XI Consiliatura 2023-2028

Measuring Productivity

Prices, Quality, Levels and Dynamics in Economies with High Internal Heterogeneity

Italy – National Productivity Board

Working Paper

No. 3, July 2026

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CONSIGLIO NAZIONALE
DELL'ECONOMIA E DEL LAVORO

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Managing Director

Renato Brunetta – *President of CNEL*

Translation note: *This English version was translated from the original Italian by Michela D'Ambrosio.*

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Measuring Productivity

Pasquale Lucio Scandizzo [1]

Introductory Essay. Measuring What Changes

The variables through which we describe the economy are not neutral portraits of reality: they are constructs, the outcome of theories and statistical-economic conventions that determine what counts as output, what counts as a cost, and what counts as an investment. Although these conventions are applied to modern economies that have undergone profound structural change and continue to evolve rapidly, they remain largely rooted in an effort to measure an economy dominated by tangible, market-traded goods that were relatively easy to account for. The economy we seek to analyse nowadays is, however, largely intangible and characterised by processes of progressive dematerialisation: it is composed of services, knowledge, software, data, relationships, public functions that are not mediated by market prices, and now also artificial intelligence. Measuring it with instruments calibrated for a world that no longer exists tends to generate a systematic gap between what we observe in the statistics and what is actually happening in the economy.

Productivity is the central variable around which this problem revolves. It is the figure that links labour to welfare, wages to growth, and the present to a country's capacity to achieve higher living standards in the future. It is a crucial economic measure because it captures the ability to make the best use of available resources; yet precisely because of its importance, it is difficult to define and even more difficult to estimate. Total factor productivity, in particular—the most ambitious measure—is not directly observable: it is calculated as a residual, representing what remains of growth once the contribution of the factors we are able to measure has been removed. In the well-known formulation, it is a measure of our ignorance.

The central argument of this Working Paper is that measuring productivity and measuring economic growth are, in fact, the same problem viewed from two different perspectives. The conventions that determine what is included in Gross Domestic Product (GDP), or in other measures of income and welfare, simultaneously determine what enters the measurement of

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productivity. Reclassifying an item from costs to investment changes both the level of output and the value of total factor productivity. For this reason, the debate on moving beyond GDP and the debate on the slowdown in productivity are not separate discussions but two sides of the same coin.

The proposal that runs through these pages is not to interpret productivity as a single figure, but rather through a sequence of six wedges. Each wedge represents a correction that brings measured productivity closer to what is actually changing in the economy. These are not competing theories, but lenses applied in succession which, when overlapped, provide a more faithful picture. The first wedge is standard growth accounting; the second reclassifies intangible investments; the third measures the extent of output trapped by the misallocation of resources; the fourth isolates the effects of market power; the fifth replaces output with a measure of welfare; and the sixth, finally, treats artificial intelligence as a partially autonomous factor rather than as a simple component of capital.

This Working Paper is organised into six chapters. The first clarifies what productivity means and why it matters. The second critically reviews the literature that has exposed the limitations of current measurement. The third presents the six wedges in non-technical language, referring readers to the footnotes accompanying each chapter for the more formal elements. The fourth applies the developed framework to the Italian case, using three social accounting matrices for 2020, 2024 and 2025, harmonised within a common structure comprising seventy-five sectors and households differentiated by income deciles, together with a computable general equilibrium model. The fifth addresses the debate on the measurement of European productivity. The sixth, in accessible language, shows where the problem of Italian productivity lies. The conclusion returns to the initial argument and draws out a number of methodological and economic policy implications.

Frequently Asked Questions

Why would measuring productivity and measuring GDP be the same problem?

Because the conventions that determine what counts as output simultaneously determine what enters the productivity residual. Reclassifying an item from costs to investment changes both the level of

GDP and the value of total factor productivity. The debate on moving beyond GDP and the debate on the slowdown in productivity are therefore two sides of the same coin rather than separate discussions.

What does the sequence of six wedges add in comparison with a single figure?

A single figure conceals the conventions that generate it; the six wedges make those conventions explicit, one at a time. They are not competing theories, but lenses applied in succession which, when overlapped, provide a more faithful picture of what is actually changing in the economy.

In which way is total factor productivity a measure of our ignorance?

Because it is not directly observable: it is obtained as a residual, representing what remains of growth once the contribution of the factors we are able to measure has been removed. Such residual captures technology, but also everything that we have not been able to measure adequately, from labour quality and resource reallocation to measurement errors.

Does this working paper propose moving beyond GDP?

No. It proposes reading output and productivity together, with full awareness of the conventions that link them. The measure of welfare introduced in the fifth wedge complements GDP to make comparisons across countries and over time, but it neither replaces GDP nor should it be used to adjust it item by item.

Why a methodological paper rather than a simple collection of data?

Because without an explicit methodology, the very same productivity figures can support opposing interpretations. Making measurement conventions visible is a prerequisite for interpreting data correctly and, in the longer term, for constructing a stable and comparable measurement framework.

Chapter 1

What Productivity Means

In its simplest definition, productivity measures how much is obtained from what is used: producing more with the same resources, or the same amount with fewer resources. It is a ratio between an outcome, output, and the inputs required to achieve it, i.e., the factors of production. Its importance does not lie in the number itself, but in what that number makes possible: over the long term, a country's ability to pay higher wages, sustain the retirement system, finance healthcare and education depends almost entirely on productivity growth. The principal challenge lies in the inevitably aggregated nature of any measure of productivity that does not require a prohibitively detailed level of information. This necessitates the use of value attribution, i.e., measures obtained by multiplying prices by quantities and aggregating heterogeneous products.

Two measures are commonly used. The first is labour productivity, i.e., output per hour worked. It is the most intuitive and the easiest to calculate, but it includes many different elements, because workers may produce more simply because they have access to better machinery, not because overall technology has improved. The second measure seeks precisely to isolate this more elusive component, total factor productivity, which represents the portion of growth that cannot be explained either by additional capital or by additional labour.

This second measure is obtained by subtraction. One begins with output growth, subtracts the contributions of capital and labour weighted according to their relative importance, and what remains is the residual[2]. The residual is often referred to as technological progress, but this is a definition by exclusion: it contains technology, but also everything that has

[2] In Solow's growth-accounting framework (1957), under perfect competition and constant returns to scale, output growth can be decomposed as the weighted sum of factor growth plus a residual: $\Delta Y/Y = \alpha(\Delta K/K) + (1-\alpha)(\Delta L/L) + \Delta A/A$, where the weights α and $(1-\alpha)$ are the income shares of capital and labour, and $\Delta A/A$ represents total factor productivity. The validity of these weights as production elasticities depends on specific assumptions—perfect competition and constant returns to scale—which the subsequent wedges will call into question.

not been measured correctly, ranging from errors in the measurement of capital to labour quality and market distortions.

A crucial distinction, often overlooked in public debate, is that between levels and dynamics. A country may exhibit a high level of productivity and yet experience little growth, or it may start from a modest level and catch up rapidly. Italy belongs to the former group: its productivity level remains relatively high by international standards, but its productivity growth has been stagnant for more than twenty years. Confusing these two dimensions leads to incorrect diagnoses and ineffective policy prescriptions. Here too, however, the problem of product heterogeneity in aggregate measurement and the role of prices are essential. Productivity dynamics may be measured by weighting different goods using the prices of a reference year ("constant prices") or the prices prevailing in each year ("current prices"), while taking into account—or not—the level and variation of the cost of living. These alternative measures often produce contrasting results that are difficult to interpret.

The unifying theme of the whole Working Paper is a tension that is simple to state yet difficult to manage: we measure well what is tangible, market-traded, and readily quantifiable, while we measure poorly what is intangible, free of charge, public, or environmental in nature. Moreover, the dynamics of the underlying processes follow a different logic and may pose interpretative challenges that are more complex than those associated with the mere quantification of productive outcomes in one or even several years. This asymmetry is not a technical detail of interest only to statisticians; it is the reason why measured productivity can systematically diverge from actual productivity, and why a methodology that makes the necessary corrections explicit, one by one, is needed.

Frequently Asked Questions

ARE PRODUCTIVITY AND GDP THE SAME THING?

No. GDP measures how much is produced; productivity measures how much is produced per unit of resources employed. GDP may grow simply because employment increases, without any improvement in productivity, and this is partly what has occurred in Italy.

IF PRODUCTIVITY DECLINES, DOES IT MEAN THAT WE ARE WORKING LESS EFFECTIVELY?

Not necessarily. A measured decline often reflects the composition of the economy—more services and a larger public sector—and the limitations of measurement conventions, rather than a genuine deterioration in performance. It is also important to distinguish between the level of productivity, which remains relatively high in Italy, and its dynamics, which have long been stagnant.

WHY IS TOTAL FACTOR PRODUCTIVITY CALLED A RESIDUAL?

Because it is not observed directly. It is obtained by subtracting from output growth the contributions of capital and labour, and looking at what remains. For this reason, it captures technology, but also everything that has not been adequately measured.

DOES HIGHER PRODUCTIVITY MEAN FEWER JOBS?

In the short term, individual tasks may be replaced, but over the long term productivity is the principal source of higher wages, a sustainable retirement system, and better public services. It is a driver of prosperity, not its adversary.

WOULD IT NOT BE SIMPLER TO FOCUS ONLY ON LABOUR PRODUCTIVITY?

It would be simpler, but also more ambiguous, because it combines two distinct effects. Workers may produce more simply because they have access to more machinery or to more efficient machinery, not because technology itself has improved. Total factor productivity seeks to disentangle these two effects.

Chapter 2

The Productivity Measurement Debate

The unavoidable starting point is the productivity paradox, synthesized in the famous observation that the computer age was visible everywhere except in productivity statistics[3]. What emerged from such observation is a vast body of literature which, from different perspectives, has shown how current measures underestimate or distort actual productivity. Four strands of research deserve particular attention, as each identifies a specific gap between what we measure and what we would like to measure.

2.1 Intangible Investments

The first strand concerns intangible capital. An increasing share of what firms spend in order to grow—organisational capital, training, brands and marketing, design, and data—is recorded as a current expense rather than as investment. Research and development and software, once treated in the same way, are now capitalised in the national accounts. The consequence is an underestimation of both output and capital, while the productivity residual tends to be inflated by what is, in reality, the accumulation of an unrecorded factor. The direction of the measurement error, however, is affected by two opposing channels. On the one hand, omitting a rapidly growing factor transfers its growth into the residual; thus, if intangible capital grows faster than tangible capital, the residual is inflated, and deflated in the opposite case. On the other hand, expensing intangible investment reduces measured output, and a rising share of such investment depresses recorded growth. The net effect is therefore an empirical

[3] The observation is due to Robert Solow (1987), in a review published in *The New York Times Book Review*. Since then, the literature has generally distinguished at least three phases: the information-technology paradox of the 1970s and 1980s; the temporary U.S. productivity revival between the late 1990s and 2004; and the generalized slowdown after 2005, paradoxical precisely because it coincided with the mass diffusion of digital technologies.

question. In the estimates of Corrado, Hulten and Sichel, the first channel dominates, resulting in a residual that is indeed inflated[4].

2.2 Resource Misallocation

The second strand shifts attention from the firm to the system as a whole. Aggregate productivity depends not only on the technology of individual firms, but also on how resources—labour and capital—are distributed among them[5]. If factors remain trapped in low-productivity firms because of barriers, poorly designed subsidies, rents, or credit frictions, aggregate output falls short of its potential level. That gap—between observed productivity and potential productivity given the same technology—is itself a wedge.

2.3 Market Power

The third strand concerns price mark-ups. When firms set prices above marginal cost, factor income shares cease to coincide with production elasticities, and the interpretation of the residual itself becomes problematic[6]. An increase in market power may reduce labour's share not

[4] The standard taxonomy is that of Corrado, Hulten, and Sichel (2009), who distinguish three categories of intangible assets: computerized information, innovative property, and economic competencies. Components already capitalized in the national accounts, such as software and research and development, belong to the first two categories; the third category—economic competencies, including organizational capital, training, brands, and marketing—remains largely outside the accounting boundary. The accounting consequence is twofold: capitalizing intangible assets increases measured output and investment, but typically reduces the productivity residual, because part of the growth previously attributed to the residual is reassigned to a factor that is now explicitly measured.

[5] The canonical reference is Hsieh and Klenow (2009), who measure misallocation through the dispersion of revenue productivity (TFPR). In the absence of distortions, such dispersion should be zero, because resources would flow toward the most productive firms until returns were equalized. Observed dispersion therefore provides an estimate of the potential productivity gains achievable through efficient reallocation. Restuccia and Rogerson (2008) provide the corresponding theoretical formulation in a framework with heterogeneous firms.

[6] De Loecker, Eeckhout, and Unger (2020) document a rise in average markups in the United States since the 1980s, estimated using the production-function approach derived from Hall, although the absolute level of such estimates remains subject to debate. For Italy, the average markup level is lower, but what matters is not the level itself so much as its

because technology has become less labour-friendly, but because the share of pure profits has increased—a phenomenon that traditional measures risk interpreting as technological progress. In the Italian case, however, the decline in labour's share does not depend solely on mark-ups. It is also driven by wage compression and weak domestic demand which, in the absence of the nominal exchange-rate instrument, have constituted the response to an overvalued real exchange rate within an export-dependent growth model. This form of internal devaluation, by reducing labour costs per unit of output, restores competitiveness but depresses wages and, with them, labour's share of income. Market power and internal devaluation are distinct, and partly competing, channels that push labour's share in the same direction, making its interpretation as a purely technological phenomenon even more fragile.

2.4 Well-Being and Beyond GDP

The fourth strand stems from a simple observation: output is not well-being. What matters is what is consumed, how much leisure time is available, how income is distributed, and whether growth occurs at the expense of resources needed by future generations[7]. Productivity relevant to well-being may diverge substantially from measured productivity, and this gap is particularly large where inequality is high or where growth is achieved through the depletion of natural capital.

dispersion. Dispersion across sectors, once rents in protected industries are removed, is modest. The substantial and economically relevant disparity occurs among firms within the same sector, as shown in Chapter 4.

[7] Jones and Klenow (2016) construct a welfare measure combining consumption, leisure, inequality, and mortality, showing that country rankings differ from those based on GDP per capita. Basu, Pascali, Schiantarelli, and Servén (2022) derive a welfare-relevant productivity measure distinct from standard total factor productivity. The Stiglitz–Sen–Fitoussi Commission (2009) had already raised the issue within the context of official statistical measurement.

2.5 Baumol's Cost Disease and the Public Sector

To these four strands must be added an issue that cuts across all of them: Baumol's cost disease[8]. The result is a paradox. As a mature economy shifts employment towards these sectors, measured aggregate productivity tends to slow for reasons that are partly accounting-related rather than purely real. This point is particularly important in the Italian case.

2.6 The Italian Debate

With regard to Italy, the literature has highlighted several recurring anomalies: a prolonged period of negative total factor productivity growth despite expanding employment; a structural lag in intangible investment compared to Germany and France; persistent territorial dualism; a fragmented firm-size structure; and the distortive effects of family-based governance. This has led to the formulation of the so-called three systemic traps—skills, scale, and governance—which constrain productivity growth independently of the mere availability of technology.

The conclusion of this chapter is straightforward: each strand identifies not a random measurement error, but a systematic gap between measured productivity and actual productivity. The contribution of this Working Paper is to organise these insights into a single coherent sequence, so that the necessary corrections can be applied one after another rather than overlapping in a confusing manner.

[8] Baumol (1967) observed that in sectors with low productivity growth—typically personal services such as health care, education, and care services—unit costs tend to rise in relative terms because wages follow the dynamics of more productive sectors. When public-sector output is measured at the cost of the factors employed, as required by accounting conventions in the absence of market prices, the productivity of that sector is, by construction, measured as close to zero regardless of any genuine qualitative improvement.

Frequently Asked Questions

WHAT IS SOLOW'S PRODUCTIVITY PARADOX?

It is Robert Solow's observation that the computer age was visible everywhere except in productivity statistics. Since then, research has sought to understand why powerful technologies do not fully translate into measured productivity.

