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LEANING INTO TFP*

by Enrico D'Elia, Leonello Tronti

Growth policies, including the European recovery facilities, aim at enhancing total factor productivity (TFP), which, in the neoclassical theoretical framework, is the sole source of overall output growth in addition to that mechanically resulting from increasing labour and capital inputs. Nevertheless, few algebraic manipulations show that TFP depends on income distribution and market power. Thus, suggestive as it may be, it is only an imperfect measure of productivity; and boosting its supposed determinants mentioned in the literature, so to accelerate economic growth, can be misleading. Suitable income and industrial policies are necessary instead.

Keywords: factors' remuneration, primary income distribution, productivity, market power.

Le politiche per la crescita, compresi i programmi europei per la ripresa, mirano a migliorare la produttività totale dei fattori (TFP), che, nel quadro teorico neoclassico, è l'unica fonte di crescita della produzione complessiva in aggiunta a quella meccanicamente derivante dall'aumento degli input di lavoro e di capitale. Tuttavia, bastano poche manipolazioni algebriche per mostrare che la TFP dipende dalla distribuzione del reddito e dal potere di mercato. Quindi, per quanto suggestiva, la TFP non è che una misura imperfetta della produttività; e, ai fini dell'accelerazione della crescita economica, il rafforzamento dei suoi presunti determinanti suggeriti dalla letteratura può essere fuorviante. Sono invece necessarie politiche economiche e industriali adeguate.

Parole chiave: remunerazione dei fattori, distribuzione primaria del reddito, produttività, potere di mercato.

That's the math*,*[+] *baby. The* math*!*
And there's nothing you can do about it.
Nothing!

[+] The *press* in the original script.
Humphrey Bogart, in *Deadline – U.S.A.*, 1952.

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1. Introduction

Measuring output, input, and productivity necessarily relies on a system of relative prices, unless the composition of each aggregate is strictly constant over time, which is implausible. Total factor productivity (TFP) aims at quantifying the output change that exceeds the growth of productive factors, typically labour and capital, overlooking the role of relative prices. Nevertheless, relative prices (and particularly the remuneration of productive factors) affect TFP as well. Solow (1957) derived a measure of TFP from a production function, but Griliches and Jorgenson (1967) pointed out that TFP comes mechanically from the accounting identity between value added, on the one hand, and the sum of the wage bill and the operating surplus, on the other. Therefore, Felipe and McCombie (2006) argued that explaining economic growth as a consequence of TFP dynamics is ultimately a pure tautology.

During the last three decades, in the European Union (EU) TFP accounted for about one third of overall growth, which is paradoxical for a component that should only be a "residual" unexplained by the labour and capital dynamics. Indeed, Abramovitz (1956) already considered TFP essentially as "a measure of our ignorance" about the factors of production and their combination. Nevertheless, the new growth theory, developed by Romer (1986) and Lucas (1988), regards TFP as an autonomous determinant of economic growth, which can be increased by suitable policies, and focus on the factors that boost it. This view implicitly assumes that the increase in TFP does not reduce the use of factors of production, which is questionable, as this document shows.

The extensive survey by Kim and Loayza (2019) identifies the main determinants of TFP as: innovation, education, market efficiency, infrastructure, and institutions. The Next Generation EU initiative fully embraces this latter view, as confirmed also by the European Commission (2020) recommendation for the euro area economic policy on the use of the recovery and resilience facilities. Fostering productivity after the Covid-19 pandemic is included in one of the six pillars defined in Article 3 of Regulation (EU) 2021/241 establishing the Recovery and Resilience Facility (precisely in letter c)), and typical TFP-improving policies are suggested also by the pillars b) (digital transformation) and f) (education and skills). In assessing the macroeconomic impact of the Next Generation EU instrument, the analysis of national plans submitted by the EU Member States provided by Bruegel (2022) shows that the pillars related to productivity account for about one third of available funds.

