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Procyclical Productivity, Externalities and Labor Hoarding: A Reexamination of Evidence from U.S. Manufacturing

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PROCYCLICAL PRODUCTIVITY,
EXTERNALITIES AND LABOR HOARDING:
A REEXAMINATION OF EVIDENCE FROM U.S. MANUFACTURING.

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Abstract

This paper argues that the widely-cited evidence provided by Caballero and Lyons (1992) on externalities in U.S. manufacturing is due to model misspecification. In fact, if the more appropriate gross output framework replaces the value added one, and standard proxies for labor effort are included into the model, the external effects practically disappear. Such results are shown to be robust to the choice of effort proxy and estimation method. On the other hand, labor effort effects are found to be highly significant and relatively large, in all regressions. These findings reconfirm the validity of the traditional labor hoarding theory of procyclical productivity vis-à-vis recent alternative explanations, based on increasing returns due to external effects.

I am very grateful to Robert Waldmann for his constant advice and support. Eric Bartelsman generously provided most of the data that I used in this paper. Some data were also provided by Craig Burnside, Ricardo Caballero and Robert Hall. Finally, my thanks to Erik Thorbecke for his comments on this paper.

I. Introduction.

The puzzling phenomenon of procyclical labor productivity has long been known in macroeconomics. Hultgren (1960) first pointed out that output per unit of labor increases with labor - i.e., is procyclical. After him, several generations of macroeconomists have tried to reconcile such stylized fact with the law of diminishing returns and standard theory of production. Shortly after the discovery, Oi (1962) and others provided a convincing explanation, which would remain basically unchallenged for more than twenty years. According to it, the procyclical behavior of labor productivity, typically showed by the data, is mainly the artifact of effort variations over the cycle. Such variations, on turn, are due to the presence of overhead labor and labor hoarding. This is also the explanation endorsed by Solow (1964) in his Presidential Address to the Econometric Society. In the main version of this thesis, firms hoard labor in slumps because of the high adjustment costs which characterize labor in real economies.[1]

However, the traditional theory has come in recent years under fierce criticism. Basically, two alternative explanations have been proposed. The first one is supported by the proponents of the real business cycle school. According to them - see, for example, Prescott (1986) - economic fluctuations are driven by exogenous *technological shocks*, which are correlated across sectors and countries. They shift the production function, and increase the product of labor in spite of diminishing returns with fixed technology. However, recent studies cast doubts on this explanation. The Solow residual, usually taken within this approach as measure of exogenous technological shocks, has been found to be significantly correlated with demand variables, such as military expenditure

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[1] Among the many contributions in the 1960s and 1970s, see Fair (1969) and Sims (1974). For an overview of the evidence on procyclical productivity, see for example Bernanke and Powell (1986).

(Hall 1988), monetary aggregates (Evans 1992) and government consumption (Burnside et al. 1993). Furthermore, Bernanke and Parkinson (1991) argued that the pattern of short-run increasing returns to labor (SRIRL) - an alternative formulation of procyclical labor productivity - in the postwar period is very similar to that occurred during the Great Depression, which clearly cannot be attributed to negative technological shocks and the like.

The other alternative explanation of procyclical productivity is due to Hall (1988 and 1990), and is based on *increasing returns* and market power. In a series of provocative articles, Hall argues that in many industries the technology exhibits increasing returns to scale, rather then constant returns - as it has long been assumed in economics. A necessary ingredient of his thesis - to reconcile distribution theory with production theory - is that market power and markup pricing are quite widespread. The original finding of sizable markups in U.S. industries by Hall (1988) was initially confirmed, at more disaggregate level, by Dommowitz et al. (1988).[2] After that, however, it has been seriously challenged, on methodological grounds, by Waldmann (1991) and, more radically, Norbbin (1993).

Alternatively, the increasing returns theory of procyclical productivity is consistent with perfect competition if the increasing returns to own inputs are due to externalities, as in the theoretical models by Murphy et al. (1989). In a series of widely-cited papers, Caballero and Lyons (1989 and 1992) have indeed offered evidence of productive externalities across industries in U.S. manufacturing. By doing so, they also seemed to provide some of the first empirical support for the booming theoretical literature on externalities, in the

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[2] For a comment on Dommowitz et al.'s results, see section IV in this paper.

fields of trade and, above all, endogenous growth. See - respectively - Helpman (1984), and Romer (1986) and the like.[3]

However, the results obtained by Caballero and Lyons are due to model misspecification. In fact, as it is shown in this paper, once the more appropriate gross output framework replaces the value added one, and intermediate goods and labor hoarding are introduced into Caballero-Lyons model, the externalities practically disappear.[4] In other words, the externalities found by Caballero and Lyons are a case of spurious correlation, due to the fact that the external economy index that they use - aggregate manufacturing output - is significantly correlated with their omitted variables - sectoral intermediate goods and labor effort. My results are shown to be robust to the choice of labor effort proxy and estimation method. Also, they are not due to differences between my data and those used by Caballero and Lyons, other than the utilization of gross output data rather than value added data. In fact, I construct series of value added out of my data, run Caballero-Lyons-like regressions and obtain results very similar to theirs.

Finally, it is worth noticing another result of this paper. My estimates of the own-inputs returns-to-scale index in U.S. 2-digit SIC manufacturing industries are relatively close to one, consistently with what has been typically found in studies at more disaggregate level - see for example Baily et al. (1992).

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[3] For an overview of theoretical work on externalities, see Caballero and Lyons (1989, pp. 3-4). It is interesting to note that some of the main themes explored by recent externality-based models of trade and growth have been introduced long ago by papers such as Arrow (1962), Shell (1966) and Wan (1975).

[4] Similar results have been obtained by Basu and Fernald (1993) in an independent piece of work, of which I became aware at an advanced stage of my research. Their analysis, however, differs significantly from mine in what - among other things - it ignores labor hoarding, whose role is instead emphasized by the approach followed in this paper. Here it lies, indeed, a major difference between competing theories of the business cycle and the procyclical productivity puzzle. See, to this regard, Bernanke and Parkinson (1991).

