a plausible answer to the difficulties encountered in interpreting empirical estimates of labor returns.

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[8] In the equations in terms of annual variation rates, the share of labor saved can be measured by the negative value of the constant.

[9] Further study may lead to a better specification of the characteristics of the technology of the model, for example, by testing different depreciation hypotheses.

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LAVORO DIRETTO E INDIRETTO IN UN MODELLO DI DOMANDA DI LAVORO

Il saggio stima, per l'industria manifatturiera americana e per il periodo 1956-84, una funzione di domanda di lavoro, espressa sia in termini di ore totali lavorate che di occupazione operaia.

L'aspetto che differenzia la forma funzionale adottata dalle equazioni più convenzionali è rappresentato dall'introduzione, fra le variabili esplicative, dello stock di capitale e della sua età media in addizione al volume della produzione. Nel modello proposto, la relazione fra input di lavoro e accumulazione di capitale ha segno positivo, in quanto si ritiene che componenti di lavoro "indiretto" si muovano in modo complementare allo stock di attrezzature produttive a cui sono asserviti. Il lavoro indiretto viene definito come quello che, sebbene tecnologicamente indispensabile alla realizzazione del processo produttivo, non dipende nel breve periodo dal flusso di produzione attivata. L'introduzione dell'età media si propone lo scopo di catturare almeno in parte l'incidenza del progresso tecnico "incorporato" sulla produttività e quindi sui fabbisogni di lavoro. Un ciclo favorevole di investimenti, che abbassa l'età media dello stock in uso, dovrebbe quindi, coeteris paribus, abbassare la domanda di lavoro.

I risultati della stima sono nel complesso confortanti per le ipotesi di base del modello, e riteniamo possano rappresentare un punto di riferimento per il dibattito circa l'interpretazione della dinamica dei rendimenti del lavoro nel breve periodo.