The research question of this paper is, then, how enhancing TFP is a feasible and effective strategy to increase productivity (whatever it means, as argued by Del Gatto *et al.*, 2011) and economic growth. There are few doubts that economic growth may benefit from technical and organisational innovation, better education and training of the workforce, market efficiency, better infrastructure, and more effective institutions. Nevertheless, this paper shows that at least two further factors matter, although seldom considered in the literature: primary income distribution and the interaction between the productivity of each factor of production. As explained in the next section, a simple accounting interpretation of TFP implies that it cannot increase if profit rate raises too much at the expense of wages, and the other way round. It follows that growth and income distribution cannot be analysed separately, contrarily to what mainstream theories assume. In addition, improving the productivity of a single factor may undercompensate the drop of the others, thus reducing TFP. To the authors' knowledge, none of the latter constrains have ever been mentioned in the literature.

The paper is composed of three other sections. The next one shows the algebraic relationships between TFP and the remuneration of the factors of production. It apparently revives one of the main conclusions of the pre-marginalist economy, that is, the trade-off between the compensation of labour and capital. The third section goes through the policy implications of the algebraic decomposition reported in the paper, pointing out the role of industrial policy, wage bargaining, and income policies in enhancing growth. Few concluding remarks close the paper.

2. TFP, INCOME DYNAMICS, AND PRODUCTIVITY

The volume of value added (Y) created by any economic activity is apportioned between labour (L) and capital (K) that contributed to the productive process, that is,

$$Y \equiv wL + rK \qquad [1]$$

where w is the average *per capita* wage at constant prices, and rK is a decomposition of the operating surplus as the product of capital services K and the corresponding return rate r. For the mere sake of simplicity, capital is treated here as a homogeneous good, whose value does not depend on relative prices[1]. An extension to more than two productive factors is straightforward. The product wL is the gross wage bill, including social contribution, where L can be measured either by headcounts, standardised units (e.g. full-time equivalent units or units adjusted for human capital), hours worked, etc., including self-employed workers, as far as w is measured conformably. Remarkably, the definition [1] is fully general, since it holds for countries, industries, or single businesses.

Deriving [1] with respect to time gives

$$\dot{Y} \equiv \alpha\dot{L} + (1-\alpha)\dot{K} + \alpha\dot{w} + (1-\alpha)\dot{r} \qquad [2]$$

[1] In what follows, we intentionally overlook the issue of the measurement of capital, labour, and output, which are strongly heterogeneous goods and services. Here K, L, and Y are intended as aggregate indices, whose composition does not change with TFP. Of course, we are fully aware that the value of output, and whatever measure of productivity depend on relative prices used to aggregate capital and labour. For instance, if only two goods are produced, the marginal productivity of capital is $P = \frac{dY}{dK} = \frac{d(Y_A + p_B Y_B)}{d(K_A + p_B K_B)}$, where the good A is taken as the numeraire to measure the price of the other good. It is worth noting that $P \neq P' = \frac{d(Y_A + p'_B Y_B)}{d(K_A + p'_B K_B)}$ if $p_B \neq p'_B$, unless $\frac{Y_A}{Y_B} = \frac{K_A}{K_B}$, which is a very special case. Thus, pairing the price of whatever heterogeneous production factor to its marginal productivity implies a circular reasoning. In particular, the factors that enhance productivity under a given system of prices could also cut it if prices were different so that, in principle, the concept of TFP is a nonsense in a fully coherent theoretical framework. To escape from this conundrum, it is necessary to assume: either (i) that only a single set of equilibrium prices may exist, which is consistent with the marginal productivity of each factor measured by using those prices; or (ii) physical and human capital is treated as pure initial endowment not to be produced and replaced over time (and necessarily traded at some prices). This is the core of the long-lasting controversy about the capital measurement and the existence of aggregate production functions, even recently surveyed by Fratini (2019).