WHY ARE INTANGIBLE INVESTMENTS A MEASUREMENT PROBLEM?

Because many of them—internally developed software, training, organisational capital, brands, and data—are recorded as expenses rather than investments. As a result, the capital they create does not appear in the accounts and instead inflates the productivity residual.

IS RESOURCE MISALLOCATION THE FAULT OF FIRMS?

Not primarily. It depends mainly on systemic frictions—barriers, rents, access to credit, and regulations—that prevent capital and labour from moving towards their most productive uses.

DOES BAUMOL'S COST DISEASE MEAN THAT HEALTHCARE AND EDUCATION ARE UNPRODUCTIVE?

No. It is useful to distinguish between two reasons that are often confused. Baumol's cost disease, properly speaking, is a real phenomenon: healthcare and education are inherently labour-intensive activities in which it is difficult to increase output per worker, because an hour of teaching or a medical consultation cannot be compressed in the same way as the production of a manufactured good. Their productivity therefore grows slowly, and when wages rise across the economy, driven by more dynamic sectors, these services become relatively more expensive and absorb an increasing share of resources, slowing aggregate productivity growth. In addition, there is a measurement problem for public services that are not sold in markets: in the absence of a market price, output is valued at factor cost, and measured productivity is, by construction, almost stagnant regardless of actual quality improvements. In neither case does this imply that healthcare or education lack value: the slow growth of measured productivity says nothing about their social usefulness.

Why is total factor productivity weak in Italy despite rising employment?

Because employment growth has occurred mainly in sectors with low measured productivity, while intangible investments have lagged behind. Taken together, these effects produce a measured residual that is weak or negative.

Chapter 3

The Six Wedges: A Non-Technical Overview

It is useful to think of measured productivity as the initial reading of a poorly calibrated instrument. Each wedge is a correction applied in order to move closer to the true magnitude. The corrections are applied sequentially, and their order matters because each builds upon the preceding ones. The first five wedges concern the way we interpret the economy as it exists today; the sixth concerns the way in which a new factor—artificial intelligence—is changing the very nature of production.

Wedge 1. Standard Growth Accounting

The first wedge is the starting point. Output growth is decomposed into three components: the portion attributable to providing each worker with more capital, the portion attributable to improvements in labour quality, and the unexplained remainder, i.e., the residual. This is an accounting exercise rather than an explanation. It tells us how much of growth can be attributed to observable factors and how much ends up in the black box of the residual. Its limitation lies precisely here: the residual does not explain; it merely names our ignorance.

Wedge 2. Intangible Investments

The second wedge reclassifies as investment what is currently recorded as expenditure: internally developed software, research and development, design, training, organisational capital, and data. The effect is partly counterintuitive[9]. This wedge is particularly important for artificial intelligence, because training a model, developing internal software, and reorganising processes are economically investments, even when the accounts record them as current expenditures.

Wedge 3. Misallocation

The third wedge measures how much output remains trapped by an inefficient distribution of resources. Even with identical technologies, aggregate output would be higher if labour and capital were allocated more efficiently across firms and sectors. That gap constitutes the wedge[10]. This wedge is especially important for Italy, where many resources remain in low-productivity activities not because technology is lacking, but because barriers, rents, and frictions prevent their reallocation.

Wedge 4. Market Power

The fourth wedge isolates the effects of price mark-ups. Where firms charge prices above marginal cost, part of what is measured as output is in fact economic rent, and income shares cease to reflect the actual contribution of

[9] Capitalizing intangible assets increases both output and the capital stock but tends to reduce the productivity residual because growth previously attributed to the residual is now explained by a measured factor. In other words, part of what had been labelled technological progress was in fact the accumulation of previously unrecorded intangible capital. See the framework of Corrado, Hulten, and Sichel, as well as subsequent updates from EU KLEMS and INTANProd.

[10] It is useful to distinguish between two levels of analysis. Intra-sectoral misallocation, among firms within the same sector, is measured through the dispersion of marginal revenue products following Hsieh and Klenow and requires firm-level data. Inter-sectoral misallocation, across sectors, is captured by the Olley–Pakes covariance between sector size and sector productivity and can be estimated directly from a disaggregated Social Accounting Matrix, following the tradition of Leal Ordóñez (2016) on cross-sectoral reallocation.

production factors[11]. Correcting for market power prevents what is merely an increase in pure profits from being mistaken for technological progress.

Wedge 5. Welfare

The fifth wedge replaces output with a measure that more closely reflects social welfare. Instead of value added, the numerator is a broader metric that takes account of consumption, leisure, income distribution, and sustainability[12]. This wedge may reveal a configuration characterised by high output and low well-being, making visible the cost of growth achieved at the expense of distributional equity or natural capital.

Wedge 6. Artificial Intelligence as an Autonomous Factor

The sixth wedge is the most innovative and deserves more extensive treatment. Artificial intelligence is not merely a new component of capital. It is a partially autonomous factor that simultaneously substitutes for and complements both labour and capital and, above all, generates ideas. Treating it solely through the first two wedges—as capital or as an intangible asset—captures its accumulative dimension but overlooks its nature as a factor capable of generating knowledge and, with it, the possibility of altering not only the level but also the long-run rate of growth.

It is useful to distinguish three stages through which artificial intelligence enhances productivity[13]. The first operates at the level of individual tasks;

[11] Markup estimation requires caution. In the national accounts, the real-estate sector includes imputed rents on owner-occupied housing, which generate an abnormally high apparent markup with no economic meaning and should therefore be excluded. Moreover, the relevant issue is not the average level of markups but their dispersion across sectors, which identifies protected areas characterized by high rents.
[12] The analysis follows Jones and Klenow (2016) and the welfare-relevant productivity concept developed by Basu, Pascali, Schiantarelli, and Servén (2022). An Atkinson-style distributive correction penalizes highly unequal distributions: for a given level of output, a more unequal distribution corresponds to lower welfare.
[13] The tripartite framework is as follows. First stage: marginal gains at the level of individual tasks, describable through Hulten's theorem and Acemoglu's lower-bound estimate of the aggregate effects of task automation. Second stage: non-marginal gains of a sectoral and factor-reallocation nature, producing a cumulative level effect that accelerates convergence toward the steady state. This corresponds to the reallocation channel identified by Baqaee and Farhi (2020), whereby Hulten's theorem fails in a distorted economy and reallocation effects become quantitatively significant. Third stage: a

the second reallocates labour and capital across sectors, producing a cumulative level effect; the third, through the production of new ideas, can permanently alter the rate of growth.

Finally, this wedge makes explicit an important governance distinction. Artificial intelligence as infrastructure—excludable and concentrated—is a source of rents. Artificial intelligence embedded in products and processes—diffused and non-excludable—is a source of productivity gains[14]. For this reason, artificial intelligence requires a wedge of its own and cannot simply be absorbed into the preceding ones.

Frequently Asked Questions

ARE THE SIX WEDGES COMPETING THEORIES?

No, they are successive lenses. Each corrects a different aspect of the gap between measured and actual productivity, and they are applied sequentially rather than as alternatives.

CAN THE SIX WEDGES BE COMBINED INTO A SINGLE FIGURE?

Only with caution. The first four remain within the same metric and can be combined. The fifth changes the metric, moving from output to welfare, and should not be added to the others. The sixth is oriented towards the future. They should be read together rather than mechanically aggregated.

WHY DOES ARTIFICIAL INTELLIGENCE DESERVE ITS OWN WEDGE?

Because it is not merely a new machine. It is a partially autonomous factor that generates ideas and diffuses without being fully priced. Treating it

Romerian (1990) spillover affecting the productivity of the economy as a whole, the only stage that alters the long-run growth rate, with the so-called singularity representing its extreme case.

[14] This dual nature has implications for both measurement and policy. Broadly diffused productivity gains should be captured through Wedges 2 and 3, whereas infrastructure-related rents should be addressed through Wedge 4. The argument is that two distinct governance regimes are required for the two sides of the same phenomenon.

solely as capital would overlook its capacity to alter the pace of economic growth.

WHICH WEDGE IS MOST IMPORTANT FOR ITALY?

The answer is the combination of the third and fourth wedges—misallocation and the dispersion of market power—because they indicate that the problem is not a lack of technology but the way resources are distributed and protected.

DOES APPLYING THE WEDGES CHANGE GDP AS WELL AS PRODUCTIVITY?

Yes. This is the central argument of the Working Paper: the conventions that determine what counts as output simultaneously change GDP and the productivity residual. Measuring one is inseparable from measuring the other.

Chapter 4

Estimating the Six Wedges and Their Components

This chapter presents the application of the framework developed in the previous chapter to the Italian case. For each wedge, the underlying idea of the model is first explained in intuitive terms, while the mathematical formulation is provided in the Appendix as a reference. The estimate is then decomposed into its constituent components, and the results are compared with those reported in the most recent literature. The estimates are based on three Social Accounting Matrices (SAMs), constructed by the Fondazione Tor Vergata research group for 2020, 2024, and 2025, harmonised within a common make/use framework comprising 171 accounts, seventy-five sectors, and households disaggregated by income deciles, calibrated using ISTAT parameters[15], together with a dynamic

[15] The matrix is calibrated on seven ISTAT benchmark parameters with a zero residual, verified through the macroeconomic control worksheet, and adjusted to remove anomalies in the treatment of indirect taxes that generated spurious structural signals. Certain

computable general equilibrium model featuring projections for the period 2025–2055. Each section concludes with an interpretative summary, and the chapter ends with a set of frequently asked questions.

4.1 Wedge 1. Standard Growth Accounting

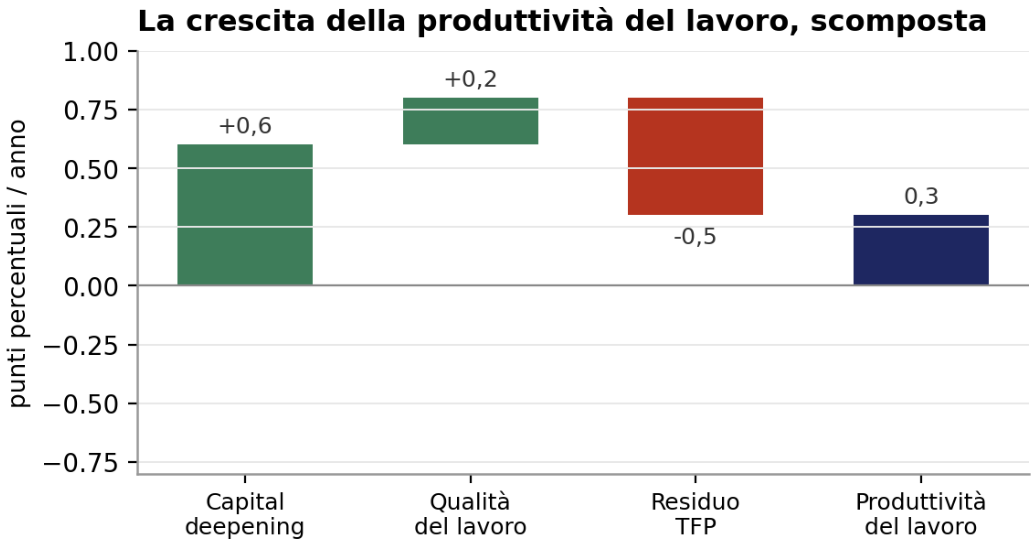
The model in words. The model presented in Appendix A.1 belongs to the growth accounting tradition initiated by Solow in 1957 and subsequently refined by Jorgenson and Griliches. The underlying idea, which the mathematical formulation in the Appendix merely makes more precise, is straightforward: output arises from the combination of capital and labour, multiplied by an efficiency factor—total factor productivity—which summarises how effectively these inputs are utilised. To determine the contribution of efficiency, one proceeds by subtraction. From output growth one removes the contributions of capital per worker and improvements in labour quality, weighted according to their importance in income distribution. What remains is the residual. This is the quantity that Abramovitz famously described as a measure of our ignorance, because it is not directly observed but obtained as whatever the accounting framework fails to explain.

The fragility of the method lies entirely in the weights. Income shares coincide with the actual contribution of production factors only under conditions of perfect competition and constant returns to scale. As soon as one allows for market power, unrecorded intangible capital, or resource misallocation, the residual ceases to measure technological progress alone and becomes a repository of measurement errors. This is precisely what the subsequent wedges are designed to disentangle. The operational benchmark today is the EU KLEMS database, against which our results should be compared.

The three SAMs for 2020, 2024, and 2025 provide both levels and their evolution over time. From the factor accounts, labour income relative to value added at factor cost yields a labour share stable at approximately 44.7

components—particularly those requiring firm-level microdata or historical time series—cannot be derived from a cross-sectional dataset and are therefore classified as non-estimable from the matrix.

per cent. From the sectoral accounts, they indicate declining apparent productivity once the treatment of indirect taxes is corrected. The availability of three years also allows the decomposition to be analysed dynamically through the method of Scandizzo and Cufari. Between 2020 and 2025, growth in the economic circuit is entirely sustained by demand and almost entirely offset by a weakening of the productive structure. EU KLEMS series remain a useful complement for long-run sectoral detail.



Illustrative framework. Labour productivity growth can be decomposed into capital deepening and labour-quality improvements, both positive, together with the total factor productivity residual, which in Italy is weak or negative. Values are illustrative and broadly consistent with EU KLEMS orders of magnitude.

Estimation and components. The three matrices provide both levels and, by covering three years, a dynamic perspective. The structural decomposition of Scandizzo and Cufari distinguishes the contribution of demand from that of productive structure, while labour disaggregation by qualification makes workforce composition observable. A more detailed decomposition of growth into capital-deepening and residual components remains more accurately captured by specialised datasets, with which our results are compared.

Component	Matrix and model	Literature (order of magnitude)
Labour share (level)	44.7% at factor cost	Consistent (ISTAT)
Apparent labour productivity	Approximately –4%	Nearly stagnant, 1995–2019 (EU KLEMS)
Capital deepening	Not separable from accounts alone	Positive contribution, fractions of a percentage point per year
Labour quality	Observable by qualification	Modest, slightly positive contribution
TFP residual	Implicit, weak	Flat or negative (EU KLEMS)

Table 4.1. Wedge 1: Components of Growth Accounting.

Comparison with literature. Both sources agree on the defining Italian characteristic: labour productivity has remained almost stagnant and total factor productivity has been weak or negative for a prolonged period, despite rising employment. The sharper declines reported in some analyses are partly an artefact of the treatment of indirect taxation.

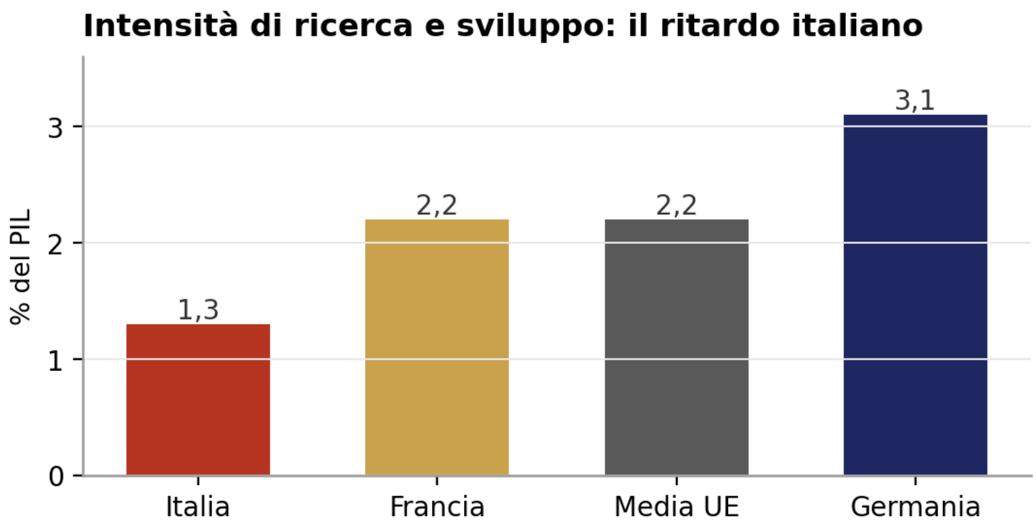
Interpretation. A negative residual does not imply technological regression but rather incomplete measurement. It indicates how little standard growth accounting is able to explain and why it is necessary to decompose the residual through the subsequent wedges.

