

Factors affecting changes in productivity

Those economists who propose to explain the behavior of labor productivity are bound to realize very soon that there is a discontinuity between theoretical analyses and empirical research. This paper is intended as a preliminary contribution toward bridging this gap.

Theoretical analysis is still to a large extent dominated by the traditional aggregate production function. However, whereas substitution is the main focus of the traditional theory, Keynesian theory is mainly preoccupied with the determinants of the level of activity. From this standpoint it appears to differ from—though it is not necessarily opposed to—the traditional theory. A more directly antagonistic position appears in the so-called “neo-Ricardians.”

1. Keynes on current profits and the marginal efficiency of capital

In Keynesian theory two strictly related distinctions are particularly relevant for our analysis: that between short- and long-term expectations and that between current profits (i.e., the excess of the value of output over the sum of input and user costs), on the one hand, and the marginal efficiency of capital (i.e., the sum of a series of expected receipts after deducting current expenses, including wages), on the other.¹ The second distinction refers to the two surpluses as if they were

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¹To quote Keynes: “The excess of the value of the resulting output over the sum of its factor cost and its user cost is the profit or, as we shall call it, the *income* of the entrepreneur” (1973, p. 23). “When a man buys an investment or a capital asset, he buys the right to a series of future receipts that he expects to obtain from the sale of its output, after deducting the running expenses incurred to obtain such output, during the life of that capital” (p. 135).

heterogeneous quantities. Indeed, Keynes treats the former surplus—current profits—as imputable to the productive process as a whole, whereas he sees the latter as deriving solely from capital goods as such. This is not correct: both surpluses, and not only the former, derive from the productive process as a whole: the differences in the time horizon and risk do not justify the different treatment of the two surpluses. An important—and misleading—consequence of this conception is that the rate of interest is compared only with the marginal efficiency of capital—the expected rate of return from a capital asset—and not with the short-term profit.

To clarify this point, consider a firm using its plants at less than full capacity but one that has plentiful stocks of raw materials because it is expecting an expansion of demand for its products. To meet an initial demand expansion, the firm may need only to hire additional workers. But if it has no internal funds to finance the higher wage bill it must also borrow in the short term. *The interest on this loan will be covered by the excess of receipts over costs, which in the case considered will appear to be imputable only to the expansion in labor employment. The same occurs when new machines are bought to meet higher demand: the excess of receipts over cost appears to be due to the capital goods, assuming that all other means of production are held in stock by the firm or by introducing the proviso "after deducting current expenses."*

Thus, for the short run, Keynes correctly assigns the excess of receipts over costs to the productive process as a whole, but when he turns to long-term expectations, his position is similar to that of traditional theory, in treating the excess as imputable exclusively to the additional capital goods.

Yet the two general approaches are profoundly different: Keynes proceeds from the perspective of effective demand, whereas traditional theory is absorbed with the substitution potential between labor and "capital." But, having imputed the long-term surplus to durable capital goods only, Keynes opens the door to the ambiguous "neoclassical synthesis." The emphasis Keynes places on the "extreme precariousness" of long-term expectations, and on the instability that they can generate, is certainly valid, but it does not eliminate the ambiguity of his asymmetric treatment of the long and short run.

The differences among the three theoretical constructs can be spotted by considering the consequences each attributes to a reduction in the rate of interest:

(a) the firm chooses more "capital" intensive (less labor intensive) techniques: this is the neoclassical point of view;

(b) investment is stimulated and, consequently, employment increases: this is the Keynesian point of view;

(c) aggregate production is stimulated: this can be defined as the commonsense analysis.

Clearly, there is a fundamental discrepancy between the neoclassical conception and the other two, for under normal circumstances an expansion of production requires an increase in investment and employment—an inference of both the Keynesian and the commonsense conceptions.

2. The classical conception of profits

The “commonsense” view has become very controversial ever since the beginning of neoclassical theory.

The “commonsense” position dovetails with the position of the classical economists. Yet, the specific source—or “cause”—of profit and, more generally, of the economic surplus, remains undetermined. Smith and Ricardo tended to see it in labor—naturally, labor “assisted” by instruments of various kinds, and combined with raw materials and intermediate products. The classical economists, however, did not probe deeply into this matter, since they considered it self-evident that the source of all value, including surplus value, was *labor*. They also considered as self-evident the fact that the surplus had to be shared among those who had advanced the means of subsistence to workers and furnished them with the other means of production.² Marx, as is well known, builds his whole theory on the assumption that labor is the source of profit and other capitalist incomes.