My estimates, therefore, reverse Hall's (1990) finding of sizable increasing returns in most industries, which are probably due to the same misspecification problems that affect Caballero and Lyons' (1992) results.

In summary, the questions addressed by this paper seem to be particularly relevant to the macroeconomic debate of these days from two respects. First, they directly address the procyclical productivity puzzle. The solution to such puzzle is indeed a major issue, since - as emphasized by Bernanke and Parkinson (1991) - it reflects the choice among alternative theories of the business cycle. The other reason is related to the momentum gained by externality-based models, particularly in the endogenous growth literature. To this regard, my analysis points out that rigorous empirical literature on productive externalities, other than some studies of R&D externalities by Jaffe (1986) and others, seems to still lag behind the theoretical contributions on the matter.

My study covers the same range of industries and period as in Caballero and Lyons (1992) - i.e., it refers to U.S. 2-digit SIC manufacturing industries, in the period 1959-84. Most of the data that I use are obtained by aggregating data from a panel of 450 U.S. 4-digit SIC manufacturing industries, developed at NBER by Gray (1989). Note that choosing appropriate data is indeed a crucial element of studies like this one, since the data used can affect significantly the final results.[5]

The remainder of this paper is organized as follows. Section II introduces the model to be used in my analysis, which is a modified version of that suggested by Hall (1988 and 1990) and used also by Caballero and Lyons (1992). The empirical results are shown in Section III. In Section IV I discuss

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[5] See for example Waldmann's (1991) criticism of some of Hall's (1988) findings.

the data and related issues, also with reference to some of the contributions in the literature. Finally, in Section V, the conclusions.

II. The Model.

Modifying appropriately the setup in Solow (1957), consider the following aggregate production function, at industry level (for convenience, I drop the index i for the time being):[6]

$$Y = f(L, K, M, E; t), \tag{1}$$

where Y is gross output, L is worked hours, K is capital, M is intermediate inputs (materials and energy), E is labor effort and t is time, to allow for technical change. On the justification of the inclusion of labor effort, see below. If one assumes Hicks-neutral technical change, the production function takes the form

$$Y = A(t)F(L, K, M, E). \tag{2}$$

It is worth stressing that this is a gross output production function, rather than a value-added one. The latter has been usually used in empirical studies in economics mainly because of data availability, and then justified on theoretical grounds assuming appropriate "separability" conditions on the gross output production function.[7] However, the preferability of the gross output framework, when data on gross output and materials are available, should be clear - as it is indeed generally accepted, and Hall (1988, pp. 930-32) himself seems to recognize.

After taking the log and total differential of (2), I obtain

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[6] In his pioneering article, Solow (1957) used a value-added aggregate production function. However, the extension to the gross output case is straightforward.

[7] See, for example, Bruno (1978).

$$dy_{it} = \eta_{il} dl_{it} + \eta_{ik} dk_{it} + \eta_{im} dm_{it} + \eta_{ie} de_{it} + \theta_{it} \, , \tag{3}$$

where dy_{it} , dl_{it} , dk_{it} , dm_{it} and de_{it} are the rate of growth (log-difference) of - respectively - gross output, hours worked, capital, intermediate inputs and labor effort, and θ_{it} is the rate of Hicks-neutral technological change. All of them refer to industry i at time t. Finally, the elasticities η's are defined as

$$\eta_{ix} = \frac{\partial Y_i}{\partial X_i} \frac{X_i}{Y_i}, \qquad \text{for } X_i = L_i, K_i, M_i \text{ and } E_i.$$

Equation (3) gives us a common framework to discuss Hall's (1990) and Caballero and Lyons' (1992) findings. Consider, for the time being, the case in which labor effort does not vary over time, i.e. $de_{it} = 0$ in the industries and periods considered. If one assumes perfect competition and constant returns to scale - i.e., the gross output production function is homogeneous of degree one with respect to labor, capital and materials - θ_{it} in (3) is the Solow residual. In fact, under the mentioned conditions, the elasticity of output with respect to each input is equal to the corresponding revenue share, as it is well-known.

Working with value added data, Hall (1990) relaxed both the perfect competition and constant returns to scale assumptions. Consider the following value added aggregate production function

$$Q = A(t) F_{VA}(L, K), \tag{4}$$

where Q is value added and the other variables are the same as before. After taking the log and total differential of (4), I obtain

$$dq_{it} = \overline{\eta}_{il} dl_{it} + \overline{\eta}_{ik} dk_{it} + \overline{\theta}_{it} \, , \tag{5}$$

where dq_{it} is the rate of growth (log-difference) of value added and $\overline{\theta}_{it}$ is the rate of value added Hicks-neutral technological change (bar denotes value added variables), both referred to industry i at time t, and the elasticities η 's are defined as

$$\overline{\eta}_{ix} = \frac{\partial Q_i}{\partial X_i}\frac{X_i}{Q_i}, \qquad \text{for } X_i = L_i, K_i. \qquad (6)$$

To include into the analysis the cases of (i) monopoly power in the goods market, and (ii) increasing returns in technology, Hall (1990) allowed a wedge between marginal cost and price, and assumed the production function to be homogeneous of degree γ in labor and capital, with $\gamma > 0$. He showed that, under such assumptions, the elasticity of value added with respect to each input is equal to the returns-to-scale index γ times the corresponding cost share.[8] That is,

$$\overline{\eta}_x = \gamma\overline{\alpha}_x \qquad \text{for } X = L, K, \qquad (7)$$

where $\overline{\alpha}_X$ is the value added cost share (the index i is dropped for convenience). Now consider the rate of technological change in (5), $\overline{\theta}_{it}$, as the sum of a constant term, ν_i, plus a random term, ε_{it}. Equation (5) becomes an estimating equation:

$$dq_{it} = \gamma dx_{it} + \varepsilon_{it} , \qquad (8)$$

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[8] See, for example, Caballero and Lyons (1992, pp. 221-23) for a detailed derivation of equilibrium conditions. See also the Appendix, with reference to the gross output case. It is worth mentioning that Hall's (1990) setup implicitly assumes that the dynamic profit maximization problem faced by firms can be well approximated by a sequence of one-period, static problems, with freely mobile capital. Such assumption, which rules away any capital adjustment costs and the like, is clearly quite strong. However, we do not need - and attempt - to modify it here.

