What is wealth and how to measure it?

The 250th anniversary of the publication of *The Wealth of Nations*

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Introduction

The year 2026 celebrates 250th anniversary of the publication of Adam Smithi's *The Wealth of Nations*. This article positions his concept of *wealth* within the unified classical approach (Itaki 2026) and attempts to reorient modern economics. The dual equation deployed in the long-term dynamic continuum plays the key role in our approach.

"What is wealth and how to measure it?" has been an old and new question since the classical political economy refuted Mercantilism which sought wealth in gold and silver. Then, "Economic analysis, serving for two centuries to win an understanding of the Nature and Causes of the Wealth of Nations, has been fobbed off with another bride - a Theory of Value" (Robinson 1956, p. xxxi). In modern macroeconomics since Keynes (1936) wealth is almost equivalent to national income or GDP. Their absolute magnitude per capita is used as one of the most important indicators of the standard of living across time and space, if measured in terms of purchasing power parity (PPP). It is interesting to note that capital gains in monetary terms we realize in portfolio investment markets does not constitute GDP, while in modern parlance they do constitute a substantial part of "wealth" for wealthy people. The official statistical definition of GDP inherits the classical tradition of Adam Smith [1776] who fought against the monetary fallacy of Mercantilism.

Smith himself comprehended wealth in a peculiar manner, which is concisely summarized in the very first sentence of *The Wealth of Nations*:

> The annual labour of every nation is the fund which originally supplies it with all the necessaries and conveniencies of life which it annually consumes, and which consist always either in the immediate produce of that labour, or in what is purchased with that produce from other nations. (Smith [1776], p. lvii.)
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> Every man is rich or poor according to the degree in which he can afford to enjoy the necessaries, conveniencies, and amusements of human life. But after the division of labour has once thoroughly taken place, … he must be rich or poor according to the quantity of that labour which he can command, or which he can afford to purchase. (Smith [1776], p. 30.)

This succinct statement revealed that wealth comes from labor of ordinary peasants and workers[1].

It should be noted, however, that Smith does not refer to any means of production such as machinery,

[1] See, for example, Hollander (1973) and Samuelson (1977) for neo-classical understanding and Dobb (1973), Pasinetti (1977, ch. I), Christensen (1979), Kurz (1980), Kurz and Salvadori (1995, pp. 1-20), and Harcourt (2006, ch. 7) for modern understanding of Smith and the classical political economy from the non-neoclassical viewpoint.

tools, or raw materials, but only to means of consumption, such as "necessaries, conveniencies, and amusements of human life," as the ultimate embodiment of nations' wealth. In his view, means of production still remain in the intermediate stages of production processes towards final consumption[2]. This observation later gains particular significance when we examine the dual equation between the income distribution and resource allocation and understand that his approach exhibits remarkable precision from the modern economic perspective[3].

We are going to scrutinize the *measurement* problem of wealth as well as its closely related categories, namely, techniques for producing wealth and their productivity in the entire *macroeconomic* context. We further extend the issue and develop a long-term *dynamic measurement model* of wealth, technique, and productivity. This incurs, however, some intrinsic difficulties:

First, the basic constitution of techniques has long been, and still now, analyzed in terms of capital intensity in neo-classical economics and the capital-output ratio in the post-Keynesian economics, though the validity of these concepts was refuted in the Cambridge capital controversy (Sraffa 1960; Harcourt 1972; Kurz and Salvadori 1995; Cohen and Harcourt 2003; Pasinetti 2003; Pasinetti and Scazzieri 2008).

Second, comprehensive measurement of productivity, neither in terms of "capital" nor labor alone, but in its totality poses substantive difficulties on the analysis even in a single production process. Furthermore, precisely measuring productivity in the macroeconomic context seems to be almost incomprehensible even if resorting to total factor productivity (TFP) (Solow 1956, 1957) or statistical index analysis of productivity growth.

Third, in the long-term dynamic continuum of economic evolution, entire engineering techniques and consumption baskets change as well as the profit rate, the real wage rate, the growth rate, and the consumption rate (Pasinetti 1981, 1993). The "dynamics of the wealth of nations" (Pasinetti 1981) requires full transformation of an economy.

We adopt for the analytical purpose and difficulties abovementioned the dual equation between income distribution and resource allocation grounded on the unified classical approach (Itaki, 2026), which consists of the Smithian productivity point (Smith [1776]), the Ricardian old corn-ratio model (Sraffa's introduction to Ricardo 1951), the Marxian exploitation (Marx [1867]), the von Neumannian

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[2] Marx, quoting the same passage in the first excerpt, criticized Smith on the grounds of Smith's confusion of the *value of the annual product* with the *annual value product* (Marx [1885], p. 453). See Itaki (2026, p. 13 footnote 20). As for the second excerpt, it is perceived to reveal another confusion of Smith between labor-commanded value and labor-embodied value (Marx 1965, S. 41-42; [1859], S. 44-45). It is noteworthy, however, that if replacing "every man" with "every worker" would make it a perfect argument, even heralding the Marxian conception of exploitation of workers.

[3] It should be noted that Robinson also pursued "the meaning of wealth" in consumption of goods and services (Robinson 1956, ch. 2), though she lamented that "Economics is the scientific study of wealth, and yet we cannot measure wealth" (Ibid., p. 24), based on conceptualization of purchasing power and expenditure.

duality (von Neumann [1937]), and Sraffian value of capital (Sraffa 1960).

The structure of the article is as follows: first, we rule out Keynesian categories of wealth, i.e., national income and GDP per capita; second, we summarize the dual equation grounded on the unified classical approach; third, the macrodynamic measurement of wealth, technique, and productivity is scrutinized; and poverty and impoverishment, the opposite concepts to wealth and enrichment, are examined. The literature review for each analytical topic will be provided where it is convenient for readers.

1. National income: indecisive measure of wealth

We first examine and rule out the Keynesian categories of wealth, i.e., national income and GDP per capita, for the purpose of measuring wealth, which is rooted in the Cambridge capital controversy.

We define y as the value of income and k as the value of production capital per unit of labor, respectively:

$$y = \boldsymbol{p}(\boldsymbol{I} - \boldsymbol{A})\boldsymbol{q} \tag{1}$$

$$k = \boldsymbol{pAq}, \tag{2}$$

in which

$\boldsymbol{p}$: a row vector $(1 \times n)$ of prices,

$\boldsymbol{q}$: a column vector $(n \times 1)$ of outputs per unit of labor,

$\boldsymbol{A}$: a square matrix $(n \times n)$ of material and service inputs per unit of output, and

$\boldsymbol{I}$: an identity matrix $(n \times n)$.

These two equations assume that y and k are generated within input-output circular reproduction processes[4]. This approach traces its roots back to French and British classical economists, such as Quesnay [1759] and Smith [1776], inherited by Marx [1885] and further developed by von Neumann [1937], Leontief (1951) and Sraffa (1960). Hence, we can avoid the criticism of the controversy that the value of k is exogenously given like a lump of homogeneous clay.

We acquire the following two equations (see Appendix)[5]:

$$y = g(k + c) + c \tag{3}$$

$$y = r(k + w) + w \tag{4}$$

in which

r: the uniform profit rate across sectors (scalar)

w: the real wage rate (scalar) paid ante factum for a unit of labor, measured in terms of

[4] See Kurz and Salvadori (1995, ch. 13).

[5] We assume wages paid ante factum. Given, otherwise, wages paid post factum, the following equations change into $y = gk + c$ and $y = kr + w$. See Kurz and Salvadori (1995, p. 114) and Schefold (1980). The former depicts, given the going rates of profit and growth, the straight lines and the simple concave curve in Figure 4.2 on p.115 in sharp contrast with Figure 1 below.

numéraire

g: the uniform growth rate of output across sectors (scalar), and

c: the real consumption rate (scalar) per unit of labor, measured in terms of numéraire.