4.2 Wedge 2. Intangible Investments

The model in words. The model in Appendix A.2 corrects a classification error and lies at the heart of the research programme developed by Corrado, Hulten, and Sichel, popularised by Haskel and Westlake in *Capitalism without Capital* and operationalised through the EU KLEMS and INTANProd databases. Many expenditures that enable firms to grow—software, research, design, training, organisational restructuring, brands, and data—are recorded as current costs that disappear in the year they are incurred, even though they actually create capital that endures over time. The idea, formalised in the Appendix, is to restore these expenditures to their appropriate place by treating them as investment, accumulating their stock with depreciation rates generally higher than those of physical machinery, and recalculating the productivity residual for the corrected economy.

The counterintuitive result lies precisely here: capitalising intangibles reduces the residual because part of what previously appeared to be mysterious technological progress was simply capital that had not been counted. The literature distinguishes three broad components—computerised information, innovative property, and economic competencies—and shows that Italy's lag is concentrated in the latter two, with research and development intensity around 1.3 per cent of GDP compared with approximately 3 per cent in Germany. This point becomes decisive again in the sixth wedge, because training an artificial intelligence model or reorganising processes around it are, from an economic perspective, intangible investments recorded as current expenditure.

This is the only wedge that the SAM cannot directly measure, and it is important to explain why. A social accounting matrix records flows as they appear in the national accounts under ESA 2010, where research and software are already capitalised, whereas so-called non-SNA intangibles—organisational capital, training, brands, and data—remain classified as intermediate consumption or labour costs. They lie outside the accounting perimeter, and neither the matrix nor the model built upon it can reclassify them without external estimates. The estimate of the wedge therefore derives from EU KLEMS and INTANProd comparisons. It is a recognised blind spot rather than a measured zero.



Research and development intensity as a percentage of GDP: Italy remains below the European average and substantially below Germany. Orders of magnitude based on Eurostat data.

Estimation and components. The wedge cannot be estimated from the SAM alone. Its components derive from comparative literature and are conventionally divided into computerised information, innovative property, and economic competencies.

Component	Matrix and model	Literature (order of magnitude)
Total intangible investment	Outside accounting perimeter	Italy below Germany and France (EU KLEMS, INTANProd)
Innovative property (R&D)	Partially included in SNA accounts	R&D intensity approximately 1.3% of GDP versus approximately 3% in Germany
Computerised information	Not observable	Moderate lag
Economic competencies (organisation, training, data)	Not included in accounts	Principal source of Italy's lag
Effect on residual	Would reduce it	Same conclusion (Corrado–Hulten–Sichel)

Table 4.2. Wedge 2: Components of Intangible Capital.

Comparison with literature. The framework developed by Corrado, Hulten, and Sichel and subsequently adopted by EU KLEMS, INTANProd, and Haskel and Westlake identifies Italy's lag as concentrated in economic competencies and innovative property. Capitalising these expenditures would increase both output and investment while reducing the productivity residual.

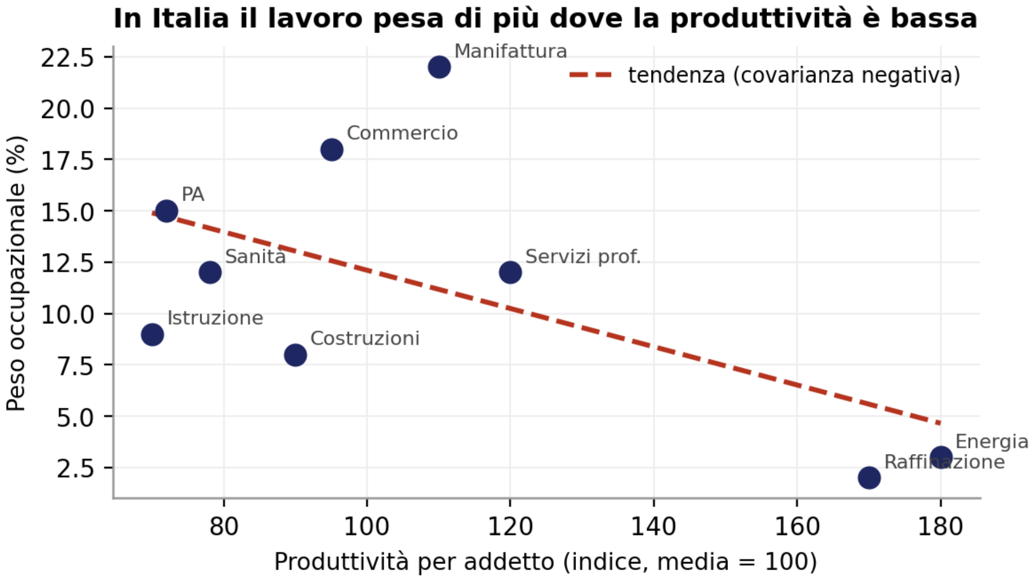
Interpretation. Part of the Italian residual is in fact disguised underinvestment in intangible capital. This point is crucial for the sixth wedge because model training and process reorganisation are investments currently recorded as costs.

4.3 Wedge 3. Misallocation

The model in words. The model presented in Appendix A.3 measures the waste arising from the inefficient allocation of resources. It is the contribution through which Hsieh and Klenow, in 2009, redirected the productivity literature, building on the theoretical foundations laid by Restuccia and Rogerson. The intuition, which the formulas in the Appendix make precise, is as follows. Each firm possesses its own technical efficiency: it produces a given quantity per unit of capital and labour employed and sells its output at a particular price. In an economy without frictions, capital and labour flow towards the most efficient firms, which expand and, by producing more, reduce their prices until the point at which the last euro of capital or labour yields the same return in every firm. At that point, the product of technical efficiency and price—that is, the revenue generated by a unit of input—is equalised across firms. When this product varies substantially from one firm to another, it signals that some force—a tax, subsidy, credit constraint, barrier, or rent—is preventing resources from moving to their most productive uses. Some firms remain too small and others too large relative to what their efficiency would justify. The dispersion of this product therefore measures how much output the economy foregoes because reallocating capital and labour until it is equalised would increase overall productivity. The same reasoning, in the tradition of Olley and Pakes and Leal Ordóñez, can be applied across sectors rather than firms. Instead of comparing firms, one examines the covariance between a sector's employment share and its productivity. This covariance is positive when labour is concentrated in the most productive sectors and negative when the opposite occurs. It must, however, be interpreted with caution because the dispersion of marginal revenues reflects not only distortions but also measurement errors, adjustment costs, and technological heterogeneity across firms. For this reason, the potential gain from complete reallocation—the largest estimate—is better understood as an unrealistic upper bound rather than a forecast, as recognised by the Italian literature, including Calligaris and co-authors.

It is here that the matrices make their strongest contribution through the structural decomposition of multipliers developed by Scandizzo and Cufari and applied across the three years. The inter-sectoral component is derived from the seventy-five sectors. For each sector, the matrices provide employment shares and value added per unit of labour. The correlation between the two is clearly negative, around –0.5, indicating that in Italy labour is concentrated in lower-productivity sectors. Productivity differences across sectors are therefore substantial, but they must be interpreted carefully because observed dispersion and removable misallocation are not the same thing. Much of the observed gap is structural rather than distortive. It reflects the growing weight of services and public functions characterised by low measured productivity, the Baumol effect discussed under the fifth wedge, and cannot be corrected simply by moving labour elsewhere because those services remain socially demanded. The genuinely removable component—namely that arising from price distortions across sectors—is small. Once rent-related mark-up dispersion is neutralised, the general equilibrium model produces a modest real gain of approximately 0.6 per cent. These findings are not contradictory.

Productivity levels are lowered because labour is concentrated in less productive sectors, but much of this gap is structural and unavoidable. The truly recoverable component between sectors is limited. The substantial removable disparity therefore lies not between sectors but between firms within the same sector. This Hsieh-and-Klenow component requires firm-level dispersion measures derived from microdata and points to much larger gaps and potential gains of a completely different order of magnitude.



Illustrative diagram. Each point represents a sector. The downward-sloping cloud indicates that, in Italy, employment tends to be concentrated in less productive sectors; in other words, the Olley–Pakes covariance is negative.

Estimation and Components. The matrices capture only the inter-sectoral component. The within-sector component, which requires firm-level microdata, is taken from the literature.

Component	Matrix and model	Literature (order of magnitude)
Inter-sectoral (Olley–Pakes correlation)	Approximately –0.5	Negative, anti-Olley-Pakes pattern
Within-sector (TFPR dispersion)	Not estimable (firm-level microdata required)	High and increasing (Calligaris et al.)
Potential gain	Approximately 0.6% across sectors	30–50% across firms towards U.S. efficiency levels (Hsieh–Klenow)
Gain from realistic reallocation (5–10%)	Between +2% and +5%	Consistent
Interaction term (shift-share)	Strongly negative	Baumol trap, cost-based valuation

Table 4.3. Wedge 3: Components of Misallocation.

Comparison with literature. Hsieh and Klenow estimated that aligning China and India with U.S. levels of allocative efficiency could generate productivity gains of between 30 and 50 per cent. For Italy, Calligaris and co-authors document, on the basis of firm-level microdata, a high and increasing degree of resource misallocation. Our results are consistent with this literature both in direction and in order of magnitude.

Interpretation. Resources remain trapped in low-productivity activities not because of a lack of technology, but because of frictions and economic rents. A note of caution is nevertheless required. Part of the low value added observed in sectors with a strong public-sector presence—education, healthcare, and public administration—is an artefact of cost-based valuation rather than evidence of genuine inefficiency. The estimated potential gain should therefore be interpreted as an upper bound[16].

Dispersion Across Firms. The within-sector component of resource misallocation finds direct confirmation in the analysis conducted by ISTAT in its *Annual Report 2026*, based on a sample of approximately 105,000 firms in industry and services, representing nearly three quarters of the value added generated by the two sectors. Firms are classified according to their degree of innovative dynamism, measured through technological choices, research expenditure, and the quality of human capital. Only 22 per cent of firms display a high level of dynamism, around 30 per cent exhibit low dynamism, and 47 per cent fall into an intermediate category.

The productivity gap across these groups is substantial. Firms with intermediate levels of dynamism are, on average, approximately 35 per cent more productive than those with low dynamism, while highly dynamic firms are more than 85 per cent more productive. Approximately 80 per cent of firms, employing nearly 60 per cent of the workforce, operate below average productivity. This is not a narrow tail of laggards; rather, the bulk of the distribution remains distant from the productivity frontier.

[16] The interaction term in the shift-share decomposition is strongly negative: sectors experiencing productivity improvements lose employment share, while labour moves toward sectors with low measured productivity. This is Baumol's cost disease, exacerbated by the allocation of recent public investment.

The analysis identifies with considerable clarity the drivers of this heterogeneity. Within a structural-equation framework, the most important variable for both productivity and innovative activity is the educational attainment of employees, followed by experience, whereas physical capital and formal research expenditure play a much smaller role. Human capital and firm size are positively associated with all three major drivers of competitiveness: digitalisation, research activity, and innovation. Dispersion therefore reflects, above all, differences in human capital and technological diffusion rather than differences in capital intensity.

Several indicators suggest that the distance between frontier firms and the rest of the economy is widening. The share of turnover accounted for by large firms has increased to 36.1 per cent. The adoption of artificial intelligence, now reaching 16.4 per cent of firms, is concentrated precisely where human capital and highly skilled occupations are already more prevalent. At the same time, the system remains weak in terms of enabling factors, with research and development expenditure amounting to only 1.3 per cent of GDP—the lowest among the major European economies—and information and communication technology specialists representing just 4.0 per cent of employment, likewise the lowest share among comparable countries. Technology is advancing at the frontier, but struggles to diffuse to lagging firms.

The 2025 *CNEL Productivity Report* reconstructs the same heterogeneity along the dimension of firm size. The productive structure remains highly fragmented, with 94.7 per cent of firms employing fewer than ten workers and more than half of all employees working in firms with fewer than twenty workers—a substantially higher share than in Germany or France. The relationship between size and productivity is particularly strong in knowledge-intensive sectors. In information and communication technologies, professional services, and advanced manufacturing, large firms outperform micro-enterprises by 70 to 80 per cent, whereas the differential is weak—below 30 per cent—in lower-productivity sectors such as retail trade and construction. Additional productivity premiums are associated with exporting activity, reaching as much as 94 per cent in manufacturing, with digitalisation, ranging between 15 and 30 per cent, and with innovation, at approximately 20 per cent.

The mechanism that should reduce this dispersion—the reallocation of labour from less productive firms towards more efficient ones—appears, however, to have stalled. Decomposing sectoral productivity growth into a within-size-class component and a reallocation component across size classes shows that the contribution of reallocation, positive until the end of the 2010s, disappeared after the pandemic. The genuine process of consolidation that occurred—with more than one hundred thousand manufacturing firms disappearing between 2008 and 2022, almost all of them employing fewer than twenty workers—did not translate into a proportional productivity gain. This is because consolidation resulted primarily from selection and internal growth rather than from an effective transfer of labour towards the most productive firms. Low levels of skills, family-based management structures, and managerial practices insufficiently oriented towards efficiency contribute to a vicious circle that keeps resources where they generate lower returns.

This is precisely the component that a sectoral accounting matrix cannot capture and that the Hsieh–Klenow literature associates with potential gains amounting to several tens of percentage points—far larger than those obtainable through reallocation across sectors alone. The corresponding policy levers—education and skills, the diffusion of digital tools, and support for technological adoption by less advanced firms—operate directly on this source of dispersion and differ fundamentally from a generic increase in the overall stock of technology.

4.4 Wedge 4. Market Power

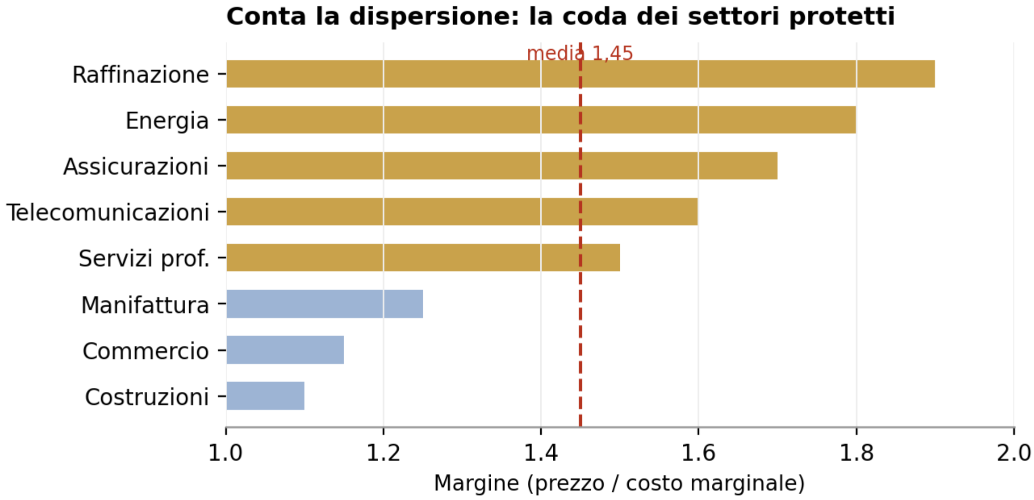
The model in words. The model presented in Appendix A.4 derives mark-ups without requiring direct information on list prices or firms' pricing strategies. It is based on the intuition linking the work of Hall to that of De Loecker and Warzynski, and underpins the broader debate on the rise of market power associated with De Loecker, Eeckhout, and Unger. The principle, expressed formally in the Appendix, is straightforward: any cost-conscious firm compares the contribution of an input to production with the cost of that input. If the two values coincide, there is no market power; if the contribution exceeds the cost, the difference constitutes the mark-up. By aggregating mark-ups and, above all, measuring their dispersion, one obtains the economically relevant picture.