The classical conception of profit thus lives on two levels. On the general level, profit is attributed to the productive process as a whole; on a specific level, it is labor—what Marx calls living or current labor—that generates profit. There is no contradiction between these two perspectives, nor does the general classical conception conflict with the position of Schumpeter, who considers profit in each economic activity as the result of the productive process as a whole, subject to the

²Smith writes (Ricardo’s views are similar): “The value which the workmen add to the materials . . . resolves itself . . . into two parts, of which the one pays their wages, the other the profits of their employer upon the whole stock of materials and wages which he advanced. He could have no interest to employ them, unless he expected from the sale of their work something more than what was sufficient to replace his stock to him; and he could have no interest to employ a great stock rather than a small one, unless his profits were to bear some proportion to the extent of his stock” (Smith, p. 54).

condition that the process is in time made more efficient through technological and organizational innovations. For Schumpeter and the classical economists, the rate of interest is a piece of the surplus; it is a tax, or transfer, on the profit of the entrepreneur. It follows that, when the rate of interest drops, other conditions remaining unchanged, the whole productive process is stimulated.

Excepting Keynes's particular position, the fundamental contrast is between the classical, including Marx and Schumpeter, and the neo-classical conceptions. According to the latter, profits and wages are equivalent factor rewards paid to capital, essentially or even exclusively fixed capital, and to labor. The equivalence of the nature of the two incomes derives from their correspondence to the marginal productivities of the two factors, i.e., the partial derivatives of total production after a very small factor variation.

Since it is impossible to produce an additional quantity, however small, of, say, cotton yarn by means of an incremental application of labor, without an increase, however small, of raw cotton, the meaning of "the marginal productivity" of a single factor is unclear. With characteristic caution Marshall (1949, pp. 426-427 and 432) qualified his analysis to the "net product" of a factor defined as the additional product obtained by an incremental application of that factor "after allowing for incidental expenses" (equivalent to Keynes's "running expenses"). This definition does not coincide with the mathematical concept of a partial derivative and is therefore not consistent with the marginalist theory of income distribution.³

Even if the concept could receive an unambiguous interpretation, it

³If we formalize Marshall's statement, we have

$$w = \frac{\partial x}{\partial L} - e$$

where w is the rate of wage, $\partial x/\partial L$ is the partial derivative of total output x with respect to total labor, L , and e represents incidental expenses per unit of output. Whereas the relation $w = \partial x/\partial L$ (without e) is consistent with the aggregate production function $x = f(L, K)$, the above relation is not. If the production function is homogeneous of the first degree, we have,

$$\frac{\partial x}{\partial L} \cdot L + \frac{\partial x}{\partial K} \cdot K = x$$

which is the general form of the marginalist interpretation of the distribution of income.

In this context it is difficult to speak of a partial derivative of output with respect to labor, since Marshall's incidental expenses imply the use of additional quantities of other means of production, such as raw materials and intermediate products.

falters in explaining the distribution of income because it refers to an aggregate production function that emanates from a logically untenable concept: aggregate capital. It is important, however, to note that this criticism need not imply that a production function cannot be applied to the individual firm, nor that such a function cannot be used to analyze the (static) substitution among the individual factors of production.

3. Schumpeter's and Sraffa's views on profits

Schumpeter, in his *Theory of Economic Development* (1912) and later in his treatise on business cycles (1939), treats the classical conception of profits in a new guise. However, he makes certain propositions that appear to contradict that conception. Sraffa, on the other hand, who has made a signal contribution to a rigorous exposition of classical, in particular, Ricardian, theory, proposes two models. In the first, wages are anticipated and enter among the means of production, just as in the classical theory. In the second, wages are paid *post factum*; here Sraffa takes some leave of the classical conception.

In his *Theory of Economic Development* Schumpeter's analysis of profit and interest is close to, and certainly consistent with, the classical conception. In the theoretical chapters of his *Business Cycles* Schumpeter repropose this analysis, but in the empirical chapters there are statements more properly consistent with the neoclassical theory; for instance:

The prevailing cheapness of money will give them [the firms] a slant toward mechanization, which may be intensified by an increase and counteracted by the previous decrease in wage rates. (p. 954)

Coupled with a cheap money policy, a high-wage-rate policy was, under the circumstances of phase and country, the very recipe for the production of a maximum unemployment. (p. 995)

From the beginning, Schumpeter had tried to present his theory as complementary, and not as alternative, to the traditional one: he was admittedly aiming at a synthesis, not a critique. However, on the "surplus" question a synthesis was not possible. True, Schumpeter refers only to the traditional view in his empirical analysis. But, logical consistency precludes the conclusions of traditional theory.⁴ The prob-