Therefore, the Keynesian fundamental identity is derived:

$$y = r(k + w) + w = g(k + c) + c \tag{5}$$

It is the dual equation à la Keynes between income distribution and resource allocation, akin to our dual equation à la von Neumann, in which $r(k + w)$ and $g(k + c)$ denote profits and investment per unit of labor, respectively.

Due to $w < c,\ g < r$, which is the *Keynesian symmetry breaking*.

This does not signify the discrepancy between income distribution and resource allocation and thus, does not need the system transformer between them, since they are both measured in terms of the same price numéraire.

Rearranging it for *k* we acquire:

$$k = \frac{(1 + g)c - (1 + r)w}{r - g} \tag{6}$$

Substituting it for *y*, we acquire:

$$y = \frac{(rc - gw) + gr(c - w)}{r - g} \tag{7}$$

which is positive unless $r = g$, regardless of $r < g$ or $g < r$.

Hence, the values of *k* and *y* fluctuate complicatedly according to different combinations of *r* and *w*, and *g* and *c* even under fixed technique. Although the Keynesian fundamental identity does hold, income *y* changes unpredictably due to similarly unpredictable changes in the value of capital *k*. In other words, it falls prey to the criticism raised in the Cambridge capital controversy: logical circularity, in which the determination of *k* and *y* necessitates predetermination of *r* or *w*, and *g* or *c*, and *vice versa*.

Furthermore, it is noteworthy that different compositions of investment goods and services incur different compositions of industrial sectors, resulting in changes in *g* and *c* and consequently, in *r* and *w*.

We conclude that the dual equation à la Keynes remains indeterminate unless in a very short term in which a set of variables *r*, *w*, *g*, and *c*, as well as investment components can be assumed to be constant for a while. Hence, aggregate income or GDP per capita is not suitable for the purpose of measuring and comparing wealth in the long term.

2. Summary of the dual equation grounded on the unified classical approach

We briefly summarize the structure of the dual equation à la von Neumann for the following argument of the measurement problem. See, if necessary, von Neumann [1937] and Itaki (2026) for

detailed explanations of the modified and/or simplified assumptions we adopt here.

It should be emphasized that aligning with von Neumann, classical economists, and Marx we assume that wages are paid *ante factum* at the beginning of each production period; and that we adopt a minimum subsistence basket of consumption goods and services as the price numéraire, encompassing those that are physiologically and socially necessary for reproducing one unit of labor force exhausted in a single production period. We soon see that the basket serves as the standard unit of both prices and quantities in the dual equation.

The price and quantity systems of a single degree of freedom can be described by the following equations:

$$\boldsymbol{p} = R(\boldsymbol{pA} + w\boldsymbol{l}), \tag{8}$$

$$\boldsymbol{pb} = 1, \tag{9}$$

$$\boldsymbol{q} = G(\boldsymbol{Aq} + c\boldsymbol{b}), \tag{10}$$

$$\boldsymbol{lq} = 1, \tag{11}$$

in which

$\boldsymbol{b}$: a column vector $(n \times 1)$ of a set of consumption goods and services, chosen as the numéraire for measuring wage rates and consumption rates,

$\boldsymbol{l}$: a row vector $(1 \times n)$ of direct labor inputs per unit of output,

R: 1 + profit rate r, and

G: 1 + growth rate g.

From these equations, we can derive the following equations for income distribution between wages and profits and resource allocation between consumption and growth when matrix $\boldsymbol{A}$ is indecomposable and non-negative:

$$Rw = \frac{1}{\boldsymbol{l}(\boldsymbol{I} - R\boldsymbol{A})^{-1}\boldsymbol{b}} \text{ and} \tag{12}$$

$$Gc = \frac{1}{\boldsymbol{l}(\boldsymbol{I} - G\boldsymbol{A})^{-1}\boldsymbol{b}}, \tag{13}$$

in which $w < c$, $G < R$, i.e., the *symmetry breaking* (Itaki 2026, pp. 14-15.) takes place in sharp contrast to the von Neumannian perfect symmetry, i.e., $w = c$ and $G = R$.

Given the total output vector $\boldsymbol{Q}$ $(n \times 1)$, the total labor force E (scalar) is

$$E = \boldsymbol{lQ}.$$

We then collect the outputs of consumer goods and services from all sectors and construct the column vector $\boldsymbol{Q_c}$ $(n \times 1)$. Then, we acquire

$$\boldsymbol{Q_c} = GEc\boldsymbol{b},$$

$$\boldsymbol{q_c} = Gc\boldsymbol{b}.$$

Since $\boldsymbol{q_c}$ is a product of a scalar multiple q_c and $\boldsymbol{b}$, we have

$$q_c\boldsymbol{b} = Gc\boldsymbol{b},$$
$$q_c = Gc. \tag{14}$$

From equations (12), (13), and (14), we obtain the *dual equation* that serves as the bridge between the quantity system and the price system:

$$\frac{1}{\boldsymbol{l}(\boldsymbol{I}-\boldsymbol{A})^{-1}\boldsymbol{b}} \geq q_c = Gc = Rw\frac{\boldsymbol{l}(\boldsymbol{I}-R\boldsymbol{A})^{-1}\boldsymbol{b}}{\boldsymbol{l}(\boldsymbol{I}-G\boldsymbol{A})^{-1}\boldsymbol{b}}, \tag{15}$$

in which the scalar ratio $\boldsymbol{l}(\boldsymbol{I}-R\boldsymbol{A})^{-1}\boldsymbol{b}/\boldsymbol{l}(\boldsymbol{I}-G\boldsymbol{A})^{-1}\boldsymbol{b}$ functions as the *system transformer* from the price system to the quantity system and q_c is what we refer to as the *net economic resource* representing the volume of means of consumption produced per unit of labor at G and R.

The dual equation can be expressed as follows:

$$\frac{1}{\boldsymbol{l}(\boldsymbol{I}-\boldsymbol{A})^{-1}\boldsymbol{b}} \geq q_c = c + gc = (w+rw)\frac{\boldsymbol{l}[\boldsymbol{I}-(1+r)\boldsymbol{A}]^{-1}\boldsymbol{b}}{\boldsymbol{l}[\boldsymbol{I}-(1+g)\boldsymbol{A}]^{-1}\boldsymbol{b}}, \tag{16}$$

It depicts an economic system in which q_c units of the consumption basket, produced per unit of direct labor, are entirely distributed between wages w and profits rw and allocated between consumption c and growth gc, as if intermediate inputs of means of production are absent. This resembles a primitive economic society, where people rely solely on manual food-gathering without the aid of tools or machinery. This is what we refer to as the "nutshell economy."