The central point, reiterated throughout this chapter, is that what matters is not the average level of the mark-up but its dispersion across sectors, because it is this disparity that distorts the allocation of resources. The

Italian literature, particularly the work of Ciapanna and co-authors at the Bank of Italy, estimates an aggregate mark-up of approximately 1.1 using a production-function approach, attributes its evolution primarily to within-firm dynamics, and does not find the type of "superstar firm" effect observed in the United States. A technical caveat is necessary. The real-estate sector, owing to the treatment of imputed rents on owner-occupied housing, generates an abnormally high apparent mark-up that lacks genuine economic meaning and must therefore be excluded from the analysis.

The input–output matrices allow for a Hall-type estimation because, for each sector, they contain both the cost structure and revenues. The ratio between an output elasticity—approximated by the technological coefficients—and the revenue share of the variable input provides an estimate of the markup, which is approximately 1.45 and declines to around 1.23 when a more conservative labour elasticity is assumed. Dispersion is calculated across seventy-five sectors. Pure rent-generating activities, such as real estate—owing to imputed rents—produce abnormally high apparent markups and must therefore be excluded. The coefficient of variation of markups, which is approximately 0.40 across the full set of sectors, falls to around 0.12 once these sectors are removed, indicating that the genuine dispersion of markups across sectors is relatively limited. The evolution of markups can be assessed through direct comparison of the three matrices, as well as through the counterfactual simulations generated by the general equilibrium model at the new equilibrium prices, following the tradition of the multiplier analysis developed by Pyatt and Round. The within-firm component lies beyond the scope of a sectorally disaggregated matrix, and it is precisely here that the discrepancy with the existing literature arises. For Italy, that literature generally places the markup at around 1.1. The difference is one of definition rather than substance.

The Hall-type estimate derives the markup as the ratio between revenues and variable costs and treats the entire capital surplus as a residual. However, that residual includes not only market power but also the normal remuneration of capital, fixed costs, and rents, thereby inflating the estimated markup towards 1.45. By contrast, econometric estimates based on production functions, such as those produced by Ciapanna and co-authors for Italy, isolate the pure markup between price and marginal cost, net of the normal return to capital. For this reason, they yield a value close to 1.1. The two figures therefore measure different concepts: one corresponds to a gross accounting markup, while the other reflects a net market markup. The discrepancy is thus a methodological artefact. The robust finding is another: the dispersion of markups across sectors is modest, whereas the substantial heterogeneity documented in firm-level data is found primarily among firms operating within the same sector.



Illustrative diagram. Sectoral distribution of markups: a small group of protected industries exhibits markups substantially above the average level of 1.45, while competitive industries cluster around a markup of 1.

Estimation and Components. The margin, or markup, is the ratio between price and marginal cost: a value of 1.45 indicates a price that is 45 per cent higher than marginal cost. What matters most is dispersion.

Component	Matrix and model	Literature (order of magnitude)
Average markup (level)	1.45 (1.23 with conservative elasticity)	approximately 1.1 (Ciapanna et al., Bank of Italy)
Dispersion (coefficient of variation)	approximately 0.40	strong sectoral and firm-level heterogeneity
Within-firm component	not separable (aggregated)	principal driver (Ciapanna et al.)
Upper tail (sectors)	energy, refining, insurance, telecommunications, professional services	consistent
Dynamics	from DCGE (benchmark and counterfactual)	flat or declining in the EU; increasing in the US (De Loecker et al.)

Table 4.4. Wedge 4: Components of Market Power.

Comparison with literature. Using a production-function approach on firm-level data, Ciapanna et al. estimate an aggregate markup of around 1.1, compared with our estimate of 1.45 obtained through Hall's approach. The difference arises because the higher measure is based on gross revenues rather than profits. Both approaches converge on the finding of strong dispersion and the absence of a dynamic driven by superstar firms, in contrast to the United States.

Interpretation. It is not the level of the markup that matters, but rather its dispersion and the upper tail of protected high-rent sectors, because it is dispersion that distorts allocation and biases the interpretation of the residual.

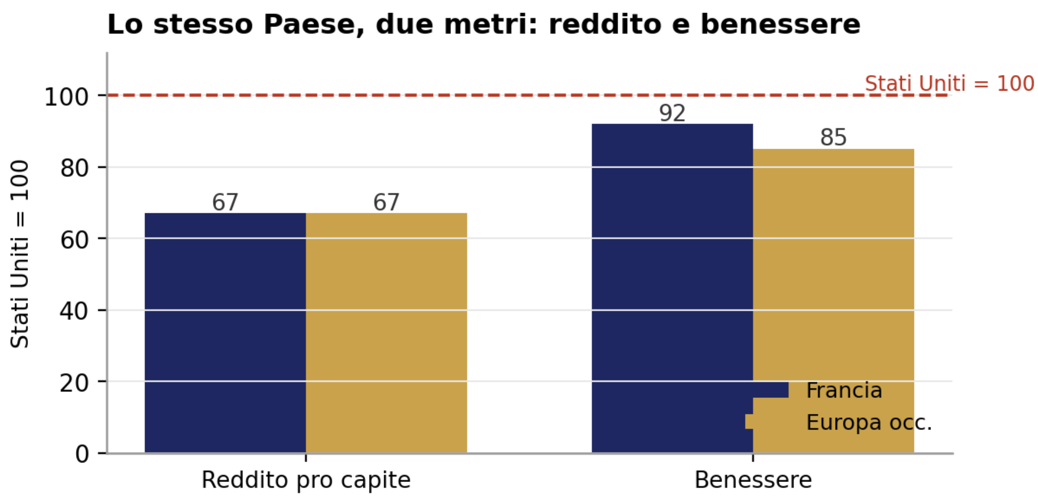
4.5 Wedge 5. Welfare

The model in words. The model presented in Appendix A.5 changes what is placed on the scales: not output, but welfare. The distinction is substantial, because two countries with the same income per capita may offer their citizens very different lives, depending on life expectancy, the amount of time available outside work, and the degree of income equality. The theoretical foundation is twofold. On the one hand, it draws on the notion of welfare-relevant productivity developed by Basu, Pascali, Schiantarelli and Servén, which links measurement to what effectively increases individuals' utility. On the other hand, it relies on the consumption-equivalent measure of Jones and Klenow, which translates these dimensions into a single comparable metric. Both approaches stem from the agenda initiated by the Stiglitz-Sen-Fitoussi Commission, which called for looking beyond gross domestic product in assessing a country's progress. This same agenda underpins the work of the European Commission to complement output measures with indicators of sustainable and inclusive well-being, for which the Joint Research Centre report by Benczur, Boskovic, Giovannini, Pagano and Sandor (2025) proposes a multidimensional dashboard.

The core idea, formalized in the appendix, is to decompose the welfare of one country relative to another into four additive components: consumption, longevity, leisure time, and the degree of income equality. The first three enter with a positive sign, since higher consumption, longer life expectancy, and greater leisure increase welfare; the last enters with a negative sign, because, holding average income constant, a more unequal distribution reduces welfare. Inequality is measured through Atkinson's equivalent consumption, that is, the level of consumption which, if distributed equally among all individuals, would generate the same welfare as the actual distribution. The further this value lies below actual average consumption, the greater the welfare loss attributable to inequality.

The implication is that welfare and output are different metrics, not two readings of the same quantity, and that a welfare measure is intended to compare countries or years rather than to adjust the output of a single country in a single year. A related concept in the productivity literature is the CWTFP variable in the Penn World Tables, which measures welfare-relevant productivity at consumer prices net of taxes.

The Social Accounting Matrix (SAM) is particularly well suited to internal calculation because it records the entire circular flow of income. From the institutional accounts, a welfare-oriented numerator is constructed—household consumption plus services financed through public expenditure—in place of value added, and the Atkinson correction is applied by exploiting the disaggregation of households into groups. The resulting metric gap amounts to 14 per cent and rises to between 16 and 18 per cent once the distributive correction is included. This represents the distance between two metrics for the same economy, not an efficiency gap, and should not be compared with the levels observed in other countries. Those levels—for example, France at 92 per cent welfare compared with 67 per cent income—derive instead from Jones and Klenow and from the Joint Research Centre, because they require the same corrections to be applied consistently across countries.



Income and welfare relative to the United States: despite income being only about two-thirds of the US level, welfare is considerably closer. Source: Jones and Klenow.

Estimates and components. The internal matrix gap measures the distance between the two metrics for the same economy; a proper comparison requires the same accounts to be calculated for multiple countries.

Component	Matrix and model	Literature (order of magnitude)
Internal metric gap (consumption and services)	approximately −14%	different metric, not directly comparable
With distributive correction (Atkinson)	between −16% and −18%	depends on inequality aversion
Welfare relative to the US (levels)	requires cross-country comparison	France approximately 92%, Western Europe approximately 85% (Jones–Klenow)
EU versus US dynamics (2010–2023)	not estimable	equivalent income: EU surpasses the US by 2022 (JRC)
Components of the welfare gap	not separable	life expectancy, leisure, inequality, approximately +10 percentage points each (France)

Table 4.5. Wedge 5, components of welfare.

Comparison with literature. Jones and Klenow provide the welfare levels, while the Joint Research Centre adds the recent dynamics, showing the European Union surpassing the United States in equivalent income by 2022. By contrast, the internal gap in our matrix measures the distance between two metrics and should not be compared with those levels.

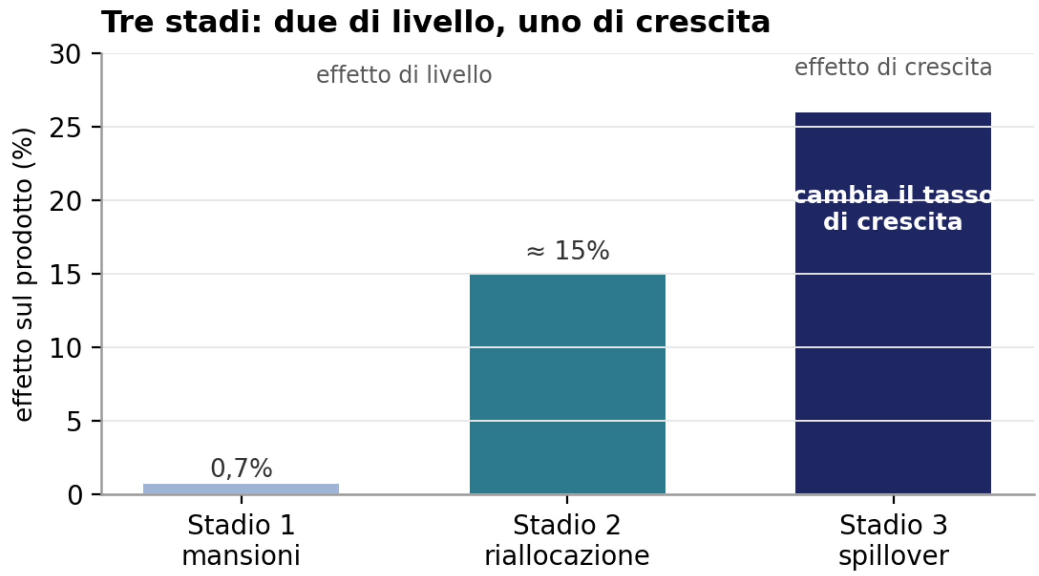
Interpretation. For Italy, the relative picture improves when moving from GDP to welfare, because long life expectancy and moderate working hours raise welfare above income. However, inequality levels higher than those observed in France or Germany reduce this gain, placing Italy toward the lower end of the European range.

4.6 Wedge 6. Artificial Intelligence

The model in words. The model presented in Appendix A.6 describes how artificial intelligence increases productivity through three stages, each with its own theoretical foundation. The first, formalized by Acemoglu following Hulten's aggregation theorem and the task-based framework of Acemoglu and Restrepo, aggregates the small cost savings generated by automating individual tasks, weighting them according to the importance of those tasks, and derives a modest productivity gain. The second, developed by Baqaee and Farhi, adds an element neglected by the first: in an economy characterized by pervasive distortions, reallocating resources from less productive to more productive uses generates an additional gain, which becomes larger the more distorted the economy is. The third, associated with Romer and rooted in the work of Aghion and Howitt, is both the most powerful and the most uncertain: if artificial intelligence contributes to the production of new ideas, rather than merely improving existing activities, it can permanently alter the rate of economic growth rather than simply raising its level.

The estimates found in the literature diverge substantially precisely because they stop at different stages. Studies that measure only task automation obtain very small effects; those that incorporate reallocation generate double-digit gains, on the order of 15–20 per cent for advanced economies; and the most optimistic projections, reaching up to 7 per cent of output, implicitly incorporate the spillover effects of the third stage. The tripartite framework serves to reconcile apparently contradictory figures by interpreting them as successive phases of a single process, while clarifying that only the third stage affects the long-run growth rate, of which the so-called singularity represents the extreme case.

It is the dynamic general equilibrium model, rather than the matrix, that carries the main analytical burden, because all three stages are inherently dynamic and general-equilibrium phenomena. The first stage consists of a summation over exposed tasks, to which the matrix contributes through sectoral weights. The second stage corresponds precisely to the type of mechanism for which a general equilibrium model is designed: by simulating a productivity shock in an economy already affected by distortions, with the markups and misallocation captured by the third and fourth wedges embedded in the calibrated matrix, the model reallocates labour and capital and generates a level effect of up to approximately 15 per cent. The third stage lies beyond the closure of a standard model and is therefore imposed as a scenario through the parameters governing idea production. The estimation strategy is thus layered: weights derived from the matrix, reallocation generated endogenously by the model, and long-run growth effects imposed as an external scenario.



Illustrative framework. The first two stages raise the level of output as a one-off effect; only the third stage, the spillover effect, changes the growth rate.

Estimates and components. The dynamic model decomposes the overall effect into three stages: only the third alters the long-run growth rate, while the first two generate level effects.

Component	Matrix and model	Literature (order of magnitude)
1. Tasks (Hulten, Acemoglu)	small in the central scenario	no more than 0.66% of TFP over ten years (Acemoglu)
2. Reallocation (Baqaee–Farhi)	up to approximately 15%	15–20% in advanced economies
3. Spillovers (Romer)	affects the growth rate	indeterminate; optimistic projections up to 7% of GDP
Net effect for Italy	level effect in the short run; growth effect only with Stage 3	very wide range
1. Tasks (Hulten, Acemoglu)	small in the central scenario	no more than 0.66% of TFP over ten years (Acemoglu)

Table 4.6. Wedge 6, components of the effect of artificial intelligence.

Comparison with literature. Estimates differ because they measure different stages. Acemoglu, focusing on the first stage, finds a modest effect. Baqaee and Farhi, focusing on the second stage, obtain double-digit gains. The most optimistic projections incorporate the third stage. Our three-stage framework reconciles these figures by interpreting them as successive phases of a single process.

Interpretation. For Italy, the immediate benefit is a level effect generated through reallocation and depends on the removal of the frictions measured by the third and fourth wedges. Without reallocation, a large share of the potential gains would remain trapped.

4.7 Synthesis Framework

The comparison between the two families of estimates—those derived from the matrices and those drawn from the literature—suggests three conclusions, depending on whether the two sources agree, diverge, or remain silent. Where they agree, the result is robust. This occurs for three of the six wedges: total factor productivity, which both approaches find to be weak; resource misallocation, which both identify as substantial; and welfare, which both place in a relatively stronger position than that suggested by output alone. These three findings can therefore be regarded with confidence.

Where the estimates diverge, as in the case of the fourth wedge, price markups, the difference is only apparent. The two methods produce different levels of markups, but this reflects the way in which they are calculated rather than any difference in the underlying economy: it is a methodological artefact. Moreover, what truly matters—not the level of markups but their dispersion—is common to both estimates. Where the matrix remains silent, as in the case of the second wedge, intangible capital, and part of the sixth wedge, artificial intelligence, the literature fills the gap, albeit with a wide margin of uncertainty that calls for caution.

Overall, the Italian picture is not that of a country suffering from a lack of technology. Rather, it is characterized by the combination of three structural bottlenecks: resources that are poorly distributed across firms, market power that varies excessively from one firm to another, and a productive structure that shifts toward less productive sectors. Artificial intelligence can potentially affect all three, but only under one condition: those frictions must first be removed.