⁴In 1949, when I was at Harvard on a scholarship, I had Schumpeter as my supervisor. After completing the study of *Business Cycles* I prepared a paper raising a few questions, among them the one just mentioned. After citing the two passages quoted above, I stated: "This point is not clear to me. The possibility, for firms to obtain 'money' more cheaply should give them a slant to increase the demand for all the

lem that surfaces in Sraffa's second model, where the wage is paid *post factum*, is completely different. Here, the abandonment of the classical assumption is by no means concerned with the nature of surplus generated by the productive process as a whole. If workers are not advanced their wages, they become "capitalists" to the extent they "advance" their wages to themselves. They have title to a share of surplus. (Such a hypothesis, which implies that saving stems not only from capitalists but also from workers, may be realistic today, but it was surely not representative of ruling conditions at the time of the classical economists, who could assume confidently that workers consumed the whole of their incomes.) Indeed, Sraffa warns the reader that, strictly speaking, it would be necessary to include that part of wages corresponding to "necessary" consumption among the means of production. On the other hand, in considering a process of development, firms lacking sufficient internal funds are compelled to apply to banks to finance their larger wage bills; and on these loans they must pay interest, in the strict sense.

The contraposition between the classical and the neoclassical conceptions, then, remains valid; and it is the earlier, "commonsense" point of view that is correct. If a businessman is asked about the probable effects of a cut in the rate of interest, he will reach for the obvious answer: the reduction will stimulate the expansion of production, without affecting the choice of techniques. To be sure, if the long-term rate of interest is reduced, the short-term rate remaining unchanged, the purchase of durable capital goods will be stimulated; but this is not a necessary outcome since it is possible to finance—or, at least, to pre-finance—the purchase of durable capital goods by means of short-term loans, renewed at each maturity, if this procedure is more

factors of production, labor included. If the firms prefer to buy more machinery and less personal services, the choice would seem to me to be based on the comparison of the prices of the various factors of production and not on the cheapness of money."

My question I think brought home to Schumpeter that he was using a type of analysis which contrasted with his conception of the rate of interest on loans to firms as the price of the use of the means of payment which the entrepreneur employs to buy all sorts of the means of production, including the hire of workers. After reading my question (before replying he would read each point aloud), he said: "But then you reject an essential part of traditional theory?" My reaction was a shrug to indicate that I was not much shaken by his comment. Schumpeter replied, "All right, all right"—and went on. Although he had the patience to devote a considerable amount of time to comment on the paper of that rather impudent young man, he never did answer the question. I think that the only answer is the one I point to in the text.

economical than the other.⁵

The confusion that prevails in this field has been augmented by the fact that a fall in the rate of interest, in particular, the long-term rate, stimulates building activity, which has a relatively long gestation period and gives rise to durable assets of longer duration than that of machines. All this, however, has nothing to do with the substitution between capital and labor. When the rate of interest goes down, building and other activities of this kind are stimulated; but there is no reason to think that the techniques used in these activities have to be changed.

4. Wages, the interest rate, and the choice of techniques: the relative wage effects

The capital-labor substitution, then, does not depend on a comparison between the interest and the wage rates, but between the price of machines and the wage rate;⁶ if the latter rises relative to the former, it will become profitable to save labor: in absolute terms, by making a more efficient use of labor, thus reducing its input per unit of output, without changing the other inputs, or, in relative terms, by substituting machines for labor, or in both ways. Such labor-saving measures need not imply a change in employment, which rather depends on whether output varies with respect to productivity. In particular, if output rises in the same proportion, then the labor-saving is not actual, but only potential; that is, total employment does not decline. (Reduction in labor input and increase in the productivity of labor are equivalent expressions.)

⁵Kalecki's conception is very close to the classical one, as may appear from the following quotation (which has been brought to my attention by Jan Kregel):

The idea that the reduction of the rate of interest stimulates the application of more capital per worker is based on the assumption that the planned *output* of the investing entrepreneur is given. On this condition a lower rate of interest makes it profitable to use more capital and less labor. If we assume, however, that the *capital* available to a firm for financing investment is given, the reduction of the rate of interest has no influence on the choice of the method of production when planning investment, because it affects the expected net profit equally, whatever the method of production adopted. . . . The main stimulus to use more capital per worker is provided by new inventions. (1944, p. 51)

Although Kalecki is right in pointing out the artificial and misleading assumption implicit in the neoclassical theory, in presenting his view he introduces a constraint which is certainly reasonable but, in my opinion, not necessary.