Fig. 1: The duality between the *R-w* and *G-c* frontiers when $w < c$

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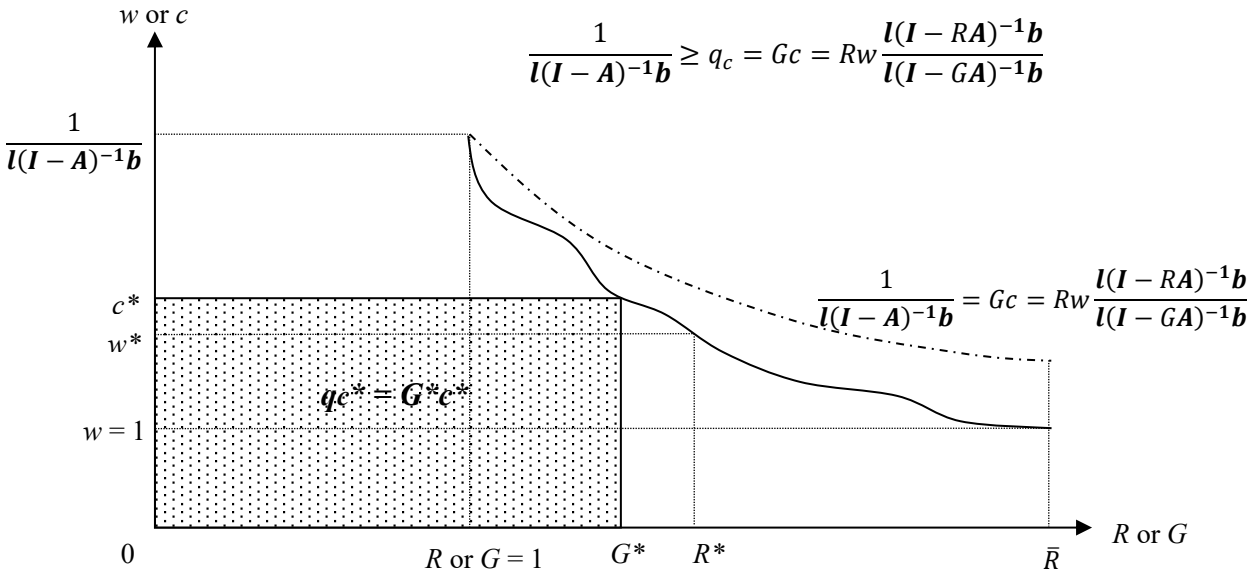
The dual equation

$$w = \frac{1}{R\boldsymbol{l}(\boldsymbol{I}-R\boldsymbol{A})^{-1}\boldsymbol{b}} \quad \text{or} \quad c = \frac{1}{G\boldsymbol{l}(\boldsymbol{I}-G\boldsymbol{A})^{-1}\boldsymbol{b}}$$



3. Macrodynamic measurement of wealth, technique, and productivity

We define and measure wealth, technique, and productivity in the macrodynamic framework grounded on the dual equation. The "nutshell economy," encapsulated in the dual equation, is derived from the multi-sector input-output economic system, without being exogenously given any supplementary conditions, and thus, they are equivalent to each other. This signifies that wealth, technique, and productivity which constitute the original system are uniquely represented by those transformed in the "nutshell economy." This is the basic premise on which their measurement problem is approached.

Wealth

L. Robbins stated that "wealth is not wealth because of its substantial qualities. It is wealth because it is scarce" (Robbins 1932, p. 47.). Built on the marginalist revolution in the 1870s by Menger, Jevons, and Walras, Robins brought forefront scarcity and utility as the substance of "wealth," in other words the subjective perception of the concept. It was in fact a declaration of abandoning quantitative measurement of the wealth of nations since comparison and aggregation of individual utilities is unconceivable in nature. We agree with J. B. Clark, in this respect, who stated that "The entire study of wealth is, indeed, meaningless unless there be a unit for measuring it; for the questions to be

answered are quantitative. How great is the wealth of a nation? Such inquiries demand that the thing which is studied shall be measured in units of some kind and that the result shall be stated as an absolute amount." (Clark 1899, p. 375).

We adopt, responding to Clark's request, Smith's objective definition of wealth[6]: i.e., "the necessaries, conveniencies, and amusements of human life." Engels, implicitly referring to Smith, precisely distinguished between wealth and natural resources: "Labour is the source of all wealth, the political economists assert. And it really is the source – next to nature, which supplies it with the material that it converts into wealth" (Engels [1873-83], p. 172.). He aligned with Marx: "the two primary creator of wealth, labour-power and land" (Marx [1867], p. 752), who specified wealth in the historical context: "The wealth of societies in which the capitalist mode of production prevails appears as an 'immense collection of commodities'" in the very first sentence of *Das Kapital* (Marx [1867], p. 125).

The first category of wealth so defined consists of goods and services that make our life enjoyable, the former of which are further divided into durable goods and non-durable goods; they are categorized as personal goods and services consumed in each household. The second category of wealth is collectively consumed ones, such as parks and government services. They necessitate the initial development outlays and recurring operational costs for their long-term maintenance. The source of wealth next to labor is natural environments, such as land, water, and air, which include mineral, floral, and faunal resources. If they are actually or assumed to be abundantly available, they become free goods with no economic value. If, otherwise, their ownership is privatized and monopolized, they turn out to be a pecuniary source of wealth and produce rent. This is the case even for beautiful scenery in tourism. Hence, we understand wealth as periodic *flow* of "the necessaries, conveniencies, and amusements of human life" in the form of goods and services enjoyed in consumption personally or collectively[7].

Numéraire $\boldsymbol{b}$ embodies wealth consumed personally, i.e., a minimum subsistence basket of "necessaries, conveniencies, and amusements" which are physiologically and socially necessary for reproducing one unit of labor force. Our "nutshell economy" built of numéraire $\boldsymbol{b}$ is a miniaturized economy which produces, distributes, and allocate the wealth so defined.

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[6] See Heilbroner (2008).

[7] UN Environment Programme (2023), by contrast, recommends the stock conception of *inclusive wealth*, which consists of produced capital (e.g., buildings, machinery, and infrastructure), human capital (e.g., education, skills, experience, and health), and natural capital (e.g., forests, land, water, minerals, biodiversity, and ecosystems). They measure each asset category and sum up the total value of inclusive wealth by means of shadow prices. High-Level Expert Group on Beyond GDP (2026) of UN proposes a dashboard of 31 indicators structured around four components: foundational principles — peace, human rights, and respect for the planet; current well-being; equity and inclusion; and sustainability and resilience. They are measured by key forms of capital: produced, human, social, institutional, and natural.

Understanding wealth as a bunch of "necessaries, conveniencies, and amusements" is one thing, but identifying their minimum basket $\boldsymbol{b}$ is another, which is for sure an empirical and statistical challenge for researchers. Despite these difficulties, they have devised measurement techniques such as the "poverty level" or "poverty threshold" in the US Census, the "basic human needs" (ILO 1976; Streeton, et al. 1981; World Bank 1980), and the "welfare ratio" among cliometricians (Allen 2001; Bassino and Ma 2005; and Allen et al. 2011)

Wealth stands for material and human resources for our well-being or means of well-being[8]. It is personally realized in households through consumption of $c\boldsymbol{b}$ per unit of labor. It should be noted that $c\boldsymbol{b}$ includes those goods and services consumed in different amounts by capitalists, rentiers, bureaucrats, and other individuals in addition to workers (Pasinetti 1977, chap. VII, Itaki 2026, p. 8.). They are necessary for the maintenance and reproduction of society and social relations among classes[9].

In summary, the measurement unit of wealth personally consumed is $\boldsymbol{b}$ and its magnitude in terms of $\boldsymbol{b}$ is c at a specific point in time. Wealth $c\boldsymbol{b}$ can be also measured in terms of labor, i.e., $c\boldsymbol{l}(\boldsymbol{I}-\boldsymbol{A})^{-1}\boldsymbol{b}$[10]. According to the theorem of parallel traverse (Itaki 2026, pp. 15-18), the magnitude of wealth, i.e., c, decreases as the growth rate g and the profit rate r increase in parallel and vice versa. Furthermore, it disproportionately shrinks as g and r expand and vice versa, according to the theorem of discrepancy and the burden of growth and profits (Itaki 2026, pp. 14-15).