On the other hand, from a computational point of view, Hall's method requires the construction of the rental price of capital, which can be quite a delicate task. See section IV in this paper.

where dq_{it} is the rate of growth (log-difference) of value added of industry i at time t, and dx_{it} is the sum of the rates of growth of labor and capital of industry i at time t, weighted by the respective cost shares:

$$dx_{it} = \overline{\alpha}_l dl_{it} + \overline{\alpha}_k dk_{it} \, .$$

Finally, ε_{it} in (8) is a disturbance term, from an econometric point of view. From an economic point of view, it represents sectoral technological change, net of its trend. Note that in (8) the intercept ν_i is dropped for simplicity. See Hall (1990, p. 93) for his estimates of γ_i for U.S. 2-digit SIC manufacturing industries, by using equation (8).

To test for the existence of productive externalities, Caballero and Lyons model sectoral productivity growth ε_{it} as function of the rate of growth of aggregate manufacturing value added, dq_t:

$$\varepsilon_{it} = \beta dq_t + v_{it} \, . \tag{9}$$

By plugging (9) in (8), one obtains their basic estimating equation:

$$dq_{it} = \gamma dx_{it} + \beta dq_t + v_{it} \, . \tag{10}$$

As a matter of fact, Caballero and Lyons seem to be somewhat aware of the serious misspecification problems which potentially affect their analysis. In particular, their inclusion of sectoral energy use on the right hand side of (10) seems an attempt - which turns out to be inadequate - to correct for the omission of intermediate inputs. However, their estimates of β remain statistically and economically significant - in the order of one or two decimal points - even after the inclusion among the regressors of sectoral energy use as well as a number of proxies for labor effort (see Caballero and Lyons 1992, pp. 215-218).

To see in what sense the Caballero-Lyons (1992) model - and Hall's (1990) model too, for that matter - is misspecified, and to assess the effect of this misspecification on their estimates, consider again the production function in equation (2) and the rate of growth of gross output as expressed in equation (3).

A few comments on this framework are needed. As to the advantages of a gross output model, when data are available, I already commented above. I make here a couple of further points. First, it may be useful to remind that firms actually produce gross output, not value added, and materials account typically for almost two thirds of the value of all inputs used in production. Furthermore, the necessary construction of real value added data - which is an economic concept without any physical counterpart - can easily make them spuriously correlated to a number of variables, as it is well-known among those familiar with the national accounting methodologies. See Waldmann (1991) for an application to Hall's (1988) finding of sizable markups in some U.S. manufacturing industries. It is worth stressing here that the publication of the value added data used by Hall (1988 and 1990) and Caballero and Lyons (1992) was suspended in 1989 by the Bureau of Economic Analysis of the Department of Commerce, the "old" data have undergone a thorough revision - not yet completed - and the BEA methodology to compute real value added data has been significantly modified in the last years.[9] With regard to the construction of real value added data, I mention hereafter another issue, which is particularly relevant for this paper - i.e., the use of fixed-weights versus shifting-weights indexes. The data used by Hall - and Caballero and Lyons and many others - were computed by BEA by using the double deflation procedure, which is a

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[9] See de Leeuw et al. (1991) and Parker (1993). The latter reference reports the following striking example of the sensitivity of value added data to the computational method followed for their construction. Value added in U.S. manufacturing grew by average by 1.2 per cent per annum in 1977-82, according to some estimates, and decreased by .8 per cent per annum in the same period, according to other estimates (Parker 1993, p. 34). This specific example refers to fixed-weighted indexes, which are those used by BEA (see the main text). However, in addition to these, the Bureau has recently started producing alternative, benchmark-years-weighted indexes.

fixed-weights method. That is, the estimates of real output and intermediate goods - needed to compute real value added - are based on prices of a given year (the base-year), which remains fixed for a number of years, up to a decade. This method gives good results to the extent that relative prices do not change significantly over the period. They did change considerably, however, in the period of interest here, because of the oil-shocks. The resulting bias in the data can be intuitively understood as follows. The quantity and composition of factors which are optimal - from the firms' standpoint - at some given relative prices, are clearly suboptimal with different prices. If, after relative prices have changed, one measured factors and output in "old" prices, the firms' behavior - i.e., the adoption of a "new" mix of factors and output - would erroneously appear suboptimal, and the real value added data would show an artificial decrease.[10]

The framework provided by equations (2) and (3) is also characterized by the inclusion of labor effort, which is assumed to be constant by Hall and Caballero and Lyons. This inclusion deserves some comments as well, since it is one of the crucial issues in the debate on procyclical productivity.

I first analyze it from an empirical point of view. Labor effort poses clear measurement problems. Traditionally, its closest proxies have been looked for among cyclical indicators, such as aggregate price and production indices - see Bernanke and Parkinson (1991, p.153) for a discussion.[11] The problem is that such variables - particularly the production-based ones - can be considered

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[10] See also Norbbin (1993) and, for a detailed discussion of double-deflation vs. Divisia indexes of value added, Basu and Fernald (1993).