where $\dot{x} = \frac{dln(x)}{dt}$ is the continuous rate of change of x over time, and $\alpha = \frac{WL}{Y}$ is the so-called labour share. Time subscripts are omitted only for brevity, but α and all the variables included in [1] and [2] may change over time. A pure algebraic interpretation of [2] is that the growth of overall value added is made of two components: a) the change in income if only the amount of labour and capital would change, at the ongoing wages and return rates (i.e.: $F = \alpha\dot{L} + (1 - \alpha)\dot{K}$), and b) the change of remuneration paid to the same factors (i.e.: $S = \alpha\dot{w} + (1 - \alpha)\dot{r}$). Notably, S is TFP contribution to the growth of value added, rather than a rate of change over time, like $\dot{L}$, $\dot{w}$, etc.

The latter decomposition of $\dot{Y}$ holds whatever the arbitrary value of α is, that is, S may be always defined once a weighted average of $\dot{L}$ and $\dot{K}$ is set. In particular, the log-linearisation of a generic continuous and differentiable production function $y = f(L, K)$ with constant returns of scale gives:

$$\dot{Y} = \alpha^*\dot{L} + (1-\alpha^*)\dot{K} + \hat{S} \qquad [3]$$

where $\alpha^* = \frac{d\ ln\ f(.)}{d\ ln(L)}$ and $\hat{S}$ is the so-called Solow residual, often referred to as total or multi-factor productivity. It is worth noting that [3] does not take into consideration the effect of prices on Y, L, and K: that is, the identity holds true for the ongoing system of relative prices.

Indeed, TFP can be properly defined as nothing more than the "unexplained" increase in factors' remuneration, where the quotation marks highlight that, for the measurement of TFP to be correct, the quality of factors shall remain unchanged during the time/scope subject to measurement. In other words, when measuring this indicator on heterogeneous aggregates of inputs (in practice, always), and over long time periods, not only the quality but also the composition of inputs and outputs and their relative prices should remain unchanged throughout the measurement period. As a matter of fact, actual measures of TFP embody a relative prices effect that cannot be considered as an effect of economic efficiency, contrarily to the mainstream interpretation of this index. An exhaustive formulation of [3] should therefore include another term, measuring the effect of relative price changes.

Subtracting [2] from [3], and rearranging the terms gives

$$\begin{aligned} \hat{S} \equiv \dot{Y} - \alpha^*\dot{L} - \ (1 - \alpha^*)\dot{K} \equiv \\ + \alpha\dot{w} + (1 - \alpha)\dot{r} + \\ + (\alpha^* - \alpha)\ (\dot{K} - \dot{L}) \end{aligned} \qquad [4]$$

where the last line is null either if $\alpha^* \cong \alpha$ or if the technical progress is Hicks-neutral, i.e. the capital- labour ratio is constant over time. From [4], the following quasi-identity comes

$$\hat{S} \cong S = \alpha\dot{w} + (1 - \alpha)\dot{r} \qquad [5]$$

A basic economic interpretation of [5] is that TFP, by increasing the market value of goods and services beyond the physical amount of intermediate goods, capital, and labour in use, is a component of value added. Thus, it must be fully allocated between the productive factors[2].

It is worth noting that TFP boosts (i.e. causes) total growth only if it does not reduce the use of capital and labour at the same time, which the mainstream theory deems unlikely, since K is negatively related to its cost r, and L to w, other conditions being the same.

Furthermore, [5] shows that TFP is simply the extra-remuneration of factors with respect to their "normal" value. Thus, TFP of a firm or a country may measure a change in its market power vs. the competitors, rather than in its efficiency. It follows that a rent-seeking behaviour can enhance mechanically TFP, while making the market more competitive and transparent will reduce it, which is quite puzzling.

Of course, innovation and technical progress could be regarded as a determinant of market power, as they can be considered as a sort of "temporary monopoly", but often market power depends on oligopolistic advantages unrelated to technical efficiency. This result generalises the conclusion of Hall (2018), who demonstrated analytically that TFP raises with the Lerner index (i.e. the ratio of prices to marginal costs), which is a typical measure of market power, only if technical progress is negligible, and the overall growth rate is positive. Thus, he admitted that "the Solow residual does not measure actual technical progress, because it does not adjust for market power".