As for wealth collectively consumed, when we assign $\bar{\boldsymbol{c}}$ as the column vector of collectively consumed goods and services per unit of labor, which may include compensation for the damage incurred by human activities on natural environments, we have an extended dual equation:

$$\frac{1}{\boldsymbol{l}(\boldsymbol{I}-\boldsymbol{A})^{-1}\boldsymbol{b}}-\frac{\boldsymbol{l}(\boldsymbol{I}-\boldsymbol{A})^{-1}\bar{\boldsymbol{c}}}{\boldsymbol{l}(\boldsymbol{I}-\boldsymbol{A})^{-1}\boldsymbol{b}}\geq q_c=Gc=\frac{1}{\boldsymbol{l}(\boldsymbol{I}-G\boldsymbol{A})^{-1}\boldsymbol{b}}-\frac{\boldsymbol{l}(\boldsymbol{I}-G\boldsymbol{A})^{-1}\bar{\boldsymbol{c}}}{\boldsymbol{l}(\boldsymbol{I}-G\boldsymbol{A})^{-1}\boldsymbol{b}}$$
$$=Rw\frac{\boldsymbol{l}(\boldsymbol{I}-R\boldsymbol{A})^{-1}\boldsymbol{b}}{\boldsymbol{l}(\boldsymbol{I}-G\boldsymbol{A})^{-1}\boldsymbol{b}}-\frac{\boldsymbol{l}(\boldsymbol{I}-G\boldsymbol{A})^{-1}\bar{\boldsymbol{c}}}{\boldsymbol{l}(\boldsymbol{I}-G\boldsymbol{A})^{-1}\boldsymbol{b}} \tag{17}$$

The maximum q_c decreases by $\bar{\boldsymbol{c}}$ converted to $\boldsymbol{b}$ in terms of labor units, and Gc and Rw decrease by $\boldsymbol{l}(\boldsymbol{I}-G\boldsymbol{A})^{-1}\bar{\boldsymbol{c}}/\boldsymbol{l}(\boldsymbol{I}-G\boldsymbol{A})^{-1}\boldsymbol{b}$. Collective consumption of wealth is a subtraction of net economic resource from society with a downward effect on both income distribution and resource allocation.

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[8] We prefer using "well-being" instead of "welfare" in welfare economics, since the latter has been theorized inseparably with the subjective concept of "utility," which is intrinsically immeasurable and not comparable among individuals. To formulate the social utility function necessitates to assume illusionary existence of the "representative agent" with no distinction among social classes.

[9] Capitalists' and other non-productive classes' consumption vector, if separated and denoted as $\boldsymbol{c}_c$, characterized by distinct volume, content, and proportion of its components can be converted into units of $\boldsymbol{b}$ at G as follows (see Itaki 2026, p. 10):

$$\frac{\boldsymbol{l}(\boldsymbol{I}-G\boldsymbol{A})^{-1}\boldsymbol{c}_c}{\boldsymbol{l}(\boldsymbol{I}-G\boldsymbol{A})^{-1}\boldsymbol{b}}.$$

[10] Ricardo [1817, ch. XX] discusses in detail on "Ricardo's paradox": technical evolution may result in a decrease in magnitude of wealth in terms of total labor even if c increases.

Hereafter, we abstract from it and concentrate our analysis on personally consumed wealth.

In dynamics, we can reasonably assume the relative stability of the measurement unit of wealth, i.e., $\boldsymbol{b}$, in terms of its content, proportion, and volume over a specified period, as long as social norms and institutions remain unchanged. Despite its stability, it is indisputable that, however gradually and slowly, it does change and changes drastically as time passes[11]. Nevertheless, it never changes its economic function, being the basis of reproducing precisely one unit of labor force with varying real wage rates and consumption rates in each historical period. In other words, it retains continuity and consistency through history and over locations as the identical entity with differing physical and human contents and proportions. In this exact sense, our measurement unit of wealth is perceived to be an "invariable standard of value" in a different context from that of Ricardo [1817, Chapter I Section VI] and Sraffa's introduction to Ricardo (1951, pp. xl-xlix), thanks to, rather than despite, its ever-changing nature[12]. The changing and different contents reflect people's distinct needs and desires and include new items that may stem from technological, medical, cultural, and educational progress. We can observe the evolution of society in terms of transforming character of the numéraire.

Transition from $\boldsymbol{b}$ to $\boldsymbol{b}^*$ over time in its content, proportion, and volume represents qualitative transformation of wealth in sharp contrast to quantitative change from c to c^*. It should be noted that the transition from $\boldsymbol{b}$ to $\boldsymbol{b}^*$ does not necessarily mean *development* in a positive unilateral direction, but rather neutral *evolution*, since it might signify the necessity of extra expenditure on air conditioning due to global warming or demand for psychic counseling due to stressful modern lifestyles. Furthermore, in historical comparison, $\boldsymbol{b}$ and $\boldsymbol{b}^*$ are usually different in the number of items contained: new goods and services have been added to, and obsolescent goods and services have been removed from, the basket for more convenient and enjoyable life.

When $\boldsymbol{b}$ changes to $\boldsymbol{b}^*$ and c changes to c^*, we ought to resort to a different measurement unit of wealth in terms of labor. The total (direct and indirect) labor embodied in $c\boldsymbol{b}$ is $c\boldsymbol{l}(\boldsymbol{I}-\boldsymbol{A})^{-1}\boldsymbol{b}$; and that in $c^*\boldsymbol{b}^*$ is $c^*\boldsymbol{l}^*(\boldsymbol{I}-\boldsymbol{A}^*)^{-1}\boldsymbol{b}^*$, in which $\boldsymbol{A}^*$ and $\boldsymbol{l}^*$ are the new material input matrix and direct

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[11] See Robinson's telling critique against fixed $\boldsymbol{b}$, "we could hardly imagine that, when the workers had a surplus to spend on beef, their physical need for wheat was unchanged" (Robinson, 1961, p. 54). She remarked in referring to Sraffa (1960, p. 9). See also Kurz and Salvadori (1995, p. 120) for similar criticism.

[12] Concerning his "dynamic standard commodity," Pasinetti wrote that "such a commodity appears to be a sort of physical *dynamic* counterpart of Ricardo's 'invariable standard of value.' I shall therefore call it the 'dynamic standard commodity.'" (Pasinetti 1981, p. 105, original italic) His "dynamic standard commodity" is also a measurement unit that changes over time, and by changing it plays the role of the "invariable standard of value." Pasinetti added, however, that "This is a point not always entirely understood. It may sound strange at first to talk of a moving 'unit of measurement,' but this is precisely what happens in a monetary production economy" (Pasinetti 2007, p. 289 note) and that "This (composite) commodity turns out to be the dynamic counterpart of Sraffa's 'standard' commodity and, jointly with it, gives a complete solution to Ricardo's idea of an 'invariable standard of value.'" (Pasinetti 2007, p. 291 note) See also Pasinetti (1981, pp. 104-106) and (1993, pp. 70-72). As for a criticism against Ricardo's conception, see Robinson and Eatwell (1973, pp. 22-23).

labor vector, respectively. Hence, qualitative and quantitative transformation from $\boldsymbol{b}$ to $\boldsymbol{b}^*$ and quantitative change from c to c^* are altogether translated into a change in the scalar value from $c\boldsymbol{l}(\boldsymbol{I}-\boldsymbol{A})^{-1}\boldsymbol{b}$ to $c^*\boldsymbol{l}^*(\boldsymbol{I}-\boldsymbol{A}^*)^{-1}\boldsymbol{b}^*$.

It is noteworthy, on the one hand, that the order relationship between them, which depends on social and institutional norms regarding the standard of living as well as technical evolution in $\boldsymbol{A}^*$ and $\boldsymbol{l}^*$, does not imply which time or society is richer or poorer. This is *social and historical relativity of wealth*: wealth is specific from economy to economy and from time to time.

On the other hand, it is also noteworthy that $c < c^*$ does indicate that the latter is wealthier than the former, since people enjoy more leeway in consumer life and higher standard of living in the latter situation, in which $\frac{c^*-c}{c}$ denotes the rate of change in wealth per unit of labor despite different baskets of wealth, $\boldsymbol{b}$ and $\boldsymbol{b}^*$. This is *social and historical comparability of the standards of living*, the ground on which cliometricians calculate the "welfare ratio" (Allen 2001; Bassino and Ma 2005; and Allen et al. 2011). If those three categories of wealth include items of education and training, $c < c^*$ can serve as a quantifiable indicator of Amartya Sen's capability approach to development (Sen 1985, 1999, and 2009).