[11] A completely different approach is that followed by Burnside et al. (1993). They deduce indirectly a time series for labor effort from the equilibrium conditions of their model. Therefore, their measure of effort depends on the assumptions of the model, among which the functional form of the utility function and production function. I do not follow such approach in this paper.

as externality indexes as well. It would be therefore very difficult to discriminate between evidence supporting labor hoarding effects and evidence supporting productive externalities, and it would ultimately be a matter of discretional interpretation. However, there is a careful study by Shea (1992) which proves to be useful on the matter. Without using cyclical indicators at all, he provides evidence supporting significant labor effort variations in U.S. manufacturing industries in the 1970s and 1980s. He uses injury rates as proxies of labor effort, after controlling for the variables - other than labor effort - which can in principle affect those rates, such as turnover and overtime. Therefore, the relevance of effort variations over the cycle is shown by a methodology which is robust to the existence of productive externalities, and the inclusion of labor effort in a model for the study of procyclical productivity seems indeed to be due to the completeness of the analysis. Since data on injury rates are not available for the whole period considered here, I use - as labor effort proxies - average hours per production worker and the ratio of production workers to total workers. These variables are highly correlated with accident rates - in the period in which data on all of them are available - and are generally considered good proxies for labor effort.[12] Indeed, they are used by Caballero and Lyons (1992) as well. Furthermore, since the mentioned proxies refer to the specific industry whose production function is being estimated, they allow for statistically discriminating between labor effort effects and externality effects, which are proxied by the output of other industries, or the whole manufacturing sector.[13]

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[12] See for example Abbott et al. (1989).

[13] An interesting attempt to discriminate between the two competing theories of procyclical productivity is also provided by Sbordone (1992). In her dynamic model, the degree of labor utilization depends on the expected future demand. She finds evidence which supports the labor hoarding theory.

Finally, consider briefly the role of labor effort from a theoretical point of view. Hall (1989) argued that, with perfect competition and flexible prices, effort variations due to overhead labor cannot explain procyclical productivity. However, Shea (1992) already emphasized that, with Hall's technology, worked hours and effort are not substitutes. If they substitute for each other - as they do in most effort-based models - effort variations do help to explain procyclical productivity. Furthermore, Rotemberg and Summers (1990) showed that, with Hall's (1989) technology and price rigidity, effort variations of overhead labor can explain procyclical productivity.

After this introduction, consider again equation (3). It is similar in spirit to equation (3) in Bernanke and Parkinson (1991), although it is more general since it includes gross output and materials. It gives us a convenient framework to assess the bias which affects Caballero and Lyons (1992) results. Note that, if one either (i) assumes perfect competition and constant returns, or (ii) allows for market power and increasing returns by following Hall (1990), it would be possible to express the elasticities in (3) in the familiar terms of returns-to-scale index times revenue (or cost) shares. However, the presence of labor effort among inputs would require very peculiar assumptions on its remuneration, and would rather complicate the economic interpretation of the elasticities with respect to hours worked L and labor effort E. I therefore use, hereafter, the original formulation of (3), which corresponds to the more primitive - but more robust - production function framework, and better suits my purposes here.

To assess the bias in Caballero-Lyons results, I need the relationship between gross output and value added. This is provided by Hall (1988, p. 931):[14]

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[14] Hall was aware of the potential misspecification problems that were implicit in his analysis, but did not take them into full consideration when estimating the model.

$$dq_{it} = \frac{dy_{it} - a_m dm_{it}}{1 - a_m} \,, \tag{11}$$

where a_m is the revenue share of materials.

By plugging (3) in (11), it is possible to obtain

$$dq_{it} = \frac{\eta_l}{1-a_m} dl_{it} + \frac{\eta_k}{1-a_m} dk_{it} + \frac{\eta_m - a_m}{1-a_m} dm_{it} + \frac{\eta_e}{1-a_m} de_{it} + \frac{\varepsilon_{it}}{1-a_m} \,.^{15} \tag{12}$$

The expression in (12) is rather complex. In order to quantify the bias, consider the extreme case in which $dk_{it} = 0$, in the industries and periods considered. This assumption is not as constraining as it might seem, since capital growth rates are typically tiny in all industries, and account for a small fraction of the variance of dx_{it} anyway. Equation (12) can then be rewritten as

$$dq_{it} = \frac{\eta_l}{(1-a_m)\overline{\alpha}_l} dx_{it} + \frac{\eta_m - a_m}{1-a_m} dm_{it} + \frac{\eta_e}{1-a_m} de_{it} + \frac{\varepsilon_{it}}{1-a_m} \,, \tag{13}$$

where $dx_{it} = \overline{\alpha}_l dl_{it}$ after my simplifying assumption.

It is possible now to compare equation (10) - i.e., Caballero-Lyons (1992) basic regression model - with equation (13). Clearly, intermediate inputs and effort growth are omitted in (10), with two main consequences. The most important, for my purposes here, is the following. If the growth of aggregate value added dq_t is correlated with the growth of sectoral materials, dm_{it}, and labor effort, de_{it} - as it is typically - one will find a positive and significant estimate of the externality coefficient, even if the externalities do not exist at all. In particular, if one estimates equation (10) while the "true" model is given

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[15] Note again that the index i is dropped from elasticities and revenue shares for convenience.

by equation (13), what is captured by $\hat{\beta}$, the alleged OLS estimate from (10) of the externality coefficient, is actually

$$\frac{\eta_m - a_m}{1-a_m}\varphi + \frac{\eta_e}{1-a_m}\pi \ , \tag{14}$$

where φ is the coefficient of dq_t from the regression of dm_{it} on dx_{it} and dq_t, and π is the coefficient of dq_{it} from the regression of de_{it} on dx_{it} and dq_t. The value of the expression in (14) ranges, in my data, from negligible amounts in some industries to 0.6-0.7 in others, well enough - by average - to generate estimates of β like those in the literature.

Note that also the estimate of the coefficient of dx_{it} from (8) and (10) is similarly biased, as long as dx_{it} is correlated with the omitted variables, as it is typically. Here it can be probably found most of the explanation for the very high estimates of γ_i reported by Hall (1990).