⁶Cp. L. L. Pasinetti, 1981, esp. pp. 192-197. The origin of the misunderstanding lies in the way "capital" is conceived. The rate of interest can properly apply to capital when it is conceived as purchasing power. When it is conceived as concrete

As for the substitution between machinery and labor, it is well to recall the following remark by Ricardo (1951a, p. 395):

Machinery and labour are in constant competition, and the former can frequently not be employed until labour rises.

If we refer to the first model proposed by Sraffa which considers production with a surplus and wages as necessary consumption, we can easily see that the choice between labor and fixed capital (plants and machinery) must depend not on the comparison between wages and interest but on that between wages and the price of machines. Naturally Sraffa's first model—which replicates in rigorous terms the classical conception—is to be construed so as to include the charges for fixed capital (Sraffa, 1960, ch. 2 and 10). As is well known, under competitive conditions, the rates of interest and of profit tend to coincide. Thus, if we start from a situation in which the two rates are equal and assume that the rate of interest is reduced, a net profit will appear, even though the entrepreneur has to pay interest to those who have lent the necessary funds. The lower rate of interest, then, will induce the firms, not to introduce fixed capital to supplant workers, but to expand production by employing greater quantities of *all* means of production, including workers. The terms of the problem become more complex in Sraffa's second model, in which production leaves a surplus and wages are paid out of the net product; but the substance of the analysis is not altered.

If wages vary with respect to the prices of capital goods, substitution will take place between labor and those goods, given technology and the organization of the productive process. However, if relative wages vary, technological and organizational changes will be stimulated. The first aspect entails the static substitution made central by the marginalist theory; the second one is a *dynamic* substitution, which is of much more relevance. Substitution—both static and dynamic—implies a relative saving of labor; the absolute saving of labor cannot be static: it is bound to be dynamic, in the sense that it can only be the result of technological or organizational changes. (In this paper, as should be clear by now, I am almost exclusively concerned with dynam-

capital goods, changes in wages and the interest rate modify the very prices of such goods; in the final analysis, this is the reason why it is wrong to compare the interest and the wage rates to interpret the substitution between labor and *concrete* capital goods. (Between the two conceptions of capital just mentioned there is an intermediate one: "capital" as a jelly. Rather than a conception, this is a *bon mot*, showing how great is the confusion still widespread in this field of economic theory.)

ic substitution and, more generally, with dynamic analysis, which allows for the changes that we have just mentioned and implies increases in productivity.)

5. Productivity increase as cause and effect of the increase of real wages

We have to broaden our analysis to take into account the fact that increases in productivity are, at the same time, cause and effect of the long-run increase in wages relative not only to the prices of machines, but to all or almost all prices: *cause*, since the increase in productivity induces trade unions to demand higher wages and, at the same time, allows the firms to pay them (under certain circumstances firms may decide spontaneously to grant higher wages both to attract and keep the most efficient workers and to ensure "social peace" within the firm); *effect*, since firms try to offset wage increases by saving labor either in absolute terms by rationalizing the productive process, or in relative terms by introducing machines capable of increasing productivity. At this point, however, it is necessary to distinguish between industrial prices in general and the prices of machines, for the behavior of the two price categories need not be the same, while it is reasonable to assume that the behavior of wages is the same in all industries.

Now, if wages increase more than productivity, i.e., if the cost of labor per unit of output rises, and firms do not succeed in passing the increase fully onto prices of finished products (the price of intermediate goods and of raw materials remaining unchanged), then their gross profit margin must fall. To counteract that tendency firms will be spurred to speed up productivity, that is, to save labor both in absolute and in relative terms. On the other hand, if wages outpace the prices of machines, firms will find it profitable to save labor by substituting machines for labor.

We may recapitulate our argument by adopting a very simplified version of the industrial price (P) equation⁷:

⁷Sidney Weintraub used such an equation in several works; see, e.g., Weintraub, 1969, especially chapter 2.

Another version of the industrial price equation is

$$P = a \frac{w}{\pi} + bM$$

where, in addition to the symbols indicated in the text, M is an index for the prices of raw materials and intermediate goods.

$$P = a(w/\pi)$$

where w is the wage rate and π is the productivity of labor and a is a constant. From this equation we get

$$a \frac{w}{P} = \pi$$

or, referring to the sector producing machines,

$$a' \frac{w}{P_{ma}} = \pi_{ma}$$

If the ratio w/P tends to outstrip π , there will be an incentive to save labor in absolute terms, i.e., to speed up the increase in productivity, without modifying the other inputs. If the ratio w/P_{ma} tends to increase, there will be an incentive to save labor in relative terms. It is quite possible to have a sequence going in the opposite direction, that is, from π to w/P or from π_{ma} to w/P_{ma} .