Wealth provides us with material and human resources for our well-being at a specific moment of time. Human well-being consists of two aspects: i.e., well-living and well-working. It is sequentially realized through three steps: first, consuming $c\boldsymbol{b}$ per unit of labor, which contains education and vocational training of workers; second, enhancing "skill, dexterity, and judgement" (Smith [1776], p. lvii), which is embodied in one unit of labor power; and third, exerting enhanced labor power for one unit of labor time and satisfying working desire in the workplace.

Technique

In standard neoclassical economics, according to Mokyr (2008), "technology is regarded as a mapping from inputs to outputs." The isoquant is a summary description of the mapping. His own definition of technology is "the utilization of natural phenomena and regularities for human purposes" and "technology is first and foremost human knowledge," which is categorized into propositional knowledge and prescriptive knowledge[13]. Griliches (1987, p. 1) regards technology as "consisting of both the average set of recipes for doing things, embedded in the current range of equipment and in the training of the existing work-force, and the currently known best way of doing things." In the post-Keynesian tradition, it is understood as "a book of blueprints"[14] in the context of choice of techniques.

[13] See also Mokyr (2002, ch. 1).

[14] This analogy is often attributed to Robinson (1956, ch. 10 "The spectrum of techniques"), for example Harris (2005, p. 91), though no such expression appears in it. It actually appeared in Robinson (1975, p. 34). See Harcourt and Kerr (2013, p. xviii).

Altuzarra (2012) and Courvisanos (2012) survey post-Keynesian understanding of technology and innovation.

While Mokyr regards *technique* as the "fundamental unit of technology," "basically a set of instructions on how to produce, much like a simple recipe" (Mokyr 2008), we make no specific distinction between technology and technique and prefer using *technique* for the present examination.

In summary, technique can be understood as a mapping from inputs to outputs or from engineering means to human purposes. This suggests that technique should be conceptualized as an engineering-cum-social combination of material and human resources; and thus, technique could not be defined or measured without referring to social needs, culture, tradition, and economic evolution of society in which it is embedded. Smith identified human purposes to be acquisition of wealth for well-being, the unit of which is $\boldsymbol{b}$ rather than $\boldsymbol{q}$. Therefore, technique is not, as commonly perceived among engineers and economists, defined as a certain combination of various means of production and labor force, i.e., ($\boldsymbol{A}$, $\boldsymbol{l}$), but rather as their certain engineering combination for producing a specific, socially defined consumption basket, i.e., ($\boldsymbol{A}$, $\boldsymbol{l}$, $\boldsymbol{b}$). It follows that technique ($\boldsymbol{A}$, $\boldsymbol{l}$, $\boldsymbol{b}$) assumes its unique scalar expression, i.e., $\boldsymbol{l(I-A)^{-1}b}$, denoting the sum of direct and indirect labor for producing one unit of numéraire[15].

Given the *R*-*w* frontier and the *G*-*c* frontier in duality, constituted by $\boldsymbol{A}$, $\boldsymbol{l}$, $\boldsymbol{b}$, *R*, *w*, *G*, and *c*, the entire features of an economy are precisely represented by these frontiers' shape and position in the coordinate space. When $G \text{ or } R = 1$, i.e., zero growth rate or zero profit rate, the net economic resource q_c reaches its maximum value $\frac{1}{\boldsymbol{l(I-A)^{-1}b}}$ at what we refer to as the Smithian point (Itaki 2026, p. 18), which is also equal to the maximum values of *c* and *w*. This is exactly where the scalar value of technique ($\boldsymbol{A}$, $\boldsymbol{l}$, $\boldsymbol{b}$) appears in the dual equation. As *G* or *R* increases, q_c, *c*, and *w* monotonically decrease despite no change in technical features of an economy. The downward traverse along the frontiers is caused solely by changes in income distribution and resource allocation.

Provided that the original economic system is transformed into the "nutshell economy," constituted of numéraires, and they are equivalent to each other, ($\boldsymbol{A}$, $\boldsymbol{l}$, $\boldsymbol{b}$) and $\boldsymbol{l(I-A)^{-1}b}$ instead of ($\boldsymbol{A}$, $\boldsymbol{l}$, $\boldsymbol{q}$) and $\boldsymbol{l(I-A)^{-1}q}$ embody the macroeconomic characteristics of technique. Labor units of means of production and direct labor for producing one unit of numéraire are, respectively,

$$\boldsymbol{l(I-A)^{-1}b - lb}$$

and

$$\boldsymbol{lb}.$$

[15] Within the realm of engineering definition of technique, Kurz and Salvadori (1995, ch. 6) identifies three alternative but equivalent descriptions of technique as well as ($\boldsymbol{A}$, $\boldsymbol{l}$): first, dated quantities of labor; second, vertically integrated technical coefficients; and third, price vectors and corresponding wage rates due to the principle of duality between prices and techniques.

Hence, capital intensity is expressed in terms of labor[16] as follows:

$$\frac{\boldsymbol{l(I-A)^{-1}b}}{\boldsymbol{lb}}-1. \tag{18}$$

The argument above does not imply that a vast number of techniques used in heterogeneous industries can be physically integrated or numerically averaged to a single scalar value; instead, we argue that $\boldsymbol{l(I-A)^{-1}b}$ uniquely corresponds to, and thus, measures the whole technical information in a single scalar value equal to the total labor necessary for producing one unit of wealth. The reason why this measurement is justifiable is that the entire economic system is reduced to a simple homogeneous construction made of numéraire, completely abstracting from means of production.

If we attempt to identify technique and its capital intensity in terms of all outputs, i.e., $\boldsymbol{q}$, the technique would be expressed as follows:

$$\boldsymbol{l(I-A)^{-1}q} \tag{19}$$

and its capital intensity as follows:

$$\frac{\boldsymbol{l(I-A)^{-1}q}}{\boldsymbol{lq}}-1,$$

in which $\boldsymbol{lq}=1$, and thus,

$$\boldsymbol{l(I-A)^{-1}q}-1. \tag{20}$$

The volume and composition of $\boldsymbol{q}$ change according to different combinations of *G* and *c*. Hence, even in terms of labor, we cannot measure technique independently from resource allocation. By the same token, if we introduced values, such as $\boldsymbol{pb}$ and $\boldsymbol{pq}$ for the measurement, they would suffer from changes in income distribution as well as resource allocation. Therefore, our definition and measurement of technique, i.e., $\boldsymbol{l(I-A)^{-1}b}$, is immune to changes in either *R*, *w*, *G*, or *c*, and thus, circumvents the criticism raised in the Cambridge capital controversy.

It follows that industrial sector *i*'s technique is as follows:

$$\boldsymbol{l(I-A)^{-1}q_i} \tag{21}$$

in which $\boldsymbol{q_i}$ denotes the *i*-th standard basis vector where its *i*-th component is unity and all others are 0. It defines and measures sector *i*'s technique that necessitates direct and indirect labor $\boldsymbol{l(I-A)^{-1}q_i}$ for producing one unit of output *i*.

Distinct features of ($\boldsymbol{A}$, $\boldsymbol{l}$, $\boldsymbol{b}$) and $\boldsymbol{l(I-A)^{-1}b}$ over space and time suggest that even the same set of $\boldsymbol{A}$ and $\boldsymbol{l}$ results in different techniques if applied to different minimum consumption baskets, i.e., $\boldsymbol{l(I-A)^{-1}b}\neq\boldsymbol{l(I-A)^{-1}b^*}$. It follows that the order relation between $\boldsymbol{l(I-A)^{-1}b}$ and $\boldsymbol{l^*(I-A^*)^{-1}b^*}$ does not indicate which technique is advanced or not. This is *social and historical relativity of technique*.