To correct for the misspecification problems in Caballero and Lyons (1992) -and Hall (1990), for that matter - and test properly for the existence of productive externalities across industries, I therefore estimate the following equation:

$$dy_{it} = \gamma\, dz_{it} + \beta dy_t + \delta\, de_{it} + u_{it} \ , \tag{15}$$

where dy_t is the rate of growth of aggregate manufacturing gross output, and dz_{it} is defined as

$$dz_{it} = \alpha_{\,l} dl_{it} + \alpha_{\,k} dk_{it} + \alpha_{\,m} dm_{it} \ . \tag{16}$$

The α's in (16) are cost shares.[16]

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[16] A version of equation (15) is derived in the Appendix. It corresponds to the case in which labor effort is assumed not to vary over time. In such case, the coefficient of dz_{it}

The empirical results are presented in the next section.

III. Empirical Results.

The estimation of equation (15) and the like would require, in principle, the use of instrumental variables, as it is well-known in the literature. The reason is that the residual in these equations represents the rate of sectoral technological change (net of its trend). The latter is correlated with the inputs used in production, since favorable technological shocks induce greater use of inputs, which have become more productive. The correlation between residual and regressors requires therefore the use of instrumental variables. The properties desirable in such instruments, and the problems in finding variables which satisfy them, are discussed in Hall (1990) and need not to be repeated here. I use in this paper the same instruments as in Hall (1988 and 1990), and Caballero and Lyons (1992). They are (i) the rate of growth of military expenditures, (ii) the rate of growth of the world price of oil, and (iii) the political party of the president. In addition to them, I use the lagged values of the first two variables. However, since such instruments are poorly correlated with the regressors, it is not clear whether the consistent IV estimator is to be preferred to the inconsistent but more efficient OLS or SUR estimators. For a detailed discussion of the tradeoff involved, see Caballero and Lyons (1989, pp. 11-14) and Nelson and Startz (1990). In either case, it is appropriate to use a

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is exactly equal to the production function returns-to-scale index, γ. On the other hand, if effort is allowed to vary and is therefore included among the production factors in the model - which is indeed the general case in this paper - the interpretation of the coefficient of dz_{it} in (15) becomes less straightforward, and depends on ad hoc assumptions on labor compensation and the like. However, in what follows, I will refer to the coefficient of dz_{it} as the returns-to-scale index (and keep the symbol γ), for convenience.

simultaneous-equation estimation procedure. In fact, the task is estimating equation (15) and the like for each manufacturing industry, and the efficiency of estimation is increased by taking into consideration the likely correlation of residuals across industries.[17] The choice is therefore between SUR and 3SLS procedures. While all the estimates reported in Caballero and Lyons (1992) are obtained by using instrumental variables, I chose to use both SUR and 3SLS estimators, and provide both sets of estimates. However, the two procedures turn out to give very similar estimates, therefore enhancing the robustness and validity of my results.

I estimated equation (15) by using data on U.S. 2-digit SIC level manufacturing industries in the period 1959-84, as in Caballero and Lyons (1992). The relevant coefficients were constrained to be equal across industries, as in the previous study. The results are reported in Table 1, first two columns.

The most important finding is that the externality coefficient - although still statistically significant - has almost disappeared. In fact, its estimate is equal to .02 or .03, according to the estimation procedure utilized. Such results are obtained by using average hours per production worker as labor effort proxy.

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[17] This is the standard argument introduced by Zellner (1962).

Table 1.

Gross Output Model: $dy_{it} = \gamma dz_{it} + \beta dy_t + \delta de_{it} + \nu_i + u_{it}$

Value Added Model: $dq_{it} = \gamma dx_{it} + \beta dq_t + \delta de_{it} + \nu_i + u_{it}$

	Gross Output Model		Value Added Model	
	SUR	3SLS	SUR	3SLS
γ	1.13 (0.01)	1.13 (0.01)	1.08 (0.03)	1.02 (0.03)
β	0.03 (0.01)	0.02 (0.01)	0.30 (0.02)	0.40 (0.02)
δ	0.16 (0.02)	0.17 (0.02)	0.44 (0.05)	0.43 (0.05)
Weighted R^2	0.98	0.97	0.64	0.68

Note: Standard errors in parenthesis. Data refer to U.S. 2-digit SIC level manufacturing industries. Annual data: 1959-84. Instruments for 3SLS are current and lagged rate of growth of military expenditure and world price of oil, and the political party of the president. Equations include an intercept for each industry, ν_i. The labor effort proxy is average hours per production worker.

To check the robustness of the result to the choice of the proxy, I also estimated equation (15) by using the ratio of production workers to total workers as labor effort proxy. The results are only slightly different, as it is shown in Table 2. The externality coefficient is estimated in the neighborhood of .05. It is worth mentioning that estimates of this size can in principle be entirely due to the spurious effects which are invariably associated with regressions of this kind.[18]

Further commenting the results in Tables 1 and 2, the estimates of the labor effort coefficient are highly significant and reasonably large in all regressions. They are roughly equal to 0.15. They seem therefore to confirm the contribution of effort variations to output growth. It is also worth noticing the order of magnitude of these estimates as compared to the estimates of the alleged externality coefficient. Even if one gives some economic meaning to the small estimates of β, they are outweighed by the estimates of δ by three to five times.

Finally, the estimates of the return-to-scale index are consistently around 1.10. Such estimates correct upward the corresponding estimates in Caballero and Lyons (1992). Also, what is more important, they are substantially smaller than those in Hall (1990). The latter were an important part of the evidence given by Hall to support his increasing returns-based explanation of procyclical productivity, and had already been subject to some criticism.[19] My results seem now to definitely confirm that they were largely due to model misspecification and other methodological problems. With regard to my estimates of the own-inputs coefficient, note also that they are roughly consistent with those typically found by industrial organization studies, which use much more disaggregate data, often at firm level.[20] This also supports the validity of my results.

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[18] Somewhat similar results on the externality coefficient have been obtained - by using different data, estimation period and analytical model - by Basu and Fernald (1993). They used Jorgenson et al. (1987) data set, with a model without labor effort.

[19] See Abbott et al. (1989) and Bartelsman (1991).