Frequently Asked Questions

ARE THE FIGURES PRESENTED IN THIS CHAPTER DEFINITIVE?

No. They are orders of magnitude consistent with the literature, derived from the three SAM matrices for 2020, 2024, and 2025, disaggregated into seventy-five sectors, and from a general equilibrium model.

Why is the markup estimated from the SAM matrices equal to 1.45, while the literature reports approximately 1.1?

Because the two figures arise from different methodologies. Our estimate derives from Hall's approach applied to the matrix, whereas the estimate in the literature derives from a production-function approach applied to firm-level data. This is not a contradiction but a methodological difference. On the aspect that truly matters—the dispersion of markups—the two sources agree.

What can the SAM matrix measure, and what cannot measure?

The matrices are well suited to measuring levels, distributive shares—including by income decile—and misallocation across sectors, which they infer from the seventy-five-sector structure. They cannot measure misallocation among firms within the same sector, which requires microdata, nor can they measure unrecorded intangible capital, which lies outside the scope of the national accounts. For these components, reliance must be placed on the literature and on firm-level data.

Can reallocation across sectors generate large gains?

No. Eliminating the dispersion of markups across sectors, once rents have been neutralized, yields only modest gains, on the order of 0.6 per cent: Italy wastes relatively little through cross-sectoral allocation. The potentially large gains—amounting to several tens of percentage points in estimates from the literature—derive instead from reallocation among firms within the same sector. Such effects cannot be measured by a sectoral matrix and require firm-level data.

Does the 14 per cent welfare gap imply that GDP overstates productivity?

No, and this is the most delicate point. Welfare and output are different metrics: their divergence measures the distance between two ways of assessing the same economy, not an error in GDP. The welfare metric should be used to compare countries or years, never as a subtractive correction to the output of a single country in a single year.

Chapter 5

Measuring Non-Rival Goods: The European Productivity Debate

The previous chapters developed a toolkit—six wedges designed to reconcile measured productivity with the forces that actually drive change. This chapter puts that toolkit to the test through a recent controversy with significant practical implications, because it concerns the diagnosis of Europe's decline. It will be shown that the dispute, apparently technical in nature, illustrates the central thesis of this Working Paper: measuring productivity and measuring output are ultimately the same problem. It will also be shown that the controversy introduces a dimension only briefly touched upon in the welfare and artificial intelligence wedges: non-rivalry.

5.1 The Controversy

In a series of recent interventions, Paul Krugman has argued that the decline of European productivity relative to that of the United States is largely a statistical artefact. Measured at current purchasing power parity, European output per hour has remained almost flat relative to the United States for twenty-five years, at approximately 86–87 per cent, implying that constant-price measures showing a widening gap are misleading. Aghion, Bergeaud, and Garicano have responded that a chained series of current purchasing power parities cannot be used to measure growth. A single purchasing power parity is a valid spatial comparison at a given point in time, but chaining such snapshots changes the valuation yardstick every year, thereby conflating changes in quantities with shifts in the price system. The productivity gap, they conclude, is real. The disagreement can be interpreted as a dispute over the appropriate price index. It is better understood, however, as a disagreement about what output actually is and at what prices it should be valued. Viewed in this way, it consists of two correct answers to two different questions.

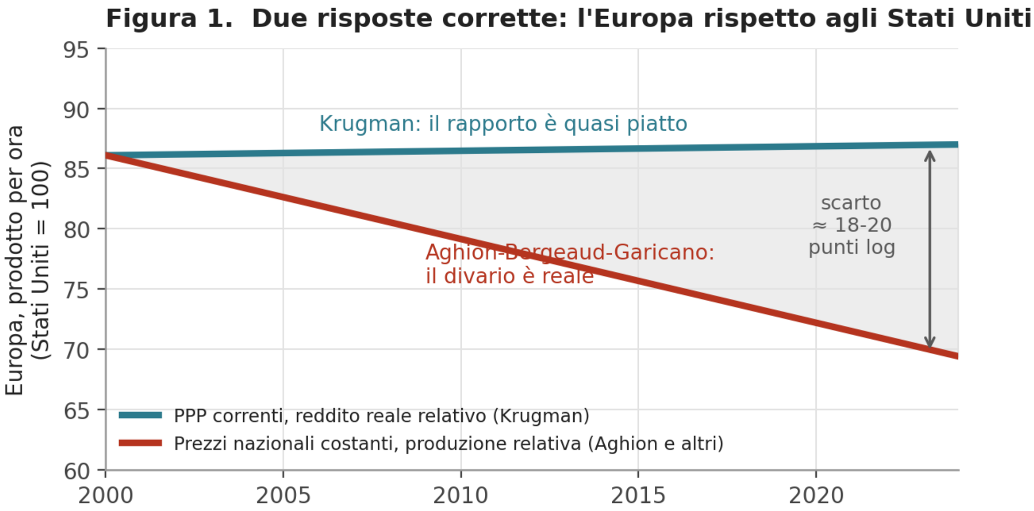


Figure 1. European output per hour as a percentage of the US level. The ratio at current purchasing power parity—relative real income according to Krugman—remains almost flat at around 86–87 per cent; the ratio at constant prices—relative production—fans out because US labour productivity grows by approximately 2.1 per cent per year compared with approximately 1.0 per cent in the euro area. The two assessments diverge by 18–20 logarithmic points, which Aghion, Bergeaud, and Garicano estimate at around 18 points for France. Sources: Krugman, Substack; ECB Economic Bulletin 6/2024, United States +50 per cent, euro area +28 per cent, 1995–2019.

5.2 A Valid Argument, but Overstated

On the mechanics, Aghion and his co-authors are correct: a series based on current purchasing power parities re-prices output each year using the international prices of that year, mixes quantities with the valuation metric, and therefore does not constitute a measure of production growth[17]. Their positive case, however, is weaker. The table of seven series leading to a single conclusion does not provide seven independent confirmations, but rather a single deflation convention applied seven times. Moreover, the entire gap between France and the United States—approximately eighteen logarithmic points—is concentrated in information technology, the sector in which quality adjustment over time and across countries is least reliable and in which the two economies adopt different conventions. The discrepancy is therefore the disagreement itself, not its resolution. Upon

[17] This is why the Penn World Tables maintain a distinction between expenditure-side real GDP, used for level comparisons, and national-accounts real GDP, used for growth measurement. The orthodox position is represented by the former approach; Krugman's construction represents the heterodox one.

closer inspection, the controversy reduces to a single parameter that the data are unable to determine[18].

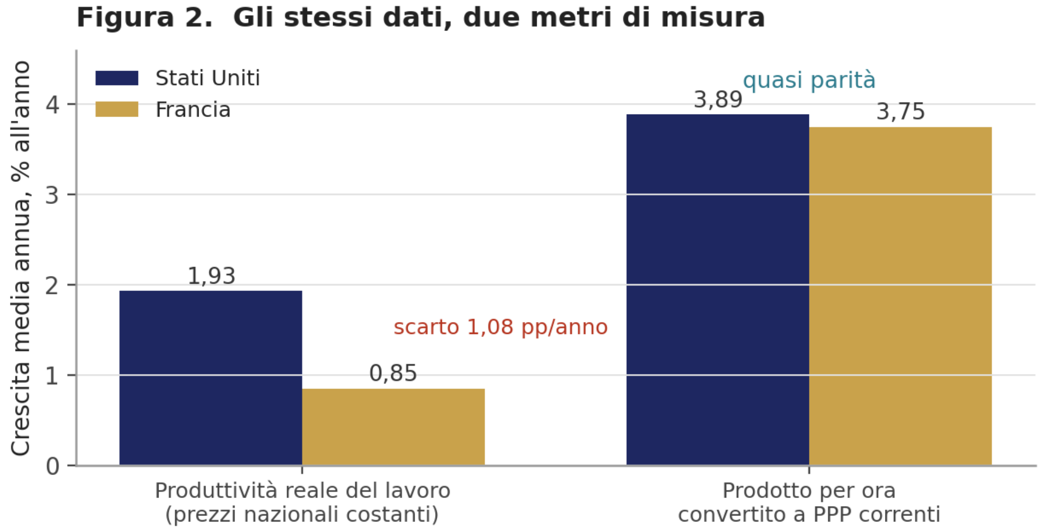


Figure 2. Average annual growth, United States versus France. At constant national prices, US real labour productivity growth, 1.93 per cent, clearly exceeds French growth, 0.85 per cent. Converted at current purchasing power parity, however, output per hour grows at almost the same rate, 3.89 versus 3.75 per cent—the near parity through which the conversion eliminates the gap. Source: Aghion, Bergeaud, and Garicano.

5.3 Shadow Prices: What the Dispute Is Really About

The consistent valuation of heterogeneous goods undergoing qualitative change is achieved through shadow prices, and under consumer sovereignty the appropriate shadow price is marginal willingness to pay. Production costs do not enter the valuation. Marginal cost determines the efficient quantity, not the value of the units produced. What market power distorts are factor shares and the equilibrium quantity, not the valuation of each unit[19].

[18] Writing the nominal price change of information and communication technology (ICT) as the sum of a quality-adjusted price component and a quality component yields a single equation with two unknowns. Both the weight effect—that is, the declining share of ICT in total value—and the growth effect—that is, the surge in measured ICT output—depend on the same parameter, and the data cannot separate them without an externally defined measure of quality.

[19] This is an important clarification relative to the fourth wedge. Markups affect weights and quantities, not the shadow price of the individual good itself. This weakens the objection that markups alone would invalidate the comparison.

It follows that there is only one fundamental question: how should the output of information technology be defined and valued? If output is understood as production, valuation at constant prices is appropriate. If output is understood as real income, valuation adjusted for the cost of living is appropriate. The two approaches answer different questions, and neither is incorrect.

5.4 The Non-Rival Core and the Productivity Residual

There are no free goods. The free applications available on a smartphone are not truly free: their value is embedded in the price of the device, a durable good that capitalizes the entire expected stream of services. From the consumer side, therefore, the value is fully measured, and information technology is not exceptional from the demand perspective. The problem lies on the production side.

The core—operating systems, software code, chips, and major innovations—is non-rival. Once produced, it serves all users at virtually zero reproduction cost and spreads throughout the economy without being invoiced. The market measures it only to the extent that the rival carrier—the device itself—can charge for access, capturing access value while truncating use value, which explains the appearance of a zero price[20]. This truncated value is realized only later through two delayed channels: incorporation into the next generation of devices and technologies, which enters GDP, and disembodied spillovers into user sectors, which do not enter GDP and instead reappear as a productivity residual.

[20] Under consumer sovereignty, a non-rival good should be valued at the vertical sum of individual willingness-to-pay schedules, because the same unit simultaneously serves all users. The market, by accounting only for access through a rival carrier good, records merely the valuation of the marginal purchaser—a horizontal slice of that aggregate valuation. Market prices therefore underestimate the social shadow price even under perfect competition and in the absence of rents. This is the structural signature of non-rivalry, not a distortion.

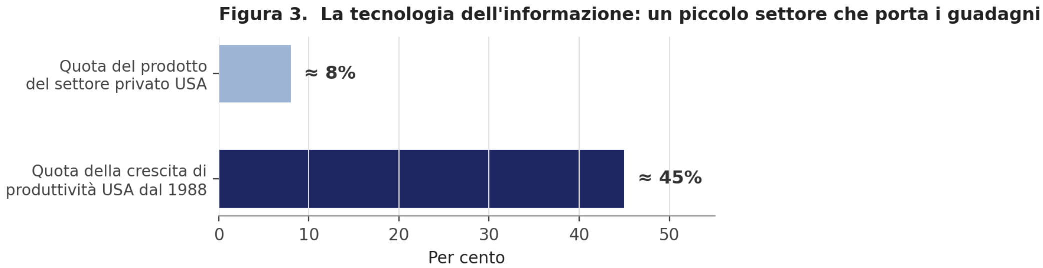


Figure 3. Information technology accounts for approximately 8 per cent of US private-sector output but explains approximately 45 per cent of productivity growth since 1988. It is the sector in which the transatlantic gap is concentrated and the principal driver of measured productivity residuals. Source: Federal Reserve Bank of Chicago, as cited in the debate.

Because spillovers have no priced input to which they can be attributed, they fall into the Solow residual by construction. Measured at market prices, they constitute a Romerian non-rivalry externality and are precisely what appears as total factor productivity. A genuine U.S. advantage in total factor productivity is therefore the baseline case rather than the suspicious one: it is the accounting representation of a genuine increasing-returns externality that the United States produces and diffuses.

None of these considerations is specific to information technology. Once non-rivalry causes the shadow price of a public or quasi-public good to equal the sum of individual valuations, every such good is mismeasured in GDP. This is the same problem encountered in Chapter 2 regarding the valuation of public-sector output at cost. The two measurement failures are mirror images of one another. Public-sector output enters national accounts at cost, implying measured productivity that is zero or negative while its weight increases. By contrast, the core of information technology enters at a truncated market value. Europe contains more of the former, while the United States contains more of the latter, and the accounting convention biases comparisons in opposite directions across the two sectors.

5.5 The Trade Channel: Why Both Measures Tell the Truth

Trade is what most complicates the debate. Under free trade and the law of one price, the quality-adjusted price of tradable information technology converges across economies. Europe, by importing at a declining world price, enjoys the gains from quality improvements and embodied spillovers without bearing the cost of producing the innovation. The United States, however, as the producer and net exporter of the good whose relative price is collapsing, experiences an erosion of real income when measured at current world prices through a terms-of-trade effect, even while the volume of its output expands dramatically.

This rationalizes Krugman's result rather than refuting it. The flat ratio at current prices correctly measures relative purchasing power at contemporary prices, and it appears low for the United States precisely because trade and non-rivalry have transferred a large share of the surplus generated across the Atlantic to European consumers and industries. The parity is the signature of the spillover crossing the ocean, not evidence against its existence. The controversy can therefore be resolved into three quantities: a productive-capacity gap in favour of the United States; a real-income gap at current prices that remains almost flat; and, between the two, a large and genuine internationally non-appropriated social return, which explains why two correct measures diverge. The two sides of the debate measure different stages of a single process: the present welfare of the importer and the accumulating productive capacity of the producer. Indeed, the gap between a comfortable present and a diverging future is the central argument underlying Draghi's diagnosis, which remains valid even if Krugman is entirely correct about what current purchasing power parity measures.

5.6 Distribution, Market Power, and Trade Policy

It is tempting to interpret the oligopolistic power of U.S. technology firms as a legitimate retention of surplus against international free riding, and to view tariffs as a means of securing a fairer share of the gains from technological progress. Both inferences are coherent, yet both are mistaken. Market power does indeed retain surplus from foreign free riders. However, a global platform price imposes the same markup on domestic consumers, creating a pure internal transfer accompanied by deadweight loss, while simultaneously restricting the very domestic diffusion that generates the largest social return.

As for tariffs, they point in the wrong direction. Under the logic of the optimal tariff, the relevant instrument belongs to the party that has leverage over the price of the good. For an exported good, this would imply a US export tax rather than a European import tariff[21]. Where the objective is genuinely distributive, the appropriate instruments are those that capture economic rents without destroying surplus: competition policy, which lowers markups and increases diffusion; taxation of economic rents at their source; and, above all, domestic capacity to produce the next embodied generation of technology, the only channel through which an importer can become a producer.

5.7 Implications for Measurement

The controversy is not, ultimately, a dispute between two price indices. It stems from the inability of GDP to price non-rivalry, compounded by a trade structure that redistributes the gains from a non-rival good across borders. Krugman correctly measures the real income available to Europe today. Aghion, Bergeaud, and Garicano correctly measure the frontier productive capacity in which the United States leads. The gap between the two is the non-appropriated social return that no single statistic can capture.