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[16] Compare our measurement method with Sraffa's: "There are two such corresponding ratios, namely the quantity-ratio of direct to indirect labour employed, and the value-ratio of net product to means of production. We shall adopt the latter here." (Sraffa 1960, p. 17.) We adopt the former in this article.

In dynamics, the process of transition from ($\boldsymbol{A}$, $\boldsymbol{l}$, $\boldsymbol{b}$) to ($\boldsymbol{A}$*, $\boldsymbol{l}$*, $\boldsymbol{b}$*) is a succinctly categorized version of what Schumpeter referred to as "creative destruction" (Schumpeter [1942], ch. 7), which concretely manifests itself as five "new combinations" (Schumpeter [1912], pp. 54-62): (1) the introduction of a new good – that is one with which consumers are not yet familiar -- or a new quality of a good, (2) the introduction of a new method of production, (3) the opening of a new market, (4) the conquest of a new source of supply of raw materials or half-manufactured goods, and (5) the carrying out of the new organization of any industry.

A change from $\boldsymbol{A}$ to $\boldsymbol{A}$* represents the creative destruction of material capital in the sense of physical and/or pecuniary destruction, disposal, and replacement[17]. Elements of $\boldsymbol{A}$ do not simply increase or decrease in volume but also are replaced by new elements of $\boldsymbol{A}$*, one of the embodiments of new engineering techniques. These material inputs, however, do not cover indirect inputs, such as industrial infrastructure often jointly provided by a government.

A change from $\boldsymbol{l}$ to $\boldsymbol{l}$* showcases reallocation of labor force among industries and their creative destruction in accordance with technological evolution and/or other factors such as the changing comparative advantage and disadvantage in international markets. It often requires workers to be equipped with different types of skill or reskilling. Industrial reallocation is always accompanied by regional reallocation of labor force, both resulting in sectoral and spatial disparity in unemployment.

A change from $\boldsymbol{b}$ to $\boldsymbol{b}$* stands for the creative destruction of people's lifestyle, whose components transform in terms of volume, proportion, range, and quality[18].

All in all, these triply categorized "creative destruction," incessantly interacting each other, drives productivity changes over time in the name of Hicks, Harrod, and Solow neutral[19].

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[17] Replacement of old machines and materials with new ones often involves that of old techniques with new ones, which is conceptually similar to Solow's "embodiment." See Solow (2000, p. xxiii). See also Marx: "[science and technology] react at the same time on that part of the original capital which has entered the stage of its renewal. This, in passing into its new shape, incorporates, free of charge, the social advances made while its old shape was being used up. Of course, this development of productivity is accompanied by a partial depreciation of the functioning capital" (Marx [1867], p. 754).

[18] Schumpeter thought that "we shall neglect any spontaneity of consumers' needs that may actually exist, and assume tastes as 'given'" and "innovations in the economic system do not as a rule take place in such a way that first new wants arise spontaneously in consumers and then the productive apparatus swings round through their pressure. … It is, however, the producer who as a rule initiates economic change, and consumers are educated by him if necessary; they are, as it were, taught to want new things" (Schumpeter [1912], pp. 54-55). In sharp contrast, those scholars emphasize consumption-driven growth, innovation, and structural change of economy, such as Pasinetti (1981, p. 69), Metcalfe (2001), Witt (2001a, b), Saviotti (2001), and McMeekin et al. (2002).

[19] For recent development of endogenous growth theories based on human capital, endogenous technological development, new consumer goods, and Schumpeterian innovation, see Lucas (1988), Romer (1986; 1990), Grossman and Helpman (1991), and Aghion and Howitt (1992), respectively. See Solow (2000, chs. 8-11) for the criticism within the mainstream from the framework of the "old" exogenous growth model. Solow, Lucas, and Romer are criticized in Acemoglu and Johnson ("bibliographic essay," 2014, p. 427) on grounds of affirming the "productivity bandwagon," i.e.,

Productivity

According to Griliches (1987, p. 1), a conventional definition of productivity is "a ratio of some measure of output to some index of input use" and "it is usual to focus on one or another version of 'multi-factor productivity,' where the list of inputs considered extends beyond labor and includes also measures of capital services and also, occasionally the use of materials and other inputs." For the estimation of macroeconomic productivity, the residual approach, i.e., total factor productivity (TFP), is conventionally adopted (Solow 1956, 1957; Griliches 1987; Comin 2008; Metcalfe 2008). However, it entails various measurement problems (Griliches 1987).

We perceive macroeconomic productivity as *productivity of labor*[20], which can be measured at the Smithian point by

$$\frac{1}{\boldsymbol{l}(\boldsymbol{I}-\boldsymbol{A})^{-1}\boldsymbol{b}}\,. \tag{22}$$

At the Smithian point where $G\ or\ R\ =\ 1$, it indicates the number of the numéraire baskets that can be produced per unit of labor, since the denominator denotes the total labor units for producing one unit of numéraire. This magnitude signifies the general level of labor productivity for the entire economy measured in the physical terms of numéraire. It remains constant regardless of changing income distribution and resource allocation, as long as the adopted production technique remains fixed. If, by contrast, we adopted $\frac{1}{\boldsymbol{l}(\boldsymbol{I}-\boldsymbol{A})^{-1}\boldsymbol{q}}$ as the measure of productivity, it would suffer from changing resource allocation between *g* and *c* despite no change in technique.

By the same token, industrial sector *i*'s productivity is as follows:

$$\frac{1}{\boldsymbol{l}(\boldsymbol{I}-\boldsymbol{A})^{-1}\boldsymbol{q_i}}, \tag{23}$$

namely, the number of output *i* produced by one unit of total labor.

The argument above holds because first, the entire economy is reduced to the dual equation made

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simultaneous improvement of productivity and wage rates. See Mokyr (2002) for another type of criticism against endogenous growth theories on the grounds that they "regard technology and knowledge as 'produced by the system,' that is, as outputs of a knowledge-creating production process that is governed by rational economic decision-making" (p. 21). He puts much emphasis on interactions and mutual reinforcement between propositional knowledge and prescriptive knowledge, in which the former serves as the epistemic base of techniques, and access costs to knowledge (ch. 1). Most of the epistemic base and prescriptive knowledge are stored and embodied in artifacts used (pp. 11 and 15), such as $\boldsymbol{A}$ in our model.

[20] "[The productivity of labor] is determined by a wide range of circumstances; it is determined amongst other things by the workers' average degree of skill, the level of development of science and its technological application, the social organization of the process of production, the extent and effectiveness of the means of production, and the conditions found in the natural environment" (Marx [1867], p. 130).

of the minimum consumption basket and second, productivity of producing means of consumption in the final production processes reflects and ultimately subsumes that of producing means of production in the intermediate production processes. Hence, productivity changes in the latter are precisely incorporated into those in the former. This is guaranteed by the industrial structure we assume in which all industries engage themselves in the production of both means of production and consumption, including special cases in which they are separated from one another and specialized in either type of production.

In dynamics, when technique ($\boldsymbol{A}$, $\boldsymbol{l}$, $\boldsymbol{b}$) changes to ($\boldsymbol{A}^*$, $\boldsymbol{l}^*$, $\boldsymbol{b}^*$), a change in productivity can be measured by a change from $\frac{1}{\boldsymbol{l}(\boldsymbol{I}-\boldsymbol{A})^{-1}\boldsymbol{b}}$ to $\frac{1}{\boldsymbol{l}^*(\boldsymbol{I}-\boldsymbol{A}^*)^{-1}\boldsymbol{b}^*}$, even if the content, proportion, volume, and the number of elements and components are different between ($\boldsymbol{A}$, $\boldsymbol{l}$, $\boldsymbol{b}$) and ($\boldsymbol{A}^*$, $\boldsymbol{l}^*$, $\boldsymbol{b}^*$). It should be noted that $\frac{1}{\boldsymbol{l}^*(\boldsymbol{I}-\boldsymbol{A}^*)^{-1}\boldsymbol{b}^*}$ is not necessarily higher than $\frac{1}{\boldsymbol{l}(\boldsymbol{I}-\boldsymbol{A})^{-1}\boldsymbol{b}}$, since the long-term tendency of the numéraire over time, i.e., an expansion in quantity of some components and an increase in their variety, may more than compensate for the long-term increasing efficiency of the engineering aspects of techniques.