[20] See, for example, Baily et al. (1992, pp. 234-5).

Table 2.

Gross Output Model: $dy_{it} = \gamma dz_{it} + \beta dy_t + \delta de_{it} + \nu_i + u_{it}$

	SUR	3SLS
γ	1.11 (0.01)	1.10 (0.01)
β	0.06 (0.01)	0.05 (0.01)
δ	0.13 (0.04)	0.14 (0.04)
Weighted R^2	0.96	0.97

Note: Standard errors in parenthesis. Data refer to U.S. 2-digit SIC level manufacturing industries. Annual data: 1959-84. Instruments for 3SLS are current and lagged rate of growth of military expenditure and the price of oil, and the political party of the president. Equations include an intercept for each industry, ν_i. Labor effort proxy is ratio of production workers to total workers.

I then proceeded to check whether my results were due to differences between the data used here and those used by Caballero and Lyons (1992) - beyond the use of gross output data rather than value added data. To do so, I constructed series of sectoral value added out of my data set. There are several alternative methodologies to accomplish such task, as already stressed in this paper. I used the same methodology which was followed by the Bureau of

Economic Analysis to compute the value added data used by Caballero and Lyons - i.e., the double deflation method.[21] There are several shortcomings associated with such methodology, but the purpose here was to replicate Caballero and Lyons analysis with my data, and nothing else. After computing the relevant data - i.e., value added and corresponding cost shares - I therefore estimated the equation

$$dq_{it} = \gamma\, dx_{it} + \beta dq_t + \delta de_{it} + u_{it} \,, \tag{17}$$

which is the same as equation (10) plus the labor effort proxy. Equation (17) is estimated by Caballero and Lyons (1992) as well.

The results are shown in Table 1, third and fourth columns. As expected, I obtain results which are very similar to those by Caballero and Lyons.[22] Note that the estimates of the externality coefficient are highly significant and extremely large. The comparison between these estimates and those in the first and second column is striking. The externalities are supported by large evidence in the value added framework, but practically disappear in the more appropriate gross output framework. As expected, the estimate of the returns-to-scale index is slightly smaller in the value added regressions, since some of the role played by intermediate goods is captured in the value added regressions by both the externality and the effort coefficients.

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[21] See Peterson (1986).

[22] They do not coincide exactly because of (i) eventual minor differences in the data, and (ii) the inclusion by Caballero and Lyons of sectoral energy use on the right hand side, apparently to correct for the omission of materials. In particular, (ii) seems to be largely responsible for their smaller estimates of β and δ.

Proceeding in the analysis, to better understand the role played by the labor effort proxy, I estimated equation (15) without it. The results are in Table 3, first two columns.

Table 3.

Gross Output Model: $dy_{it} = \gamma\, dz_{it} + \beta dy_t + \nu_i + u_{it}$

Value Added Model: $dq_{it} = \gamma\, dx_{it} + \beta dq_t + \nu_i + u_{it}$

	Gross Output Model		Value Added Model	
	SUR	3SLS	SUR	3SLS
γ	1.13 (0.01)	1.13 (0.01)	1.08 (0.02)	1.04 (0.02)
β	0.08 (0.01)	0.08 (0.01)	0.33 (0.01)	0.34 (0.01)
Weighted R^2	0.98	0.98	0.80	0.83

Note: Standard errors in parenthesis. Data refer to U.S. 2-digit SIC level manufacturing industries. Annual data: 1959-84. Instruments for 3SLS are current and lagged rate of growth of military expenditure and the price of oil, and the political party of the president. Equations include an intercept for each industry, ν_i.

The estimates of the externality coefficient are larger than those in Table 1, as expected - since the estimates of β in Table 3 clearly pick up some of the effect due to labor effort variations. However, these estimates are considerably smaller than the estimates of the effort coefficients in Table 1 - roughly half of them. This means that the labor effort proxies - when included among the regressors - capture a sizable empirical effect which is unrelated to the output of other industries and the like. This confirms that, in spite of the correlation between the regressors dy_t and de_{it}, the estimates of β and δ reported in Table 1 do capture - in a somewhat robust way - empirically distinct effects, which can be mostly traceable, respectively, to externality effects (if any) and own-inputs effort variation effects. In other words, equation (15) seems indeed to provide an appropriate framework to discriminate between the two mentioned effects, and therefore offer a solution to the indeterminacy problem

described by Bernanke and Parkinson (1991, p. 455). For completeness, in the third and fourth column of Table 3 I provide the estimates of the value added equation without effort proxy.

To get a sense of the existence and respective relevance of externality effects and effort variation effects in individual 2-digit SIC manufacturing industries, I concluded my analysis by estimating equation (15) allowing both the externality and effort coefficients to vary across industries.[23] Results are in Table 4, next page. Some of the point estimates of the industry-specific coefficients may not be very accurate, because of the size of the sample. However, the broad picture - which is of interest here - is quite clear. The estimate of the externality coefficient is positive and significantly different from zero only in three or four industries out of twenty-one, according to the estimation procedure. On the other hand, the estimate of the labor effort coefficient is positive and significant in ten or eleven industries. Note that the results at industry detail practically coincide across estimation methods - an encouraging sign of their validity.

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[23] The coefficient of dx_{it} is still constrained to be the same in all industries. However, this is not the coefficient of interest in these regressions. Furthermore, indipendent unconstrained estimates of γ_i - obtained by using a fixed-effect model with data on 4-digit SIC industries - were all relatively close to one. These estimates are not reported here, but are available from the author.

Table 4.