The easier it is for firms to shift cost increases onto prices, the weaker the incentive to raise productivity due to wage increases; in fact, if P or P_{ma} can be quickly raised in proportion to w , then the w/P and w/P_{ma} ratios do not vary and the incentive under discussion does not operate. The said shift is more or less difficult depending on market forms, on the intensity of foreign competition, and on the economic policy—including the foreign exchange rates policy—adopted by the government.

To explain productivity variations, then, we have to include the ratios w/P and w/P_{ma} among the explanatory variables. They can be merged if we assume that the behavior of the two price categories is the same. We will make precisely this assumption and hypothesize that the extent of shifting of cost increases on prices is partial.

An objection to including w/P_{ma} among the explanatory variables of productivity changes is that the entire price system varies with the distribution of income, as Sraffa has conclusively demonstrated; this implies that the numerator and the denominator of the w/P_{ma} ratio are interdependent.

However, it is not our task to discuss the relation between the changes in the distributive shares and those of relative prices: for our analysis it is enough to recognize that if, for whatever reason, the ratio of wages to the price of capital goods increases firms will find it profitable to save labor in relative terms. This point may be clarified further with the aid of Sraffa's models. Although these models assume *fixed* quantities of commodities, we could make use of them by assum-

ing that, due to technological innovation, the production of a certain commodity employing the same means of production and the same labor is increased. This implies greater efficiency, including an increase in the productivity of labor. If we also assume that the (unique) rate of profit stays unchanged and that the industry considered is the one producing machines, we can easily see that the price of machines necessarily diminishes with respect to those of all other commodities and that the ratio w/P_{ma} is necessarily lifted. However, such assumptions are redundant, for w/P_{ma} may increase because of a change in distribution, rather than from higher productivity in the machine-producing industry.

6. The output effect in the short and the long run

Productivity, then, can be stimulated by increases in w/P and w/P_{ma} , but productivity depends also on the size of the market, and on new capital investment. We return to those ratios later; here we comment on the size of the market and productivity increases.

This relation was first considered by Adam Smith: for him, "the division of labour is limited by the extent of the market" (title of chapter 3, book I, of the *Wealth of Nations*) and "the division of labour . . . occasions, in every art, a proportionable increase of the productive power of labour" (ch. 1, book I). The modern version of this proposition, which takes the volume of output as an index of the size of the market, is the so-called Verdoorn Law, which relates productivity changes to changes in the volume of output (Verdoorn, 1949)⁸; in turn, the variations of output express those of effective demand.

Economists, discussing this law, however, seldom make the necessary distinction between long- and short-run effects of changes in output volume on productivity. In the short run an increase in output can determine a more efficient use of labor, often by exploiting earlier innovations ("learning by doing" takes time). This increase of production does not call for additional investment, so it can mean an absolute saving of labor. But if output grows, in the long run firms will introduce more efficient additional machines to replace existing ones. Furthermore, if the market expands, certain plants and machines can be introduced that were not profitable in a more limited market. Pro-

⁸Compare the Spring 1983 issue of *JPKE*—the special Nicholas Kaldor seventy-fifth birthday issue—for Lord Kaldor's writings on this subject.

ductivity then increases by way of the reorganization process and by the introduction of new, more efficient machines. But in the short run (say, up to one year), only the first type of adaptation is likely.

The impact on productivity of changes in output therefore comes at the end of a complex process. The increase in output stimulates a rationalization in the use of the labor force, especially when labor is a quasi-fixed factor. But this tendency can be accelerated or retarded by various economic factors, as, for instance, the changes in the w/P ratio.

7. Productivity and investment: the disturbance effect of investment

In principle, all economists agree that investment is a primary source of productivity increases, since most innovations become embodied in new plant and machinery. However, relevant econometric studies are rare. Perhaps the reason is that investment is supposed to affect productivity only in the long run and, in addition, after an unsystematic time lag.