Equation [5] is fully consistent with the mainstream interpretation of TFP, since S is also a weighted average of the productivity of each factor. Actually, the continuous rates of change of the labour share and the capital share are

$$\dot{\alpha} = \dot{w} + \dot{L} - \dot{Y} = \dot{w} - \dot{\pi}_L \qquad [6]$$

and

$$(1 \dot{-} \alpha) = \dot{r} + \dot{K} - \dot{Y} = \dot{r} - \dot{\pi}_K \qquad [7]$$

where $\dot{\pi}_Z = \dot{Y} - \dot{Z}$ is the change of the average apparent productivity of the Z factor, which generally differs from its marginal productivity. Thus, the equation [5] gives

$$\begin{aligned} S = \alpha(\dot{\alpha} + \dot{\pi}_L) + (1 - \alpha)\left((1 \dot{-} \alpha) + \dot{\pi}_K\right) = \qquad [8] \\ = \alpha\dot{\pi}_L + (1 - \alpha)\dot{\pi}_K + \\ \alpha\dot{\alpha} + (1 - \alpha)(1 \dot{-} \alpha) \end{aligned}$$

where the last row is null because the rates of change of the two income shares sum to 1 by definition.

[2] As far as value added depends on market prices and remunerations, the TFP depends on the price system as well. For instance, the introduction of hedonic and shadow prices (possibly including environmental costs) results in different productivity assessment.

It follows that TFP admits a dual interpretation: a) the change of unit remuneration of factors, that is, the view supported by [5], and b) the average apparent productivity of factors, that is, the usual view endorsed by [8].

Under both interpretations, and assuming that TFP does not affect K and L as usual, the equations [5] and [8] imply that TFP gives a positive contribution to overall growth only if

$$\dot{w} \geq -\dot{r}\,\frac{1-\alpha}{\alpha} \qquad [9]$$

and

$$\dot{\pi}_L \geq -\dot{\pi}_K\,\frac{1-\alpha}{\alpha} \qquad [10]$$

It follows that, in order to increase TFP, the compensation of employees, and the productivity of labour cannot change less than a given threshold. The constraints [9] and [10] are always fulfilled if all the changes are positive, otherwise TFP may be negative even if one of the factors of production gains remuneration and productivity. For instance, TFP could be virtually unaffected by innovation and training, that are typical drivers of productivity, when technical progress and globalisation raise the remuneration of capital but reduce too much $\dot{w}$, as argued by Piketty (2018). TFP may also slow down or reduce if a new technology displaces labour, raising mechanically the $\frac{Y}{L}$ ratio, since less workforce is needed for producing the same output, and reducing $\frac{Y}{K}$, since the capital intensity raises correspondingly. In an extreme scenario, in which a new technology makes labour fully redundant, α collapses to 0, consequently no reduction of the $\frac{Y}{K}$ ratio may satisfy the inequality [10], and the same concept of TFP necessarily loses any meaning. Brynjolfsson *et al.* (2019) addressed a similar paradox in explaining why, contrarily to what expected, artificial intelligence has not increased TFP in Japan.

3. Some policy consequences

The constraints [9] and [10] derive from simple algebraic manipulations of the accounting identity [1], rather than from some theory of production and income distribution. For this reason, our results are very robust, and seriously challenge the traditional interpretation of TFP as a measure of productivity of a country, an industry, or a firm. Indeed, TFP should only be considered as a fraction of output growth, hardly separable from other factors of production. In particular, increasing TFP could even reduce the use of capital and labour, because the components of TFP are exactly the changes of the cost of using the factors of production. In any case, the drivers of TFP are strictly related to primary income distribution and market competitiveness, rather than investment, innovation, and business environment. These pure algebraic results hold true regardless of the interpretation of the decomposition [2], and challenge traditional growth theory and development policies. Thus, either TFP is an irrelevant concept, as argued by Felipe and McCombie (2006), or it supports a number of policy recommendations that conflict with the traditional ones.