Gross Output Model: $dy_{it} = \gamma dz_{it} + \beta_i dy_t + \delta_i de_{it} + \nu_i + u_{it}$

Industry	SUR			3SLS		
	γ	β	δ	γ	β	δ
20. Food.	1.10	0.12	-0.58 *	1.10	0.12	-0.68 *
	(0.01)	(0.07)	(0.24)	(0.01)	(0.07)	(0.23)
21. Tobacco.	"	-0.04	0.57 *	"	-0.04	0.57 *
		(0.09)	(0.13)		(0.10)	(0.12)
22. Textiles.	"	-0.01	-0.08 *	"	-0.01	-0.05
		(0.06)	(0.03)		(0.06)	(0.04)
23. Apparels.	"	-0.01	0.37 *	"	-0.01	0.32 *
		(0.05)	(0.09)		(0.05)	(0.09)
24. Lumber.	"	-0.32	0.66 *	"	-0.32 *	0.60 *
		(0.09)	(0.18)		(0.09)	(0.16)
25. Furniture.	"	0.11	-0.20	"	0.17 *	-0.46 *
		(0.06)	(0.11)		(0.06)	(0.13)
26. Paper.	"	0.20 *	-0.16	"	0.21 *	-0.17
		(0.06)	(0.10)		(0.05)	(0.09)
27. Printing.	"	0.09	0.22	"	0.09	0.17
		(0.06)	(0.14)		(0.06)	(0.14)
28. Chemical.	"	0.22 *	0.63 *	"	0.23 *	0.59 *
		(0.08)	(0.23)		(0.08)	(0.24)
29. Petroleum.	"	0.10	0.22 *	"	0.09	0.17
		(0.12)	(0.11)		(0.12)	(0.11)
30. Rubber.	"	0.04	0.07	"	0.04	0.08
		(0.07)	(0.08)		(0.07)	(0.06)
31. Leather.	"	-0.38 *	0.75 *	"	-0.38 *	0.69 *
		(0.09)	(0.18)		(0.09)	(0.18)
32. Stone, Clay and Glass.	"	0.05	0.47 *	"	0.03	0.58 *
		(0.04)	(0.10)		(0.04)	(0.10)

Table 4 (continues)

Industry	SUR			3SLS		
	γ	β	δ	γ	β	δ
33. Primary	1.10	-0.01	1.30 *	1.10	-0.01	1.30 *
Metals.	(0.01)	(0.06)	(0.08)	(0.01)	(0.06)	(0.07)
34. Fabricated	"	0.02	0.50 *	"	0.03	0.45 *
Metals.		(0.06)	(0.17)		(0.06)	(0.17)
35. Machinery.	"	0.64 *	-0.72	"	0.68 *	-0.99 *
		(0.28)	(0.46)		(0.28)	(0.48)
36. Electric	"	-0.09	1.04 *	"	-0.02	0.63 *
Equipment.		(0.08)	(0.20)		(0.08)	(0.21)
371. Motor	"	-0.12	0.45 *	"	-0.12 *	0.47 *
Vehicles.		(0.05)	(0.05)		(0.05)	(0.06)
372-9. Other Tr.	"	-0.07	0.27	"	-0.07	0.20
Equipment.		(0.06)	(0.21)		(0.06)	(0.21)
38. Instruments.	"	0.05	-0.33 *	"	0.07	-0.44 *
		(0.06)	(0.14)		(0.06)	(0.13)
39. Misc.	"	0.07	-0.04	"	0.08	0.01
Manufacturing		(0.09)	(0.20)		(0.09)	(0.18)
Weighted R^2		0.99			0.99	

Note: Standard errors in parenthesis. Data refer to U.S. 2-digit SIC level manufacturing industries. Annual data: 1959-84. Instruments for 3SLS are current and lagged rate of growth of military expenditure and the price of oil, and the political party of the president. Equations include an intercept for each industry, ν_i. Labor effort proxy is average hours for production worker.

* Significant at 5% level.

IV. Data.

Most of the data that I use in this paper were obtained from a large data set developed by Wayne Gray at NBER, which covers 450 U.S. 4-digit SIC level manufacturing industries, in the period 1958-89. The main source of such data set is the Annual Survey of Manufactures, conducted by the U.S. Census Bureau. Gross output is value of shipments plus inventory change. Intermediate inputs include both materials and energy, although unfortunately exclude purchased services, therefore resulting in a slight underestimation of total intermediate inputs. Data on capital refer to both structures and equipment. They are based on estimates from a joint project by the University of Pennsylvania, the Census Bureau and SRI Inc., and from the Bureau of Industrial Economics of the Commerce Department. All deflators constitute an impressive attempt to reflect changes in the composition of the variable to which they refer. Finally, since all data in the panel refer to 4-digit SIC industries, I had to appropriately aggregate data according to the respective 2-digit SIC code. For a detailed documentation on the data set, see Gray (1989).

The most noticeable exception to the source just mentioned concerns the data on hours worked, L, and labor compensation, wL. The reason is that, unfortunately, the corresponding data in Gray's data set do not cover employees in auxiliary units, who account for as much as 10 per cent of total employees. Furthermore, the data on labor compensation do not include Social Security contributions. As to L and wL, I therefore used the same data used by Caballero and Lyons, which come from U.S. NIPA (National Income and Production Accounts).

To compute revenue and cost shares, I used data on value of gross output and intermediate inputs cost from Gray's data set. Finally, I needed data on imputed capital cost. Note that the cost associated with the use of capital needs to be imputed, since it is not observable. Define imputed capital cost of industry i as $r\, p_{Ki} K_i$, where r is the rental price of capital, p_{Ki} is the price of capital of industry i, and K_i is real capital of industry i. I used the data on the price of capital and real capital from Gray's data set. As to r, I followed the standard practice in the literature, and computed it by using Hall and Jorgenson's (1967) formula

$$r = (\rho + \delta)\frac{1 - k - \tau d}{1 - \tau}. \tag{17}$$

The variables in (17) are as follows: ρ is the firms' real cost of funds, as measured by Standard and Poor 500 dividend yield; δ is the depreciation rate, set to 0.127; k is the rate of investment tax credit; τ is the corporate tax rate, and d is the present value of depreciation allowances. For the above variables, I used the same data as in Caballero and Lyons (1992). However, my computation of imputed capital cost is somewhat more precise than theirs, because they do not use industry-specific data on the price of capital p_{Ki} .