If we take the view that there cannot be a rigidly determined time lag before the effects of investment are felt in productivity, shall we assume that such effects are necessarily irregular, or shall we assume that they are distributed according to some regular time sequence—of the form, for instance, of a Gaussian curve? An empirical test is the only way to settle this question. To this end, we consider productivity as a function of: (a) total output, (b) the w/P_{ma} ratio, and (c) investment. Total output represents the short-run output effect, as reflected in available yearly data. The w/P_{ma} ratio can be assumed to represent an important incentive to save labor either absolutely or by introducing labor-saving machines. Since the effect takes time to manifest itself, it is reasonable also to lag this variable and, likewise, for analogous reasons, the investment variable.

As for investment, it is necessary to distinguish the determinants of its level from those of its composition (labor-saving and capacity-increasing investment). The *level* of investment depends primarily on demand pressure, as expressed by the degree of utilized capacity; current profits, as the source of self-financing; the expected rate of profit; and the availability and the cost of external finance (Sylos-Labini, 1974, ch. 1). The *composition* of investment depends primarily on the relative cost of labor. However, it is impossible to say to what extent a labor-saving investment is stimulated by an increase in the w/P_{ma} ratio, and to what extent it is independent of the increase. As it

can be profitable to introduce labor-saving innovations even if that ratio holds firm, it would be wrong to assume that the changes in that ratio are the only reason, or even the main reason, for the labor-saving investment. Consequently, we cannot exclude one of the two variables on the ground that its influence is already fully contained in the other; it is advisable, instead, to include both variables. Conversely, the ratio w/P is not included inasmuch as I hypothesize that its behavior coincides with that of the w/P_{ma} ratio.

Thus we have the following productivity equation to test:

$$(1) \quad \hat{\pi} = a + b\hat{Y} + c\hat{w/P}_{ma(t-n)} + dI_{t-n}$$

The cap over a variable indicates a rate of change.⁹ I have used the rate of change for three of the variables (π , Y , and w/P_{ma}); for the fourth variable, I , the investment level is used, since this variable represents the net addition to the stock of capital and, therefore, its behavior conforms generally to that of the rate of change of the capital stock. As for the lags of investment and of the relative cost of labor, from what we have said it follows that we have to test two hypotheses: one on distributed lags and the other on a single lag, which is to be interpreted as the modal value of a series of effects.

The estimates of equation (1) seem to be reasonably satisfactory. However, in calculating the various lags, including a zero lag, I also checked the belief that current investment has no effect on productivity (and on productive capacity). To my surprise, the tests showed that current investment does affect productivity, but *negatively* (cf. Sylos-Labini, 1980).

The explanation of this paradox lies probably in the fact that year-by-year the majority of investment projects are carried out by existing firms, not by new firms, and that the installation of new plant and equipment generates various disturbances in the ordinary operations of current production. It even hinders physically some operations and absorbs the energies of managers and engineers, who can devote less care to the ordinary business of their firms.¹⁰ It is important to point out

⁹Since the rate of change of total employment is equal to the rate of change of total income *less* the rate of change of productivity, or

$$\hat{N} = \hat{Y} - \hat{\pi}$$

Substituting $\hat{\pi}$ with equation (1) and writing $1 - b = b^*$ we have

$$\hat{N} = \hat{Y} - b^*w\hat{P}_{ma} - dI_{t-n}$$

¹⁰The explanation became clear after discussing the matter with Piero Quarantelli, an engineer with wide managerial experience.

that current investment is negative and statistically significant in both countries for which the tests were carried out, Italy and the United States. We will call the said negative effect of current investment on productivity "the disturbance effect."

8. Productivity and research and development expenditure

A perplexing issue is whether it was necessary to include among the explanatory variables the expenditure on research and development. This idea is rejected, for two reasons. First, the very meaning of that expenditure is ambiguous, since in certain industries "development" in the commercial sense is more important than "research" in the proper sense; in such industries the effects of the said expenditure can be more important for the volume of sales and production than for productivity; therefore, only indirectly can that expenditure affect the increase of productivity. Second, as mentioned earlier, most innovations are embodied in investment; and innovations are very often the fruit of research and development expenditure. Thus it would be advisable to include this expenditure among the explanatory variables of investment, not of productivity; investment, in turn, affects productivity.

An important warning: although I have distinguished between short-run and long-run output effects, in my productivity equation I use only the rate of change of current output, which only to a small extent can be seen as embodying the long-run output effect. More generally, in the productivity equation I present current variables as expressing "short-run" and lagged variables as expressing "long-run" influences of the various factors. This procedure can be justified by the limited purposes of my analysis. If we take a broader view of the long run and of the factors affecting productivity we would have to take into account several other factors—to mention only one: the extent and the trend of the technical lag between the follower countries and the lead country, in our time the European countries and Japan on the one side, the United States on the other; *ceteris paribus* the productivity increases are easier and therefore higher in the former countries than in the lead country (see Maddison, 1982, ch. 5). However, this type of problem lies outside the scope of my analysis.