The constructive implication is methodological, and it is the same lesson that runs throughout this Notebook. A defensible measure of productivity should value both non-rival sectors—privately produced information technology and publicly produced services—using consistent social shadow prices under a single explicit welfare function, rather than treating one as a footnote in the "beyond GDP" debate and the other as the headline story of productivity. Doing so would compress the apparent level gap arising from the public sector and the apparent welfare parity arising from information technology, leaving as the residual the only term whose sign is not a measurement artefact: the differing capacity to produce and diffuse non-rival inputs at the technological frontier. This residual—the frontier capability of the United States net of both corrections—is almost certainly positive and is the only term whose sign survives every choice of welfare function, because it is a statement about the technological frontier rather than about how output is priced.

[21] A European import tariff would raise the price precisely of the declining-price good through which Europe captures the spillover, effectively taxing away its own terms-of-trade windfall. It is the one policy instrument that would sacrifice efficiency itself—that is, the entire surplus at stake.

Frequently Asked Questions

IN THE EUROPEAN DEBATE, IS KRUGMAN OR AGHION CORRECT?

Both are correct because they answer different questions. Krugman correctly measures the real income available to Europe today. Aghion, Bergeaud, and Garicano measure frontier productive capacity. The two measures diverge because they measure different things.

ARE THE "FREE" APPLICATIONS ON A SMARTPHONE REALLY FREE?

No. Their value is embedded in the price of the device, which capitalizes the expected stream of services. From the consumer perspective everything is measured; the problem lies on the production side.

WHY DO TECHNOLOGY SPILLOVERS APPEAR IN THE RESIDUAL?

Because they diffuse without a priced input to which they can be attributed. Measured at market prices, they reappear as total factor productivity. They are a non-rivalry externality, not a measurement error.

WOULD A EUROPEAN TARIFF ON TECHNOLOGY HELP?

No. It would raise the price of the very good through which Europe captures the spillover, effectively taxing away its own terms-of-trade advantage. The appropriate instruments are competition policy, rent taxation, and the capacity to produce the next generation of technology.

DOES DRAGHI'S DIAGNOSIS OF EUROPE'S LAG STILL HOLD?

Yes, even if one grants Krugman that relative real income is almost flat. The key issue is the gap between a comfortable present—partly supported by imported welfare—and a frontier productive capacity in which Europe remains behind.

Chapter 6

Where the Italian Productivity Problem Lies

For a quarter of a century, Italian productivity has grown very little, while the other major European economies have continued to advance. The instinctive reaction is to attribute the problem to a lack of technology or investment. This chapter argues, in straightforward terms, that the core of the problem lies elsewhere: not in the amount of technology available, but in the way resources, workers, and capital are distributed across firms.

Italy's best-performing firms are as productive as the best firms in Europe. The problem is that they coexist with a long tail of much less productive firms, and that too many workers and too much capital remain employed in the latter. A country's productivity is an average: if a large share of resources remains concentrated in low-productivity firms, the average will remain low even when the leading firms are highly efficient.

It is useful to distinguish between two types of gaps. The first is the gap across sectors: labour tends to concentrate in sectors where productivity is lower, for example in parts of the service sector and in the public sector. This matters but correcting it alone would yield only limited gains. The second, and far more important, is the gap among firms within the same sector. In every industry, alongside frontier firms there are many others that produce substantially less output per employee. The distance between the frontier and the laggards is considerable, and it is there that a large share of lost productivity is hidden.

Data from the Italian National Institute of Statistics (ISTAT) make this picture concrete. When firms are classified according to their degree of innovative dynamism, the most dynamic firms are found to be more than 85 per cent more productive than the least dynamic ones. Yet approximately 80 per cent of firms, accounting for almost 60 per cent of total employment, are located below the average. Dynamic firms are generally larger, employ more highly skilled workers, invest more heavily in technology and digital tools, and innovate more intensively.

In a well-functioning economy, labour and capital gradually move from less productive firms to more productive ones, thereby raising average productivity. In Italy, this reallocation process is weak: resources remain trapped where they generate lower returns. The reasons are numerous, ranging from the small average size of firms to the still limited diffusion of skills and digital technologies. Taken together, these factors constitute the real bottleneck.

All of this also has a social dimension. An economy that rewards capital more than labour, and that concentrates the most productive activities in a minority of firms, tends to distribute income unevenly. Productivity and income distribution are not two separate problems; they are two sides of the same structural reality.

Artificial intelligence is often presented as the solution. It can indeed raise the level of productivity, and perhaps even its rate of growth, but its benefits depend on the same process of resource reallocation. If resources remain locked within firms that are unable to use it effectively, a large part of its potential will remain trapped. It is no coincidence that its adoption is still concentrated among larger firms—the same firms that were already the most advanced. Artificial intelligence amplifies a system that already works; by itself, it does not unlock a stagnant one.

The key lever, therefore, is not simply more technology, but a system that allows resources to flow toward their most productive uses: helping lagging firms either to catch up or to make room for others; investing in people's skills and in the diffusion of digital technologies; and removing the obstacles that prevent the economy from reallocating resources efficiently. Measuring productivity correctly, as argued throughout the rest of this Working Paper, is the prerequisite for effective action.

Frequently Asked Questions

If Italy's best firms are competitive, why is average productivity low?

Because they coexist with many much less productive firms that employ a large share of the workforce. As a result, the national average is pulled downward, even when frontier firms perform at European levels.

Is the problem that Italy lacks technology?

No. The most productive firms already possess it. The problem is that technology is not diffused widely enough and that resources do not move sufficiently toward those who use it most effectively.

Does increasing productivity mean losing jobs?

No. In the short term, individual tasks may change, but in the long term, productivity is the primary source of higher wages, a sustainable retirement system, and better public services. It is a driver of prosperity, not its enemy.

Is artificial intelligence sufficient to solve the problem?

No. It provides an important boost, but only if resources can move toward firms capable of using it effectively. If resources remain locked in place, much of its potential will remain unrealized.

What can be done in practice?

Promote the recovery or orderly exit of lagging firms; invest in skills development and the diffusion of digital technologies; and remove the barriers that prevent resources from moving toward their most productive uses.

Conclusion

Productivity is not a quantity that is directly observed; it is a quantity that is constructed. The six wedges presented in this Working Paper are intended precisely to make this construction explicit, revealing one by one the conventions that separate measured productivity from real productivity. Considered sequentially, they lead back to the central argument from which we began: measuring output and measuring productivity are the same problem, because the conventions that determine what counts as output simultaneously distort both GDP and the productivity residual.

For Italy, the application of this framework clearly identifies where the constraints lie. The issue is not a generalized shortage of technology, but rather a combination of resource misallocation, dispersion in market power, and a trap arising from the interaction of Baumol's effect and the composition of public investment, which shifts labour toward sectors with low measured productivity. In this context, artificial intelligence currently offers primarily a level effect, and only under certain conditions an effect on the rate of growth. Yet a large share of its potential would remain trapped unless the frictions highlighted by the third and fourth wedges were first removed.

This leads to both a methodological and an institutional implication. Chapter 5 adds a further reason: the non-rival nature of an increasing share of output, both private and public, escapes market pricing by construction and therefore must be evaluated using consistent social shadow prices. From a methodological perspective, none of the corrections proposed in this Working Paper is meaningful in isolation. What is required is an integrated measurement framework capable of applying them sequentially and of comparing their results across time and across countries. From an institutional perspective, such a framework requires a permanent institutional home and dedicated resources, particularly young researchers capable of undertaking the original quantitative work on which this type of analysis depends. Without such resources, an exercise of this kind risks remaining purely descriptive. It is precisely this need that the proposal for an Economic Development Observatory seeks to address, and of which this Working Paper constitutes an initial methodological contribution.

Measuring what changes is not a statistical exercise pursued for its own sake. It is the precondition for governing change.

Frequently Asked Questions

WHAT IS THE DIAGNOSIS FOR ITALY, IN A SINGLE SENTENCE?

Not a generalized shortage of technology, but rather a combination of resource misallocation, dispersion in market power, and a trap arising from the interaction of Baumol's effect and the composition of public expenditure, which shifts labour toward sectors with low measured productivity.

IF THE PROBLEM IS NOT TECHNOLOGY, IS ARTIFICIAL INTELLIGENCE OF LIMITED USE?

It is useful, but only under certain conditions. At present, it mainly generates a level effect, and only in some cases an effect on the growth rate. However, a large share of its potential would remain trapped unless the frictions highlighted by the third and fourth wedges were first removed.

WHY IS AN INTEGRATED MEASUREMENT FRAMEWORK NEEDED RATHER THAN INDIVIDUAL CORRECTIONS?

Because none of the proposed corrections is meaningful alone. The wedges must be applied sequentially, and their results compared across time and countries. Only an integrated framework prevents each individual lens, from producing a partial or potentially misleading picture.

WHAT IS THE ECONOMIC DEVELOPMENT OBSERVATORY PROPOSED IN THE CONCLUSION?

It is a permanent institutional structure, supported by dedicated resources and, in particular, by young researchers, capable of carrying out the original quantitative analyses required by this type of measurement framework. Without such an institution, an analysis of this kind risks remaining purely descriptive.

WHAT IS THE NOTEBOOK'S MAIN METHODOLOGICAL CONCLUSION?

That productivity is not a quantity that is directly observed, but one that is constructed. Making this construction explicit, by measuring what changes, is the precondition for governing change and not merely a statistical exercise pursued for its own sake.

Appendix A. The Mathematical Models of the Six Wedges

This appendix presents the formal core of each wedge, using the notation employed in Chapter 4. Uppercase letters denote aggregate variables, lowercase letters denote unit-level or per-capita variables, the subscript i denotes a sector or firm, the operator Δ indicates a change, and *ln* denotes the natural logarithm.

A.1 Wedge 1. Growth Accounting

The analysis begins with an aggregate production function under constant returns to scale, where A measures total factor productivity.

$$Y = A\,F(K,\ L) \tag{A.1}$$

Differentiating in logarithms and using factor income shares as weights—valid as elasticities only under perfect competition and constant returns to scale—output growth can be decomposed into the contributions of capital, labour, and the residual.

$$\Delta\ln Y = \alpha\,\Delta\ln K + (1-\alpha)\,\Delta\ln L + \Delta\ln A \tag{A.2}$$

The residual, that is, total factor productivity, is obtained as a difference and represents the quantity that the subsequent wedges seek to decompose. The labour term can in turn be separated into hours worked and labour-force quality.

$$\Delta\ln A = \Delta\ln Y - \alpha\,\Delta\ln K - (1-\alpha)\,\Delta\ln L \tag{A.3}$$

A.2 Wedge 2. Capitalization of Intangible Investments

The correction proposed by Corrado, Hulten, and Sichel reclassifies intangible expenditure N, previously recorded as a cost, as investment, and accumulates a corresponding stock R. Both output and capital increase as a result.

$$Y^* = Y + N, \qquad K^* = K + R \tag{A.4}$$

The intangible stock follows a perpetual inventory accumulation law, with a depreciation rate that is generally higher than that of physical capital.

$$R_t = (1 - \delta_N)\, R_{t-1} + N_t \tag{A.5}$$

The residual recalculated on the expanded aggregate is normally lower than the standard residual, because part of the growth previously attributed to total factor productivity is reassigned to a factor that is now explicitly measured.

$$\Delta \ln A^* = \Delta \ln Y^* - \alpha_K\, \Delta \ln K^* - \alpha_R\, \Delta \ln R - \alpha_L\, \Delta \ln L \tag{A.6}$$

A.3 Wedge 3. Misallocation

At the firm level, revenue productivity (*TFPR*) summarizes the combined effect of prices and physical productivity. In the absence of distortions, it is equalized across firms, and its dispersion provides a measure of misallocation.

$$\mathrm{TFPR}_i \equiv P_i\, A_i \tag{A.7}$$

Under constant-elasticity demand, with elasticity σ, and assuming a lognormal distribution of TFPR, the loss in aggregate productivity relative to the efficient allocation is proportional to the variance of the logarithm of TFPR.

$$\ln \frac{A}{A_{\mathrm{eff}}} = -\frac{\sigma}{2}\, \mathrm{Var}(\ln \mathrm{TFPR}_i) \tag{A.8}$$

The cross-sectoral component is instead captured by the Olley–Pakes decomposition, in which aggregate productivity equals the unweighted average plus a covariance term between sectoral shares and sectoral productivity. A negative covariance indicates that economic weight is concentrated in less productive sectors.

$$\Omega = \bar{\omega} + \sum_i (s_i - \bar{s})(\omega_i - \bar{\omega}) \tag{A.9}$$

A.4 Wedge 4. Market Markups

From cost minimization, a firm's markup is given by the ratio between the elasticity of production with respect to a variable input and that input's revenue share. This is the basis of the De Loecker–Warzynski approach.

$$\mu_i = \theta_i^V \left(\frac{P_i^V X_i^V}{P_i Q_i} \right)^{-1} \tag{A.10}$$

The aggregate markup is a weighted average of firm-level markups, with weights given by the relevant shares. However, the quantity that matters for resource allocation is not the level of markups but their dispersion, measured here by the coefficient of variation.

$$\bar{\mu} = \sum_i s_i \, \mu_i \, , \qquad CV = \frac{\sigma_\mu}{\bar{\mu}} \tag{A.11}$$

A.5 Wedge 5. Welfare Productivity

In the consumption-equivalent framework of Jones and Klenow, the relative welfare of a country can be decomposed, as a first approximation, into a consumption component, a life-expectancy component, a leisure-time component, and an inequality component, the latter entering with a negative sign.

$$\ln \lambda \approx \ln \frac{c}{c_{\text{us}}} + g_{\text{vita}} + g_{\text{tempo}} - \frac{1}{2}\left(\sigma^2 - \sigma_{\text{us}}^2\right) \tag{A.12}$$

The distributive correction is formalized through Atkinson's equally distributed equivalent consumption, where the inequality-aversion parameter determines the penalty assigned to more unequal distributions.

$$c_{\text{ede}} = \left(\sum_j p_j \, c_j^{\,1-\eta} \right)^{\frac{1}{1-\eta}} \tag{A.13}$$

A.6 Wedge 6. Artificial Intelligence as a Factor

At the first stage, the aggregate effect follows a version of Hulten's theorem: the productivity gain equals the product of the share of tasks exposed to artificial intelligence and the average cost saving at the task level. This yields Acemoglu's lower-bound estimate.

$$\Delta \ln \mathrm{TFP} = \sum_i b_i \, \Delta \ln A_i \approx \tau \bar{\pi} \tag{A.14}$$

At the second stage, in a distorted economy Hulten's theorem no longer holds, and a reallocation term—normally neglected—emerges and becomes quantitatively significant. This is the Baqaee–Farhi channel.

$$d \ln Y = \sum_i \lambda_i \, d \ln A_i + \Delta_{\text{riall}} \tag{A.15}$$

At the third stage, artificial intelligence affects the production of ideas in the Romerian sense. By altering the parameters of the ideas-production equation, it can permanently affect the rate of growth rather than merely the level of output.

$$\frac{\dot{A}}{A} = \delta \, H_A^{\lambda} \, A^{\phi - 1} \tag{A.16}$$

Appendix B. A Brief Glossary of Productivity

This glossary brings together the key terms that recur throughout the Notebook, presented in straightforward language for readers approaching the subject without formal training in economics.

Productivity

The amount of output produced per unit of resources employed. The higher productivity is, the more value is generated from the same amount of labour and capital.

Labour Productivity

The output produced per hour worked or per employee. It is the most immediate measure of productivity, but it does not distinguish whether higher output is achieved through greater efficiency or simply through the use of more machinery and equipment.

Total Factor Productivity

The portion of growth that cannot be explained by increases in labour and capital alone. It is a residual that encompasses technology, organization, labour quality, and many other factors, and for this reason it has often been described as "a measure of our ignorance."

Frontier

The group of the most productive firms within a sector, serving as the benchmark toward which other firms may potentially converge.

Reallocation

The movement of labour and capital from less productive firms to more productive firms. When this process is weak, national productivity tends to stagnate.

Allocative Efficiency

The extent to which resources are distributed across alternative uses in an efficient manner. Allocative efficiency is high when resources are employed where they generate the greatest returns, and low when they remain where returns are lower.

Level Effect and Growth Effect

A level effect is a one-time improvement in the level of productivity. A growth effect is a permanent increase in the rate at which productivity grows. A technology may generate the former without generating the latter.