That we can measure productivity of an entire economy and compare it over time in terms of unique scalar values is what we refer to as the *macrodynamic productivity theorem*.

Measurement unit of wealth, technique, and productivity

When technique ($\boldsymbol{A}_0$, $\boldsymbol{l}_0$, $\boldsymbol{b}_0$) takes the value of unity, we define it as the *measurement unit of technique*:

$$\boldsymbol{l}_0(\boldsymbol{I}-\boldsymbol{A}_0)^{-1}\boldsymbol{b}_0 = 1. \tag{24}$$

It is a hypothetical unit of measurement in theory, whereby one unit of the minimum basket $\boldsymbol{b}_0$ embodies exactly one unit of total labor.

Hence, the productivity it achieves is

$$\frac{1}{\boldsymbol{l}_0(\boldsymbol{I}-\boldsymbol{A}_0)^{-1}\boldsymbol{b}_0} = 1, \tag{25}$$

whereby one unit of the minimum basket $\boldsymbol{b}_0$ is produced by one unit of total labor, defined as the *measurement unit of productivity*. It is a historical unit of productivity, under which human beings lived exactly at the level of subsistence and no class society could be sustained. Under the minimum productivity for subsistence the consumption rate turns out to be unity, leaving no possibility of economic growth. Thus, the wealth at this level of productivity is measured in terms of labor as follows:

$$c\boldsymbol{l}_0(\boldsymbol{I}-\boldsymbol{A}_0)^{-1}\boldsymbol{b}_0 = 1. \tag{26}$$

It is the *measurement unit of wealth* at the historical origin of human society.

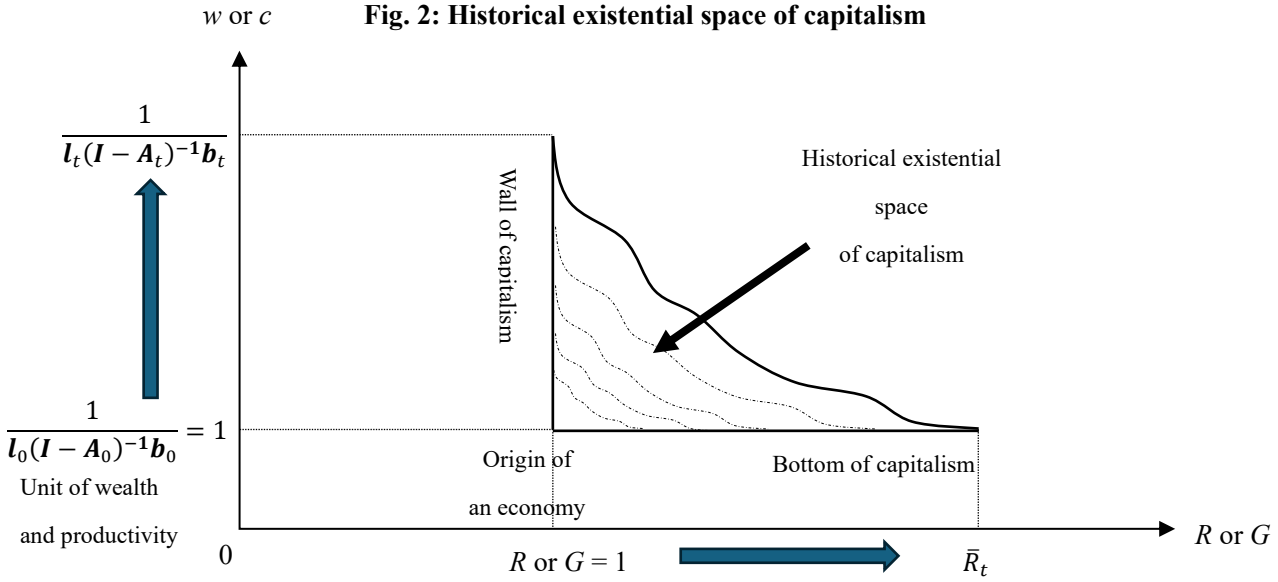


Fig. 2: Historical existential space of capitalism

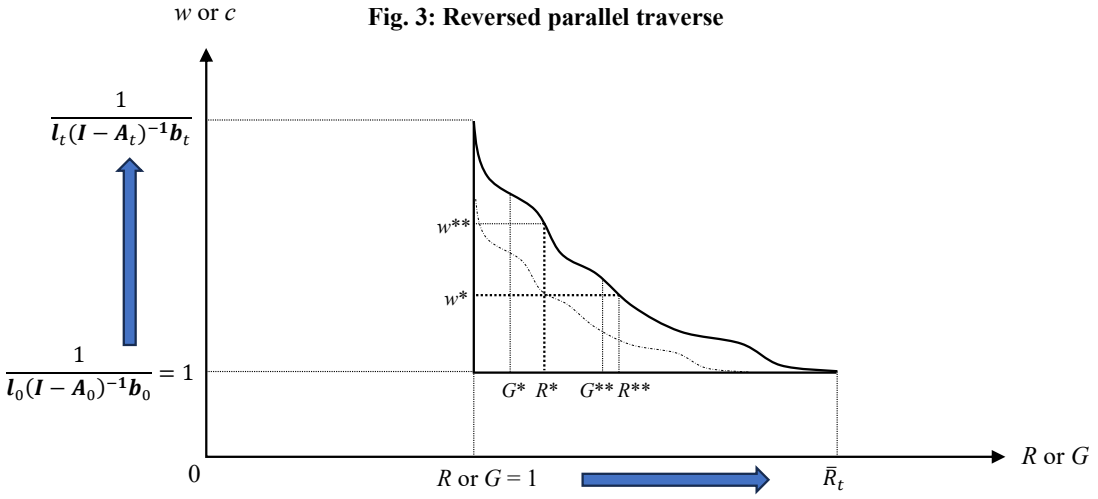
See Figure 2. When $\frac{1}{\boldsymbol{l_0(I-A_0)^{-1}b_0}} = 1$, R, G, and c are necessarily unity, namely, no exploitation, no growth, and no savings, respectively. It is the historical origin of human society and economy. As productivity increases beyond the origin, there appears the possibility of exploitation either in the form of ancient slavery, medieval serfdom, or modern wage labor. Focusing on capitalism since the 16th century, the horizontal line where $\frac{1}{\boldsymbol{l_0(I-A_0)^{-1}b_0}} = 1$ forms the "bottom of capitalism," under which wage workers could not survive; and the vertical line where $R = 1$ forms the "wall of capitalism," in the left-hand side of which capitalists could not survive. The triangle-like space bounded by the "bottom," the "wall," and the R-w and G-c dual frontiers constitutes the historical existential space of capitalism, which has generally expanded over time but exceptional economic crises.