9. The productivity equation

The productivity equation to be considered is:

$$(2) \quad \hat{\pi} = a + b\hat{Y} + cw\hat{P}_{ma}(t-n) + dI_{t-n} - eI$$

where I_{t-n} is the long-run effect and I the short-run effect of investment. More generally, the equation incorporates factors that operate both in the short and the relatively long run, the latter, as I said, being represented by the lagged variables.¹¹

For the econometric estimates, though I have examined both the whole economy and the manufacturing sector of Italy and the United States, I present only the results concerning the manufacturing sector, because productivity per hour is a much more precise concept than productivity per person, but productivity for the whole economy is measured, by necessity, in persons employed. Moreover, if we refer to manufacturing industry we avoid the problem of the effects on productivity growth of the shifts in the employment shares.

For the manufacturing sector, we have tested both hypotheses concerning lags—distributed lags and a single dominant lag. The periods considered were 1962 to 1980 for Italy and 1950 to 1981 for the United States (the different time lengths used were determined by the availability of data). In the case of the United States an additional estimate was made for the period 1970 to 1981, because the behavior of productivity underwent important changes in the 1970s (case b').

The estimates refer to the two countries and the two hypotheses in this way: case a equations are for a single lag; case b for distributed lags. Following a suggestion of Gianni De Nicoló, who calculated all the equations, we tested an additional case (case a') for Italy, in which,

¹¹As is well known, the w/P_{ma} variable is lacking in the productivity equations estimated by economists who accept traditional theory and take the aggregate production function as the starting point in their empirical investigations. However, it is clearly absurd not to consider, in such investigations, the prices of capital goods at least as an element in the process of substitution between capital and labor; therefore several economists have introduced a special variable, the "rental of capital goods," intended to combine the traditional variable—the rate of interest—with the prices of capital goods. In fact, this "rental" has been conceived as the product of the said two quantities (some use this "rental" net of taxes but gross of depreciation) (see Jorgenson and Griliches, 1967). Now, this concept is open to an objection similar to that raised to Marshall's "net product," i.e., that it is inconsistent with the neoclassical theory of distribution. Indeed, if we define the said rental as $p_K \cdot i$, the relation

$$p_K \cdot i = \frac{\partial x}{\partial K}$$

fails to confront with the aggregate production function and the theory of distribution derived from it.

instead of investment, we used in our estimates the first difference in the stock of capital (ΔK). As for the single-lag hypothesis, in both countries the best results have been obtained with a two-year lag. In Italy the distributed lags hypothesis has proved to be relevant only for investment with the following weights attributed to this variable lagged 1, 2, and 3 years: 0.25, 0.50, and 0.25. A single two-year lag also proved to be the most convenient in the case of the relative cost of labor, as seen in equations for cases a and a'. In the United States the most convenient lag structure of investment appears to be the same as that used for Italy. The lag structure of the relative cost of labor is 0.50, 0.25, and 0.25 for the variable lagged 2, 3, and 4 years. The distributed lag hypothesis has been adopted both for the entire 1950 to 1981 period and for the subperiod 1970 to 1981.

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Italy

$$\begin{aligned}
 \text{(a)} \quad \hat{\pi} &= .53\hat{Y} + .30w\hat{P}_{ma(-n)} + .08I_{(-n)} - .06I \quad R^2 = .796 \\
 & \quad 6.63 \quad 1.77 \quad 2.70 \quad 2.43 \quad DW = 1.910 \\
 \text{(a')} \quad \hat{\pi} &= .54\hat{Y} + .35w\hat{P}_{ma(-n)} + .04\Delta K_{(-n)} - .03I \quad R^2 = .783 \\
 & \quad 6.45 \quad 2.08 \quad 2.16 \quad 1.95 \quad DW = 1.832 \\
 \text{(b)} \quad \hat{\pi} &= .56\hat{Y} + .32w\hat{P}_{ma(-n)} + .09I_{(-n)} - .07I \quad R^2 = .770 \\
 & \quad 6.56 \quad 1.76 \quad 2.21 \quad 2.13 \quad DW = 1.857
 \end{aligned}$$