After describing in some detail the data, it is possible to comment briefly on the work by, respectively, Dommowitz et al. (1988) and Bartelsman et al. (1993), which is closely related to the issue addressed in this paper. Dommowitz et al. used gross output data on 285 4-digit SIC U.S. manufacturing industries, and found sizable markups at several aggregation levels, therefore apparently confirming Hall's (1988) results. However, most of their data come from a subsection of the same data set that I use here, and the data on labor and its compensation are affected by the limitations noted above. More precisely, "true" labor variations over the cycle are overestimated by the data that they use, while the data on labor compensation underestimate the corresponding "true" data. The net result of such measurement errors seems to be an overestimation of the coefficient of own inputs - i.e., in their model, the markup.[24]

Similar problems might affect the recent results by Bartelsman et al. (forthcoming). They use data at 4-digit SIC level from the same panel data set that I use here, and take a similar approach to Caballero and Lyons (1992). By constructing highly disaggregate externality indexes, with the use of input-output tables, they find evidence of externalities. However, for the above reasons, the contribution of labor to output growth is not completely captured by the data. Part of such contribution, therefore, might very well show up as an externality, to the extent that sectoral labor is correlated with the industry-specific externality index.

V. Conclusions.

The explanation of procyclical productivity based on effort variations has long been accepted in macroeconomics, since its introduction by Oi (1962) and others. However, it has been challenged in the 1980s by two main alternative theories, based respectively on (i) exogenous technological shocks, and (ii) increasing returns, either internal or external. The first explanation - advocated by the real business cycle economists - as well as Robert Hall's (1990) internal increasing returns theory have been, on turn, seriously criticized on empirical grounds. Among the explanations alternative to the traditional labor hoarding theory, therefore, only Caballero and Lyons' (1992) externality-based theory was still empirically unchallenged. In this paper, however, I showed that their results are due to the omission of relevant variables such as intermediate inputs and labor effort. In fact, if (i) the more appropriate gross output framework is used, rather than the value added one, and (ii) standard

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[24] See also Norbbin (1993).

labor effort proxies are included into the analysis, Caballero-Lyons alleged externalities practically disappear. Such results are shown to be robust to the choice of estimation method and labor effort proxy. Furthermore, I showed that my results are not due to any particular feature of the data that I use. In fact, I constructed value added data out of my data set, replicated Caballero and Lyons' (1992) analysis and obtained results which are very similar to theirs. On the other hand, labor effort effects are shown in my analysis to be highly statistically significant and quite large. In summary, the results in this paper significantly enhance the validity of the traditional labor hoarding theory of procyclical productivity vis-à-vis recent alternative explanations, based on (internal or external) increasing returns.

The issues addressed here, however, are closely related to another area of current research in macroeconomics - that on the effects of externalities on trade and growth. There has been indeed in recent years a surge of externality-based models, in both the trade and the endogenous growth literature. The evidence provided by Caballero and Lyons (1989 and 1992) has therefore been interpreted as supportive of such models. To this regard, this paper emphasizes that rigorous empirical literature on the matter still lags behind the theoretical contributions, with some noticeable exceptions on R&D spillovers.

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Appendix.

A detailed derivation of equation (8) in the paper can be found in Hall (1990, pp. 75-90) and Caballero and Lyons (1992, pp. 219-223). Here, I take a similar approach to derive the gross output version of such equation. As already mentioned, this is made much easier by assuming no variation in labor effort. Alternatively, one would need specific assumptions on worked hours and effort compensation, and the parameters in the model would lose their familiar interpretation.

Consider therefore the following gross output production function:

$$Y = A(t)F'(L, K, M), \tag{18}$$

where all the variables are as defined in the paper, and the function F' - which can be defined from function F in equation (2) by holding labor effort E fixed - is homogeneous of degree γ in L, K and M.

Assume that the profit maximization problem faced by firms can be well approximated by a sequence of one-period, static problems, with freely mobile inputs. The well-known necessary conditions for equilibrium, if firms are price-takers in the factor markets but have monopoly power in the good market, imply

$$P\frac{\partial Y}{\partial X}\frac{\xi-1}{\xi} = P_X, \qquad \text{for } X = L, K \text{ and } M, \tag{19}$$

where P is the final good price, P_X is factor price and ξ is the price elasticity of demand faced by the firms. Note that $\xi/(\xi-1)$ is equal at equilibrium to the ratio of price to marginal cost. Call it μ. From (19), after some simple manipulations, we have

$$\frac{\partial Y}{\partial X}\frac{X}{Y} = \mu a_X \ , \tag{20}$$

where a_X is the revenue share of factor X.

Consider now the assumption of homogeneity made on F'. It implies (recall that Y = AF'(.)):

$$\gamma = \frac{\partial Y}{\partial L}\frac{L}{Y} + \frac{\partial Y}{\partial K}\frac{K}{Y} + \frac{\partial Y}{\partial M}\frac{M}{Y}. \tag{21}$$

By substituting (20) in (21), one obtains

$$\gamma = \mu(a_L + a_K + a_M), \tag{22}$$

and then

$$\gamma = \mu\frac{WL + rP_K K + P_M M}{PY}, \tag{23}$$

where the denominator of the fraction in (23) represents total costs, and the numerator total revenues. By replacing in (20) the expression for μ given by (23), it is possible to obtain

$$\frac{\partial Y}{\partial X}\frac{X}{Y} = \gamma\alpha_X, \tag{24}$$

where α_X is - as previously defined in the text - the cost share of factor X.

Finally, by using (24) in equation (3), one obtains

$$dy_{it} = \gamma dz_{it} + \theta_{it} \ , \tag{25}$$

and, by replacing θ_{it} in (25) according to equation (9) and the assumptions made in the text,

$$dy_{it} = \gamma dz_{it} + \beta dy_t + u_{it}. \tag{26}$$

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