Human Capital

The stock of workers' skills, education, and experience. It is one of the characteristics that distinguish more productive firms from those that lag behind.

Intangible Assets

Investments without a physical form, such as software, data, brands, organizational capital, and research. These assets account for an increasingly important share of modern economies and are only partially captured by traditional measurement frameworks.

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Understanding Productivity

Emanuele Canegrati [22]

Productivity: Questions and Answers. Between History of Economic Thought and Contemporary Measurement

1. What is productivity in economics?

In very simple terms, productivity is a measure of efficiency in the use of resources within an economic system or a specific production process. It is defined as the ratio between the output generated through the production of goods and services and the inputs (labour, capital, raw materials) used to produce them. In other words, productivity tells us how efficiently available resources are converted into goods or services.

Conceptually:

$$Productivity = \frac{Output}{Input}$$

2. Why is productivity such an important concept?

Economists generally regard high productivity as a prerequisite for long-term economic growth, higher living standards, and higher wages for workers.

3. What determines productivity?

According to a study by Chad Syverson published in the *Journal of Economic Literature*, productivity depends on a unique combination of internal business practices and external operating environments. The main factors associated with persistently high productivity include high-quality labour and capital inputs, advanced technologies, efficient management practices, favourable organizational structures, and competitive market conditions.

Perhaps the economist who most successfully explained the origins of productivity—and especially its continuous growth in modern economies—was Joseph Alois Schumpeter.

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Figure 1 – *Joseph Alois Schumpeter*

According to Schumpeter, productivity originates from what he famously defined as the principle of "creative destruction", namely a process through which continuous innovation generated by entrepreneurs' ideas constantly renders existing technologies, products, and organizational methods obsolete, replacing them with new and more efficient solutions.

Long-term economic growth therefore derives from the disruption of existing paradigms and equilibria (*dynamic efficiency*) rather than from the mere efficient functioning of an economic system within an existing framework (*static efficiency*). Schumpeter argued that prioritizing efficiency at a given point in time (*static efficiency*) may, in fact, hinder long-term progress. Genuine economic advancement inevitably requires the disruption of an existing equilibrium. The entrepreneur is thus the central figure in this process: the individual who, through innovation and creative vision, breaks a static equilibrium and introduces new productive possibilities.

According to Schumpeter, economic growth is therefore not a linear process. Rather, it unfolds through what he described as unpredictable "*waves of creation and destruction*", which develop over time following an exponential pattern. These waves are driven by financial institutions that provide the resources necessary to support innovation, rather than by systems of centralized planning. Diagram 1 illustrates the exponential acceleration of human innovation observed from the British Industrial Revolution (second half of the eighteenth century) to the sixth wave, known as the Sustainability Wave, which began around the year 2000. The diagram, proposed by Michael Harrison Smith and Karlson James Hargroves in 2007, demonstrates how the principle of creative destruction, observed on a global scale, unfolds through technological cycles that become progressively shorter, faster, and characterized by increasingly intense rates of innovation.

Chronologically, the six waves of innovation identified by the authors are:

1. Industrial Revolution (Mechanization, water power)
2. Age of Steam (Railways, steam locomotives)
3. Age of Electricity (Heavy engineering, steel production)
4. Age of Mass Production (Automobiles, petrochemicals)
5. Information Age (Digital networks, Information and Communication Technologies – ICT)
6. Age of Sustainability (Clean technologies, circular economies)

Schumpeter also believed that innovation necessarily originates from the bottom up—from entrepreneurs immersed in everyday business realities rather than from policymakers. Innovation possesses intrinsic characteristics such as unpredictability, spontaneity, and the impossibility of precise ex ante measurement. Consequently, productivity itself is continually subject to unpredictable changes, reducing the precision with which it can be measured.

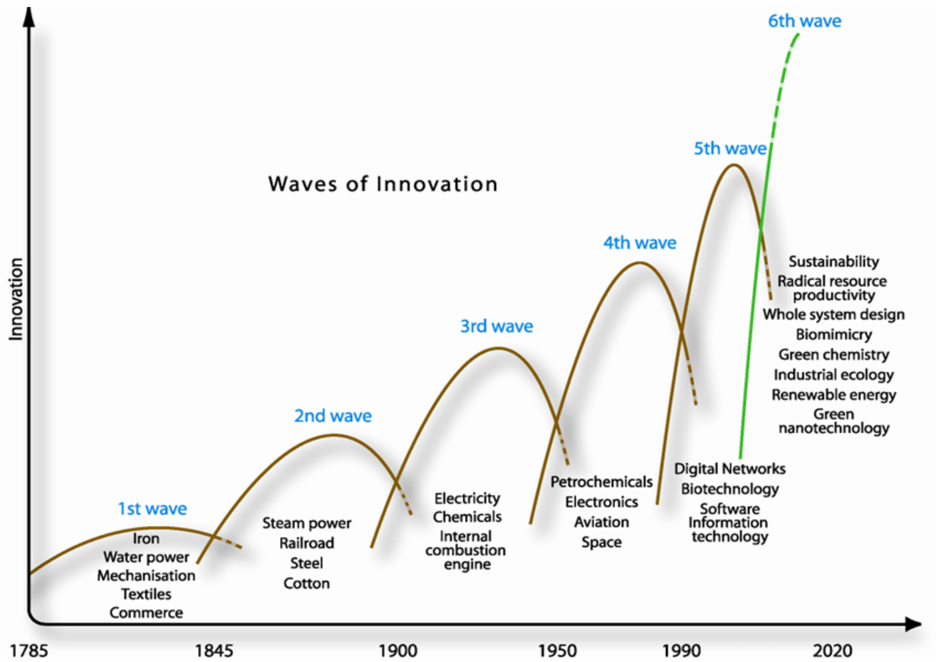

Diagram 1 – *Schumpeter's "waves of human innovation" (Smith & Hargroves, 2007)*

The Italian economist Piero Sraffa also regarded the relationship between productivity and technology as central, although from a very different perspective. Rather than focusing on technological progress itself, Sraffa emphasized methods of production.

Figure 2 – *Piero Sraffa*

In his seminal work *Production of Commodities by Means of Commodities* (1960), Sraffa models technology as a system of equations that describes how commodities are produced through the use of other commodities (referred to as technical inputs) and labour. According to Sraffa, the key characteristics of a production system are as follows:

- Given Technical Conditions: Technology is treated as given and physically measurable. Sraffa demonstrates that, once the technical conditions of production are known and either the wage rate or the profit rate is fixed, it becomes possible to determine mathematically both the relative prices of all commodities and the remaining distributive variable.
- Choice of Technique: Within his analytical framework, Sraffa also examines the role of technological change. When different production methods or technologies are available for producing the same commodity, capitalists will adopt the technique that guarantees the highest rate of profit at the prevailing wage level.

4. Why Is Productivity Considered a Determining Factor for a Nation in a Globalized Economy?

The relationship between productivity and international trade is both direct and bidirectional. Higher productivity enables firms to export more goods and services, while openness to international markets stimulates productivity through increased competition and access to new technologies—access that would not be available in a closed economy. Countries characterized by higher productivity levels tend to dominate export markets thanks to their comparative advantages.

According to the influential theories of comparative advantage and opportunity cost, developed during the nineteenth and twentieth centuries by economists David Ricardo and Gottfried von Haberler, international trade remains beneficial even for a country that is less efficient in the production of every good.

Figure 3 – *David Ricardo*

Until the development of the theory of comparative advantage, introduced by Ricardo in 1817 as a critique of the British Corn Laws, economic thought generally held that a country should produce and export all goods for which it enjoyed an absolute cost advantage, a concept originally articulated by Adam Smith in *The Wealth of Nations* (1776). According to this perspective, it was entirely possible for a country possessing lower production costs across all goods to produce and export everything to countries facing higher production costs.

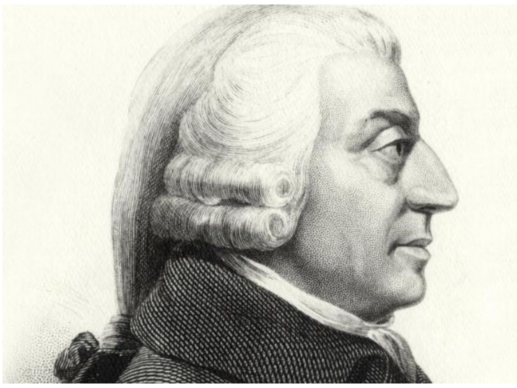

Figure 4 – *Adam Smith*

Ricardo fundamentally transformed this understanding. According to his theory, every country benefits from specializing in the production of those goods in which it is relatively more productive, namely those for which the opportunity cost of production is lower. Through international exchange, all countries participating in trade are able to achieve gains. It should be noted, however, that the concept of opportunity cost, which was implicit in Ricardo's reasoning, was formally developed and rigorously articulated only in the twentieth century by Gottfried von Haberler.

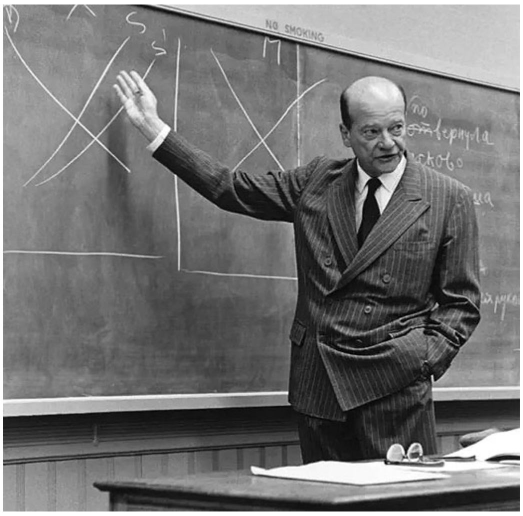

Figure 5 – *Gottfried von Haberler*

A substantial body of empirical research has confirmed the validity of the theories advanced by Ricardo and Haberler, as well as the economic benefits derived from specialization in international trade. In the influential article *Technology, Geography, and Trade*, published in the academic journal *Econometrica*, economists Jonathan Eaton and Samuel Kortum developed an advanced Ricardian model. By analysing trade data from multiple countries, they demonstrated that differences in productivity and geographic barriers systematically explain actual bilateral trade flows. At the macroeconomic level, studies conducted by organizations such as the Organisation for Economic Co-operation and Development (OECD) and the World Trade Organization (WTO) confirm that openness to international trade, driven by comparative advantages, promotes income growth and facilitates the reallocation of resources toward goods and services with higher value added. The empirical evidence is equally strong at the microeconomic level. Analyses based on WTO data indicate that individual firms are significantly more likely to export when they operate in sectors where their country possesses a comparative advantage, while simultaneously maximizing their own productivity. Italy, for example, enjoys a strong comparative advantage in sectors that embody the excellence of the Made in Italy brand. These include, in particular, specialized manufacturing industries—often referred to as the "3 Fs": Fashion, Food, and Furniture—as well as advanced industrial automation, pharmaceuticals, and international tourism.

5. Why does higher productivity imply higher wages?

In economic theory, high productivity is associated with higher wages because workers generate more value—or output—in less time, allowing firms to raise compensation without increasing unit labour costs. When labour productivity—measured, for example, as output per hour worked—increases, the overall economic "pie" becomes larger. Workers can then claim a greater share of that pie through wage increases or performance-related pay, provided that the economy is supported by appropriate redistributive policies and a competitive labour market.

6. Does division of labour increase productivity?

Yes. In his landmark work *The Wealth of Nations* (1776), the Scottish economist Adam Smith revolutionised economic thought by introducing the concept of the division of labour, demonstrating how worker specialisation can dramatically increase efficiency and the production of goods and services. In particular, the division of labour raises productivity because it allows each worker to specialise in a single task. As Smith argued, there are three main reasons why specialisation enhances productivity:

- Greater skill and dexterity. Focusing on a single repetitive task enables workers to develop higher levels of proficiency and efficiency.
- Time savings. Specialisation eliminates the time lost and the decline in concentration associated with continually switching between different stages of production.
- Technological innovation. Simplifying tasks makes them more amenable to mechanisation, facilitating the introduction of machinery that can increase output exponentially.

The principle of the division of labour is perhaps most clearly illustrated by Fordism, a model of industrial organisation based on the extreme fragmentation of tasks. Introduced by the American entrepreneur Henry Ford in 1913 in the automobile industry, Fordism combined the assembly-line principle with a sharp separation between intellectual labour (design and planning) and manual labour (execution). The production process was broken down into simple, repetitive operations that required little specialised skill. Management planned and controlled the pace of work—following the principles of Taylorism—while workers merely carried out the prescribed tasks. In this way, productivity increased substantially. This model dominated much of the twentieth-century economy until the emergence of post-Fordism and more flexible forms of production.

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Figure 6 – *Ford's assembly line, symbol of the division of labour*

7. Why does a competitive labour market encourage increases in labour productivity?

An increase in productivity enables firms to operate more efficiently in their production processes and, consequently, to increase output while maintaining the same labour costs. This results in higher profitability, which may either be retained by ownership or redistributed to workers in the form of higher wages or performance-related bonuses. A competitive labour market is characterised by greater mobility, as it guarantees workers the freedom to offer their labour to firms that provide higher remuneration. Consequently, productivity gains provide firms with greater resources to raise wages and attract the most qualified workers—an incentive that would not exist in a non-competitive labour market. As a result, a competitive labour market creates incentives to increase productivity, since workers are aware that productivity improvements can translate into better remuneration opportunities for them.

8. What is the relationship between productivity and income distribution?

Economists David Ricardo and Piero Sraffa both rejected the notion that incomes are determined by marginal productivity. Both regarded the social product (or surplus) as the starting point and viewed the distribution between wages and profits as a zero-sum process, determined by historical and institutional factors, power relations, and physical constraints.

Ricardo argued that, as the population grows, cultivation must progressively extend to less fertile or more distant land, thereby reducing agricultural productivity as a consequence of the law of diminishing returns. The increase in the cost of grain also raises landowners' rents. Owing to lower productivity, the cost of feeding workers—who receive only a subsistence wage—increases. Since total output is limited, if real wages rise, the rate of profit accruing to capitalists must necessarily decline.

By contrast, Sraffa rejected the neoclassical theory of diminishing marginal productivity, arguing that it is not possible to measure the remuneration of capital independently of prices and income distribution. For Sraffa, distribution is essentially a policy variable: the rate of profit and wages are not linked to the productivity of individual factors of production but are instead determined by institutional and social factors. The wage rate (or, alternatively, the profit rate) is fixed exogenously, since only once one of these variables has been established can relative prices and the other distributive share be determined automatically, thereby maintaining equilibrium within the economic system. The inverse relationship between wages and profits remains at the core of the theory: given unchanged technical conditions (productivity), a reduction in wages entails an increase in the rate of profit.

9. "Productivity isn't everything, but in the long run it is almost everything." Who coined this famous statement?

The statement was made by economist Paul Krugman. According to the Nobel Prize laureate, a nation's standard of living, real economic growth, and wage increases depend almost entirely on an economy's ability to produce more output with the same amount of resources.

His perspective is structured around three key concepts:

- The Engine of Prosperity: In the long run, improvements in living standards do not stem from aggressive trade policies or geopolitical competition, but rather from technological innovation, greater efficiency, and higher output per worker.
- Political Short-Sightedness: Krugman strongly criticises the view that governments should focus exclusively on increasing employment in the short term while neglecting productivity growth. He argues that firms and nations that fail to improve their efficiency are ultimately destined to become poorer.
- Statistical Illusions: At the macroeconomic level, Krugman cautions that productivity measurements can be misleading and must always be interpreted within their broader context. For example, in his analyses of European and Italian economic developments, he has argued that apparent declines in productivity may sometimes conceal measurement problems or reflect labour-market rigidities and distortions.

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Figure 7 – *Paul Krugman*

How Productivity Is Measured

10. How many types of productivity are there?

In economic science, productivity is traditionally measured at two levels: **partial productivity**, which measures the productivity of a single production factor, and **multifactor productivity**, which measures the joint productivity of several factors.