For instance, the performance of Italian economy has been unsatisfactory for a long time, and most scholars and international institutions have suggested accelerating economic growth by enhancing TFP. Ciccarone and Saltari (2010 and 2015), among others, explained the modest long-term growth of GDP (on average 0.2% per year between 1995 and 2020) as a consequence of declining capital productivity and TFP. Thus, they recommend fostering investment in innovation, training, and the quality of institutions, which are typically acknowledged as policy measures that increase TFP. However, the previous section shows that this would be not enough even assuming that TFP is an independent driver of growth, since improving overall performance of economy requires appropriate income and industrial policies as well. In particular, Ricci and Tronti (2018), among others, pointed out that, in the same period, the labour share of income has shrunk, and Italy has fallen into what has been termed a "real wage issue"; thus, enhancing TFP index requires higher compensation for workers, exactly as suggested by the pure algebraic interpretation of TFP.

Inequalities [9] and [10] highlight the fundamental role of income distribution in economic growth and, in particular, the one of labour remuneration. From a theoretical point of view, our algebraic analysis, confirms, to some extent and in a dynamic setting, the so-called "Bowley's law", which envisages a medium-term constancy of the labour share. It is worth noting that that this condition plays a crucial role, for example, in a balanced growth model *à la* Kaldor, where it is one of the conditions that ensure the stability of the profit rate in the stationary state. Furthermore, always on a macroeconomic standpoint, the constancy of the labour share encourages maximum consumption growth without wages exerting inflationary pressures on the gross operating surplus.

Moreover, in connection with these macroeconomic considerations, the algebraic analysis proposed here, which is also valid at company level, highlights the role of the so-called "golden rule" of wage policies: the microeconomic counterpart of Bowley's Law, requiring real wages to grow at the same rate as labour productivity (Tronti, 2010). In this case, the targets are not only price and profit stability, and maximum non-inflationary consumption as well, but also the fact that the rule ensures that the change rates in both compensation of employees, and gross margin are identical and anchored to that of labour productivity. In this way, the rule cements the common interest of business and labour to increase productivity and, by rewarding both in the same relative measure, stimulates social cooperation for growth and continuous improvement, promoting the quality of industrial relations necessary for "concerted" development, innovation, and investment.

We should not forget the analysis of the influence of wage growth on labour productivity increase proposed for more than two decades (from 1984 to 2004) by Paolo Sylos Labini through his formalisation of the "productivity function"[3], which envisages, among other things, the presence of a kind of "wage whip" acting at various levels. The whip effect predicts productivity increases induced by wage growth through three different channels: (a) the "Ricardo effect", that is, a rise in labour costs higher than that in the price of man-replacing machinery (or a reduction in the latter, or else a sharp increase in its productivity at the same cost); this effect fosters output through larger investment and organisational innovation; (b) the "organisational effect", that is, an increase in unit labour costs higher than the growth of product price (i.e. an increase of absolute or real unit labour cost),

[3] Sylos Labini estimated and proposed for the first time his productivity function in 1984, and then repeated its tests for 20 years on different periods, countries, and economic sectors, in at least nine different scientific publications. An extensive recount of the function, the results obtained, and the publications is provided by Corsi and Guarini (2007).

resulting in a fall in the share of capital (leading in itself, along inequality [9], to an increase in TFP), with possible price increases, reorganisation, and/or downsizing of employment; and (c) an increase in the domestic market for consumer goods, as a result of an autonomous increase in wages, with scale economies (i.e. an application of the "Smith effect" and/or Kaldor-Verdoorn Law) on the industries producing those goods.