United States

$$\begin{aligned}
 \text{(a)} \quad \hat{\pi} &= .18\hat{Y} + .30w\hat{P}_{ma(-n)} + .13I_{(-n)} - .09I \quad R^2 = .719 \\
 & \quad 5.88 \quad 2.67 \quad 5.13 \quad 4.16 \quad DW = 2.036 \\
 \text{(b)} \quad \hat{\pi} &= .20\hat{Y} + .43w\hat{P}_{ma(-n)} + .13I_{(-n)} - .10I \quad R^2 = .722 \\
 & \quad 7.30 \quad 2.57 \quad 4.85 \quad 4.01 \quad DW = 1.997 \\
 \text{(b')} \quad \hat{\pi} &= .17\hat{Y} + .25w\hat{P}_{ma(-n)} + .14I_{(-n)} - .12I \quad R^2 = .938 \\
 & \quad 5.60 \quad 3.36 \quad 9.52 \quad 8.36 \quad DW = 2.692
 \end{aligned}$$

10. The slowdown in productivity growth

The productivity equation can shed light on a phenomenon that has puzzled many economists, the slowdown in productivity growth. This slowdown has been particularly serious in the United States and there

still has been no explanation for it.¹²

Among all the variables in the productivity equation which, beginning with the output variable, have contributed to a slowdown in productivity growth, the w/P_{ma} ratio in recent years diminished significantly. It is well to point out that the diminution of this ratio, which is a rather exceptional event in the economic history of the United States, has been brought about because the price of machines has increased considerably due to an increase in energy and raw material prices, whereas money wages have increased to a lesser extent.¹³ The problem is then to understand why wages and salaries have increased so slowly—since the late 1970s real wages have declined. I think that the main reasons are two: the great influx of workers from Latin America and the rapid absorption of women in services (from 1971 to 1981 total employment in the United States increased by 21 million; of this figure 13 million are women). Although the two phenomena have powerfully contributed to slow down the increase in money wages, at the same time the entry of women into the labor force has raised the number of families obtaining at least two incomes, and so has lessened the impact of the decrease in real wages.

In Italy the slowdown in productivity growth has been less pronounced than in the United States. What seems to be the main reason is that, contrary to what has happened in the United States, since the late 1970s the relative cost of labor has continued to increase, though at a

¹²The following observations (*Economic Report of the President*, 1982, p. 114) are still valid: "There have been concerted efforts to explain the measured slowdown. These efforts have met with only limited success. While there are a number of possible explanatory variables, available studies suggest that none separately nor in combination is capable of explaining more than half of the decline."

¹³It has been found that the increase in the price of energy has contributed to the productivity slowdown (see Hudson and Jorgenson, quoted in Norsworthy, Harper, and Kunze, 1979, pp. 388 and 412). This finding is fully consistent with the view put forward in the text, since machinery and energy are to a large extent complementary inputs—the price of energy is an important part of the running expenses of machines—so that the price of machines could be substituted by an index combining the prices of the two inputs. On the other hand, as already noticed, the increase in the price of energy has contributed to push up the price of machines and, thus, to pull down the w/P_{ma} ratio. If this is so, then it does not seem to be necessary to consider separately the price of energy in the productivity equation; the ratio w/P_{ma} appears to be adequate. (Strictly speaking, this ratio would have to be modified in the following way: $w/(\alpha P_{ma} + \beta P_{en})$, where P_{en} is the price index of a unit of energy and α and β are appropriate weights.) Let us add that, though the increase in the price and in the running expenses of machines has reduced the incentive to substitute machines for labor, it has stimulated the absolute saving of machines; i.e., it has increased the incentive to save the use of machines per unit of output.

lower speed than in the past. Real wages, again contrary to what has happened in the United States, did not decline in the 1970s; only in the first two years of the 1980s has a certain decline occurred, but outside the market, i.e., as a consequence of fiscal drag. (It must be observed, however, that in Italy in the 1970s the level of employment rose only slightly, but in the underground economy, where usually subnormal wages are paid, it expanded.)

Considering the great importance of the w/P_{ma} ratio to the slowdown in productivity growth in Italy and the United States, it may prove promising, after critical appraisal of the implications of the whole productivity equation, to make detailed—possibly disaggregated—empirical analyses for the said two countries and for other developed countries along the lines worked out here.¹⁴

¹⁴Since completing this article, I have seen the March 1983 issue of the *Economic Journal*, in which there are three papers, together with a commentary, on the slowdown of productivity growth that has occurred in recent years in all developed countries. The authors are: A. Lindbeck, H. Giersch and F. Wolter, and E. F. Denison, and D. J. Morris, who is the author of the comment on the paper by Professor Lindbeck. I recommend that the reader compare my conclusions with those reached in these three papers, which follow the traditional approach.

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