More specifically, partial productivity measures the efficiency with which a single input is utilized relative to total output. The principal categories are:

1. **Labour productivity**: the most widely used productivity measure, calculated as output per hour worked or per worker. It is generally regarded as a key indicator of a nation's standard of living.

2. **Capital productivity**: measures how effectively physical capital (machinery, equipment, buildings, etc.) is used to generate a given level of output.

3. **Raw material productivity**: measures the relationship between production and the quantity of raw materials or natural resources consumed in the production process.

Multifactor productivity, also known as Total Factor Productivity (TFP), measures the efficiency of combined inputs—typically labour and capital—in producing a given level of output. In economics, it is often referred to as the **"**Residual**"**, because it captures that portion of growth which cannot be explained simply by adding more workers or more machines to the production process. This residual component incorporates factors such as technological innovation, organizational improvements, and more effective management practices. Some advanced productivity measures, such as the KLEMS framework, include five categories of inputs: Capital (K), Labour (L), Energy (E), Materials (M), and Services (S).

11. What is marginal productivity?

Marginal productivity is the increase in output obtained by employing one additional unit of a production factor (labour or capital), while holding all other factors constant.

In most production processes, marginal productivity is not constant.

It generally follows three possible patterns:

- Increasing: the first additions of a production factor increase output more than proportionally (for example, through a more efficient division of labour).
- Decreasing: beyond a certain threshold, each additional unit generates progressively smaller increases in output (for example, workers begin to interfere with one another or physical space becomes constrained).
- Negative: beyond a certain point, the addition of a further unit of a factor actually reduces total output.

The concept of marginal productivity, and particularly its assumed behaviour, was subject to substantial criticism by the Italian economist Piero Sraffa. In his early essays, such as *On the Relations Between Cost and Quantity Produced* (1925) and *The Laws of Returns Under Competitive Conditions* (1926), Sraffa sharply criticized the neoclassical theory previously developed by Alfred Marshall. He argued that Marshall's assumption of diminishing productivity as output expands is logically inconsistent in most real-world markets, because cost variations experienced by a single firm influence the wider economy in asymmetric ways.

In his principal work, *Production of Commodities by Means of Commodities* (1960), Sraffa abandoned the subjective approach of marginalism and adopted the objective framework of the classical economists, particularly David Ricardo and Karl Marx.

Sraffa's treatment of productivity rests upon several key concepts:

- Rejection of marginal productivity: Sraffa rejected the notion that the remuneration of productive factors (wages and profits) depends on their physical contribution to production (marginal productivity).

Instead, he argued that the distribution of the economic surplus among social groups depends on their relative bargaining power.

- Changes in production methods: the third part of the book is devoted to transformations in production techniques. Sraffa examines how the adoption of new methods that are more productive than previous ones alters both the structure of prices and the distribution of income.
- The surplus: production is not viewed as an isolated operation but rather as a circular process in which output exceeds the means employed. Increased productivity generates this **surplus**, and the distribution of that surplus determines profits and wages.

12. What is the Production Possibility Frontier (PPF)?

The Production Possibility Frontier (PPF) is a graphical model of economic theory developed by the Austrian economist Gottfried von Haberler of Harvard University. It illustrates the maximum combinations of two goods that an economy can produce by fully and efficiently utilizing all available resources and technology. The PPF visually represents the concepts of scarcity, efficiency (productivity), and opportunity cost.

The curve is concave because of specialization in the production of goods and services. Workers are not equally skilled at producing food or clothing. The more an economy specializes in producing one good, the more it must employ workers who are less suited to that activity, thereby sacrificing increasingly larger quantities of the alternative good.

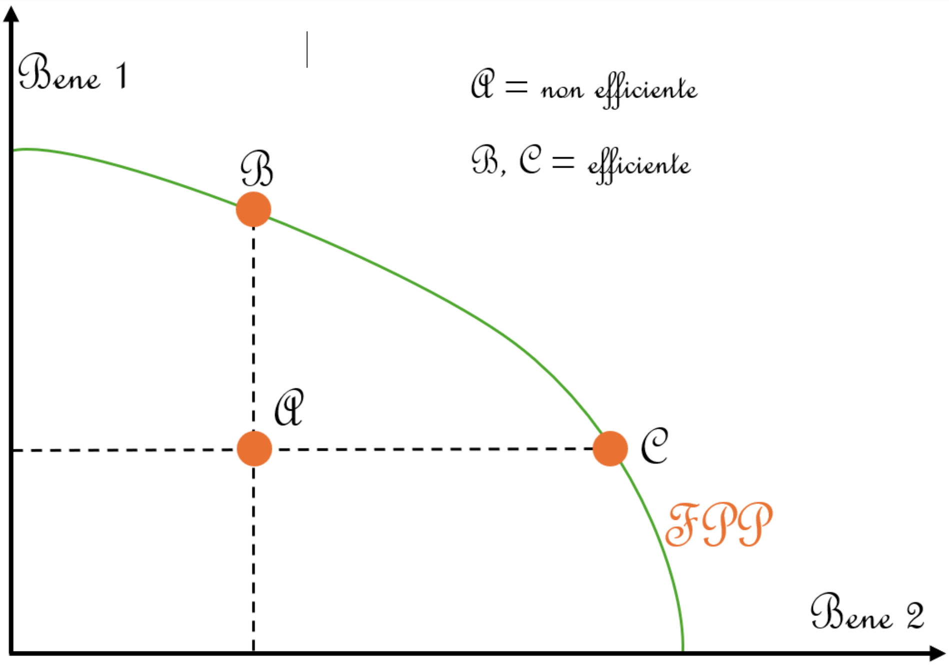

Diagram 2 – *Production Possibility Frontier (FPP)*

13. Why does the PPF depend on productivity?

The frontier is not static. If an economy experiences significant technological progress or an increase in available resources (more capital or more workers), the entire curve shifts outward, making previously unattainable production combinations achievable.

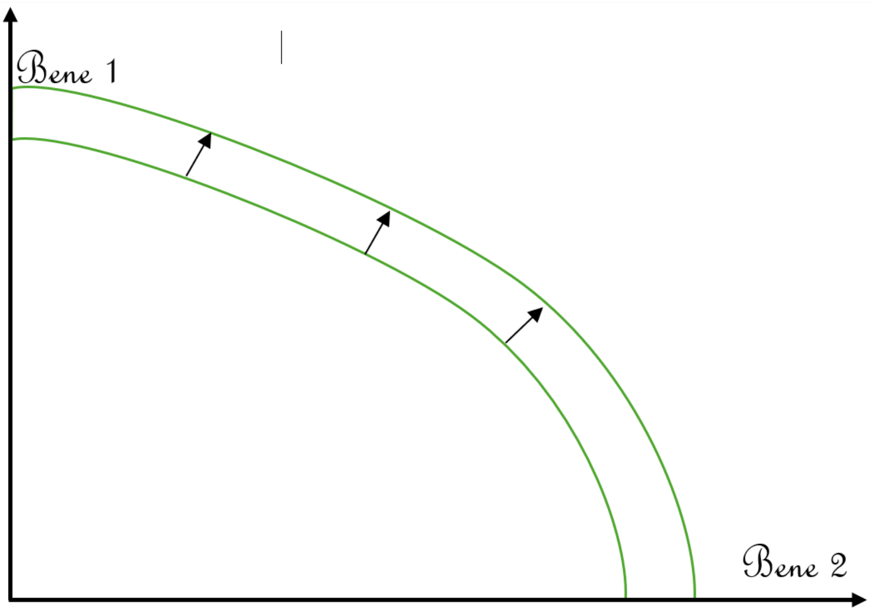

Diagram 3 – *Outward shift of the Production Possibility Frontier (PPF) induced by technological progress*

14. How is productivity calculated?

Productivity is always measured as a ratio, specifically between the outputs and inputs involved in the production of goods and services, whether at the individual or aggregate level. Output may be measured either in physical terms or in monetary terms, depending on the purpose of the analysis.

- **Physical Terms (Physical Productivity):** measures the physical quantity of goods or services produced (e.g., units produced, tonnes, litres, customers served) relative to the input used. This measure is particularly suitable for assessing the technical efficiency of a specific department or firm producing homogeneous goods.
- **Monetary Terms (Economic or Value Productivity):** measures the economic value of output (e.g., turnover, value added, GDP) relative to the input employed. This approach is necessary when analysing firms that produce heterogeneous products or when conducting macroeconomic analysis (e.g., value added per hour worked).

For example, the Italian National Institute of Statistics (ISTAT) measures productivity as the ratio between value added in volume terms and one or more productive factors employed in generating that value. On the basis of this definition, several productivity measures can be calculated, including labour productivity, capital productivity, and total productivity, the latter being measured as the relationship between value added and the combined use of labour and capital services.

15. How is labour productivity calculated?

Labour productivity, as noted above, is a partial measure of productivity. It indicates how much output is produced for each unit of labour employed. At the macroeconomic level, labour productivity is calculated as the ratio between total output (GDP) and labour input, typically measured by total hours worked. At the microeconomic level, particularly within firms, a commonly used proxy is **revenue per employee**.

16. How is capital productivity calculated?

Capital productivity is likewise a partial productivity measure. It evaluates the efficiency with which physical assets—such as machinery, equipment, and industrial plants—are utilized. At the macroeconomic level, it is calculated as the ratio between total output and the amount of capital input employed. Capital input is frequently measured as the **flow of services** generated by the capital stock, rather than by the monetary value of the equipment itself.

17. How is Total Factor Productivity calculated?

Total Factor Productivity (TFP), also known as Multifactor Productivity, captures the growth in output that cannot be explained solely by increases in labour or capital inputs. It is therefore calculated as a residual. TFP is typically estimated through growth accounting, often based on a Cobb–Douglas production function, where it appears as the well-known Solow residual.

The Austrian economist Friedrich A. Hayek provided an important framework for understanding why Total Factor Productivity can differ dramatically across economies and economic systems. In one of his most influential works, *The Use of Knowledge in Society* (1945), Hayek argued that the central economic problem facing policymakers is not how to allocate given resources—a task traditionally associated with central planning—but rather how to make effective use of information that is dispersed throughout society and not fully known by any single individual.

According to Hayek, the market mechanism enables prices to function as an extraordinary decentralized communication and signalling system through which dispersed knowledge and the preferences of millions of individuals can be transmitted almost instantaneously. Since the Total Factor Productivity of an economy depends fundamentally on its capacity to harness the intelligence, creativity, and innovative potential of workers and entrepreneurs, decentralized market economies inherently encourage continuous problem-solving at the microeconomic level and foster innovation, thereby increasing TFP.

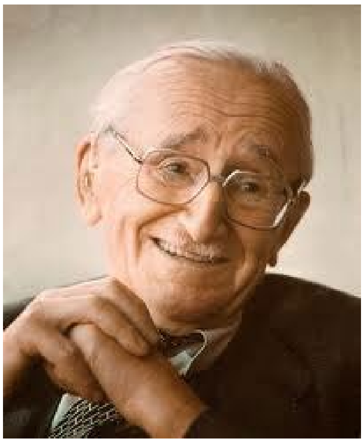

Figure 8 – *Friedrich A. von Hayek*

Reliability in the Measurement of Productivity

18. Are productivity measurement systems truly reliable?

This is one of the questions most frequently raised in economic science and one of the most difficult to answer definitively. In general terms, economists consider the most commonly used productivity measures sufficiently reliable for monitoring long-term trends. However, because productivity measurement systems rely on proxies and approximations, they often fail to capture the full complexity of modern work. The degree of approximation varies according to the object being observed.

1. **Labour Productivity**. Economists generally regard labour productivity measures as reliable when work is performed within production processes—such as manufacturing—where output is largely physical and directly observable. They are considered less reliable in knowledge-based activities, where the traditional unit of measurement, namely hours worked, is often regarded as a poor indicator of the value actually created. In these contexts, intellectual contributions, creativity, problem-solving capacity, and innovation may generate substantial economic value without corresponding directly to the amount of time spent working.
2. **Total Factor Productivity (TFP).** Total Factor Productivity is often referred to by economists as "the measure of our ignorance". This expression reflects the fact that TFP is calculated as a residual after labour productivity and capital productivity have already been estimated. Consequently, any errors in the measurement of labour or capital inevitably flow into the estimate of TFP itself, making it particularly sensitive to measurement inaccuracies and therefore subject to a significant degree of uncertainty.

19. What are the main sources of uncertainty in productivity measurement?

Several factors contribute to uncertainty in the measurement of productivity.

1. **Defining Output in the Service Sector.** In many service industries, particularly financial services and healthcare, the principal challenge lies in defining what output actually is. The use of proxies—such as the number of insurance policies sold or the number of patients treated—often fails to capture improvements in the quality of services provided. For example, a medical procedure that achieves better clinical outcomes or is performed more efficiently may represent a productivity improvement even if it generates lower revenues.
2. **The Digital Economy Productivity Paradox.** Traditional productivity measures generally do not account for the existence of free digital goods and services, such as Wikipedia or Google Maps, for which users pay no explicit price. These services undoubtedly generate substantial economic and social value, yet that value is largely absent from Gross Domestic Product (GDP) statistics. This omission contributes to what economists often call the "digital productivity paradox." While there is little doubt that digital technologies have dramatically improved efficiency in many areas of economic activity, conventional measurement systems often fail to capture these gains adequately.
3. **Difficulties in Valuing Capital.** The value of physical capital is often difficult to determine precisely because of differing depreciation rates and the challenges associated with measuring intangible assets such as software, intellectual property, brands, and organizational capital.

As service-based and technology-intensive sectors frequently elude traditional volume-based measures (such as the number of units produced), alternative approaches have been developed to assess the real value created.

Some examples are presented below.

1. Healthcare: From Quantity to Quality of Outcomes

Within the healthcare sector, measuring productivity solely on the basis of the number of patients treated may encourage a reduction in the quality of care. To address this risk, healthcare economists increasingly rely on **quality-adjusted measures**.

- **QALY and PALY.** The Quality-Adjusted Life Year (QALY) is a metric that evaluates the effectiveness of a treatment not only in terms of survival but also in terms of the quality of life gained by a patient. The more recent Productivity-Adjusted Life Year (PALY) estimates the number of productive working years restored to a patient as a result of medical treatment.
- **Risk Adjustment.** Organizations such as the National Health Service (NHS) weigh activities—for example, surgical procedures—according to their complexity and clinical outcomes. This approach prevents a hospital from appearing more productive merely because it performs a large number of relatively simple procedures.

2. The Technology Sector: From Lines of Code to Software Impact

Measuring programmer productivity solely on the basis of hours worked or lines of code written is now widely regarded as misleading. Leading technology companies increasingly rely on more sophisticated measurement frameworks.

- **DORA Metrics.** Developed within the software engineering community and popularized through research associated with Google, DORA metrics focus on software delivery performance through four key indicators: deployment frequency, lead time for changes, change failure rate, and mean time to restore service. These indicators emphasize speed, reliability, and operational effectiveness rather than raw coding output.
- **The SPACE Framework.** Major technology firms such as Microsoft and GitHub have adopted the SPACE Framework, which combines quantitative indicators (such as the number of pull requests completed) with qualitative dimensions, including developer well-being, collaboration quality, and organizational effectiveness.
- **Real-Time Monitoring Systems.** In advanced manufacturing environments, newly developed tools such as Pico MES (a cloud-based Manufacturing Execution System) integrate operational data

directly into production workflows. These systems reduce errors associated with manual data entry and continuously monitor indicators such as First Pass Yield, namely the percentage of products correctly manufactured without requiring rework.

3. Financial Services: Sector-Specific Output Proxies

Because the revenues of financial institutions fluctuate significantly with market conditions, traditional revenue-based productivity measures may provide a distorted picture of actual performance. For this reason, more specialized output indicators have been developed.

- **Banking.** Productivity is often measured through the ratio of new loans originated per employee; or new deposits acquired per employee.
- **Insurance.** In the insurance industry, productivity is frequently measured through the ratio between sales commissions generated and the number of employees or agents involved in the sales process.

These alternative measures seek to capture operational performance more accurately than traditional revenue-based indicators, which may be heavily influenced by factors external to the productive activities of the institution.

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