Interestingly enough, the line of economic reasoning on the effects of income distribution on productivity growth, which is reflected in empirical analyses such as those based on the "classical" model of Sylos Labini (for a recent example, see Carnevali, Godin, Lucarelli, and Veronese Passarella, 2020), is confirmed by the purely "arithmetic" analysis of TFP developed in this article. In fact, our analysis shows that the growth of TFP (whatever its significance) is limited by the size of the share of wages in value added and, in particular, that the greater the share of wages, the greater the wage increases (inequality [9]), or, alternatively, the share of labour productivity (inequality [10]), which will be transferred to the growth of TFP.

A non-trivial outcome of our exercise is, therefore, that an in-depth analysis of TFP shows that, for the sake of productivity growth, expansionary wage policies independent of productivity growth itself are necessary. Therefore, the wage policies resulting from analyses such as that of Paolo Sylos Labini's productivity function cannot be rejected, as they are not the mere result of a non-mainstream approach, but they are enshrined also in a cornerstone of mainstream theory.

4. Concluding remarks

Our results intentionally derive from pure algebraic manipulations of the income accounting identity, without any further theoretical assumption; they nevertheless help to explain some evidence that challenges the theoretical literature on the determinants of productivity and growth. For instance, Stiglitz (1996) and Felipe (1999) investigated the paradox of the "Asian miracle", where growth apparently took place with a minor or even negative contribution of TFP, notwithstanding the overwhelming technical innovation, R&D expenditure, and educational programmes. Kim and Loayza (2019) found that technical innovation is not the main driver of TFP in less developed countries. Danquah *et al.* (2014) report that some unobservable country-specific factors apparently explain the TFP dynamics, even when controlling the results for the usual determinants of productivity, including investment in innovation, human capital, R&D, etc. Indeed, the supposed drivers of TFP require a balance between primary incomes and between factor productivities, which failed to occur in the cases mentioned above.

Even remaining within the traditional approach, which assumes that there is no trade-off between TFP and the use of capital and labour, this paper shows that TFP and growth may increase only if the compensation of employees and labour productivity increase above a threshold that depends on the growth of the return to capital or of capital productivity, as well as on the functional distribution of income. In order for the contribution of TFP to growth to be positive, it is necessary that wages, profit rates, labour productivity, and capital productivity all show positive developments. Otherwise, TFP may decrease even if one of the factors of production increases its remuneration and/or productivity. For example, TFP may not be practically affected by innovation and training, which are typically considered productivity drivers, when technical progress and globalisation increase the return on capital but reduce too much w, as argued by Piketty (2018). TFP can also slow

down or decrease if a new technology displaces labour, mechanically increasing the Y/L ratio, as less labour is needed to produce the same output and Y/K is reduced accordingly, as capital intensity increases.

The consequences of our analysis for growth policies, and particularly for the Next Generation EU initiative, are clear-cut. First, improving human and physical capital, and the quality of institutions may be not enough in order to enhance TFP and overall growth, since suitable income and industrial policies are requested as well. Second, if they increase apparent productivity of some single factors while reducing too much that of the others, some structural reforms may paradoxically reduce TFP. In particular, enhancing market competition may cut overall growth, since competition possibly raises output and the employment of capital and labour, but also erases the margins for extra-compensation of workers and entrepreneurs.

Furthermore, in assessing the impact on GDP of privatising State-owned companies and other structural reforms, relative prices effects should be carefully considered. Also, the tertiarisation of the economic system and the effects of these processes on productivity (according to the Baumol disease) should be taken into account. Finally, interpreting TFP as a measure of market power could be insightful in analysing the effects on output of mass schooling and the computer revolution, which must be associated to the changed balance of power between social classes.

In conclusion, our findings suggest the TFP index be considered as a mere statistical indicator of the production process, influenced by demand effects and devoid of any special and autonomous significance, rather than a crucial variable, capable of explaining and thus driving economic growth. Consequently, the huge number of empirical attempts to identify the "determinants" of TFP should be considered as lacking any ability to suggest effective development policies.

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