The static comparison among economic regimes under the assumption of constant technique (Itaki 2026, pp. 17-18) ought to be developed into a dynamic model in which trajectories in east-northeast and north-northeast directions from the origin on Figure 2 will replace downward and upward traverses on the fixed R-w and G-c frontiers in the previous static model. The slope and shape of these trajectories have been heavily influenced by institutions, dominant vision, and cultural norms in history (Acemoglu and Johnson 2024). When a dynamic trajectory begins from a low-productivity frontier to a high-productivity frontier in the north-northeast direction, it generates a larger symmetry breaking than another trajectory in the east-northeast direction. This is because in the former workers will enjoy more favorable income distribution than the latter under higher productivity, resulting in a relatively less increase in G than R. The two extreme cases are depicted in Figure 3, one with the maximum increase in w and no change in R and another with the opposite conditions, which result in *shrinking* symmetry breaking, i.e., $R^{**} - G^{**} < R^{*} - G^{*}$. This is what we refer to as the *reversed*

parallel traverse between the profit rate and the growth rate with increasing productivity, whilst in the static model the symmetry breaking between R and G *widens* as R increases in their parallel traverse[21]. Therefore, the value of the system transformer becomes smaller:

$$\frac{\boldsymbol{l}^{**}(\boldsymbol{I}-R^{**}\boldsymbol{A}^{**})^{-1}\boldsymbol{b}^{**}}{\boldsymbol{l}^{**}(\boldsymbol{I}-G^{**}\boldsymbol{A}^{**})^{-1}\boldsymbol{b}^{**}} < \frac{\boldsymbol{l}^{*}(\boldsymbol{I}-R^{*}\boldsymbol{A}^{*})^{-1}\boldsymbol{b}^{*}}{\boldsymbol{l}^{*}(\boldsymbol{I}-G^{*}\boldsymbol{A}^{*})^{-1}\boldsymbol{b}^{*}}.$$

Fig. 3: Reversed parallel traverse



4. Poverty and impoverishment

Our examination of wealth, technique, and productivity can be extended to an argument about poverty and impoverishment, the opposite concepts to wealth and enrichment. Their measurement units discussed above represent the state of *absolute* poverty at the origin of human society. After departing from there we deal with *relative* wealth and poverty quantitatively in terms of the consumption rate c and qualitatively in terms of the wealth numéraire $\boldsymbol{b}$.

A transition from one state to another is either enrichment or impoverishment of society. Focusing on impoverishment we can classify the problem into two cases: first, fixed technique with constant $\boldsymbol{A}$, $\boldsymbol{l}$, and $\boldsymbol{b}$; and second, evolving techniques with variable $\boldsymbol{A}$, $\boldsymbol{l}$, and $\boldsymbol{b}$.

First, given constant $\boldsymbol{A}$, $\boldsymbol{l}$, and $\boldsymbol{b}$, poverty is represented by a lower rightward position on the G-c frontier accompanied by a further lower rightward position on the R-w frontier according to the theorem of parallel traverse (Itaki 2026, pp. 15-18). Society is understood to be poor and impoverished despite, or exactly because of, higher profit rates and robust growth under the fixed technique and productivity. Constrained wages and consumption of workers characterize impoverishment of society. The case is formulated as a transition from c to c^* and from w to w^* as follows:

[21] A necessary condition for the reversed parallel traverse to hold is that the propensity to consume among workers and capitalists will not drastically change in the process of productivity improvement.

$$c^* = \frac{1}{G^*\boldsymbol{l}(\boldsymbol{I} - G^*\boldsymbol{A})^{-1}\boldsymbol{b}} < c = \frac{1}{G\boldsymbol{l}(\boldsymbol{I} - G\boldsymbol{A})^{-1}\boldsymbol{b}}\,, \tag{27}$$

$$w^* = \frac{1}{R^*\boldsymbol{l}(\boldsymbol{I} - R^*\boldsymbol{A})^{-1}\boldsymbol{b}} < w = \frac{1}{R\boldsymbol{l}(\boldsymbol{I} - R\boldsymbol{A})^{-1}\boldsymbol{b}}\,, \tag{28}$$

$$w^* < c^*, \text{and } w < c.$$

A peculiar configuration of poverty is one that combines a lower rightward position of *R* and *w* with a substantially lagging position of *G* and *c* somewhere in the middle of the frontier, or even with a higher leftward position of *G* and *c*. In such a case, a relatively high overall consumption rate cannot be explained by workers' low consumption, but rather by capitalists' extravagant consumption financed by high profit rates or by capital gains realized in securities markets (Itaki 2026, p. 18). The society is in poverty since the majority of its members are poorly paid and consumes, while it is affluent since the overall consumption is substantially high thanks to capitalists' lavish consumption.

Second, let us assume that transformation from $\boldsymbol{b}$ to $\boldsymbol{b}^*$ and a change from *c* to *c** take place, accompanied by a change from $\boldsymbol{A}$ and $\boldsymbol{l}$ to $\boldsymbol{A}^*$ and $\boldsymbol{l}^*$. As discussed above, the transition from $\boldsymbol{b}$ to $\boldsymbol{b}^*$ does not necessarily mean development of human life in a positive direction. However, it usually manifests itself as a long-term transforming tendency: i.e., an expansion in quantity of some components and an increased variety of components contained in the numéraire. This is because society has been and will be deepening its complexity, which requires more sophisticated consumption for compensating it. Such a temporal transition of the minimum wealth takes place regardless of our recognition about whether it signifies enrichment or impoverishment of society.

The long-term tendency may result in actual impoverishment, however, if the transition from $\boldsymbol{b}$ to $\boldsymbol{b}^*$ causes a decline in the consumption rate from *c* to *c**, i.e., a loss of leeway in consumer life. Given the growth rate *g* kept constant at a specific level, impoverishment can be expressed as a shift down of the *G*-*c* frontier as follows:

$$c^* = \frac{1}{G\boldsymbol{l}^*(\boldsymbol{I} - G\boldsymbol{A}^*)^{-1}\boldsymbol{b}^*} < c = \frac{1}{G\boldsymbol{l}(\boldsymbol{I} - G\boldsymbol{A})^{-1}\boldsymbol{b}}$$

$$\frac{c^*}{c} = \frac{\boldsymbol{l}(\boldsymbol{I} - G\boldsymbol{A})^{-1}\boldsymbol{b}}{\boldsymbol{l}^*(\boldsymbol{I} - G\boldsymbol{A}^*)^{-1}\boldsymbol{b}^*} < 1. \tag{29}$$

The *G*-*c* and *G*-*c** frontiers are separate from each other, never intersecting each other, and the latter is always below the former. The shift down of the *G*-*c* frontier is accompanied by that of the *R*-*w* frontier:

$$\frac{w^*}{w} = \frac{\boldsymbol{l}(\boldsymbol{I} - R\boldsymbol{A})^{-1}\boldsymbol{b}}{\boldsymbol{l}^*(\boldsymbol{I} - G\boldsymbol{R})^{-1}\boldsymbol{b}^*} < 1. \tag{30}$$

Impoverishment occurs when sophistication of the wealth numéraire from $\boldsymbol{b}$ to $\boldsymbol{b}^*$ incurs deterioration of productivity, i.e., $\boldsymbol{l}(\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{b} < \boldsymbol{l}^*(\boldsymbol{I} - \boldsymbol{A}^*)^{-1}\boldsymbol{b}^*$, at any point on the frontier, i.e., $\boldsymbol{l}(\boldsymbol{I} - G\boldsymbol{A})^{-1}\boldsymbol{b} < \boldsymbol{l}^*(\boldsymbol{I} - G\boldsymbol{A}^*)^{-1}\boldsymbol{b}^*$, despite the new engineering technique represented by $\boldsymbol{A}^*$ and $\boldsymbol{l}^*$.

Hence, the consumption rate shrinks from c to c^*, regardless of the growth rates. This is accompanied by deterioration of the real wage rate from w to w^*, i.e., $\boldsymbol{l}(\boldsymbol{I}-R\boldsymbol{A})^{-1}\boldsymbol{b} < \boldsymbol{l}^*(\boldsymbol{I}-R\boldsymbol{A}^*)^{-1}\boldsymbol{b}^*$.

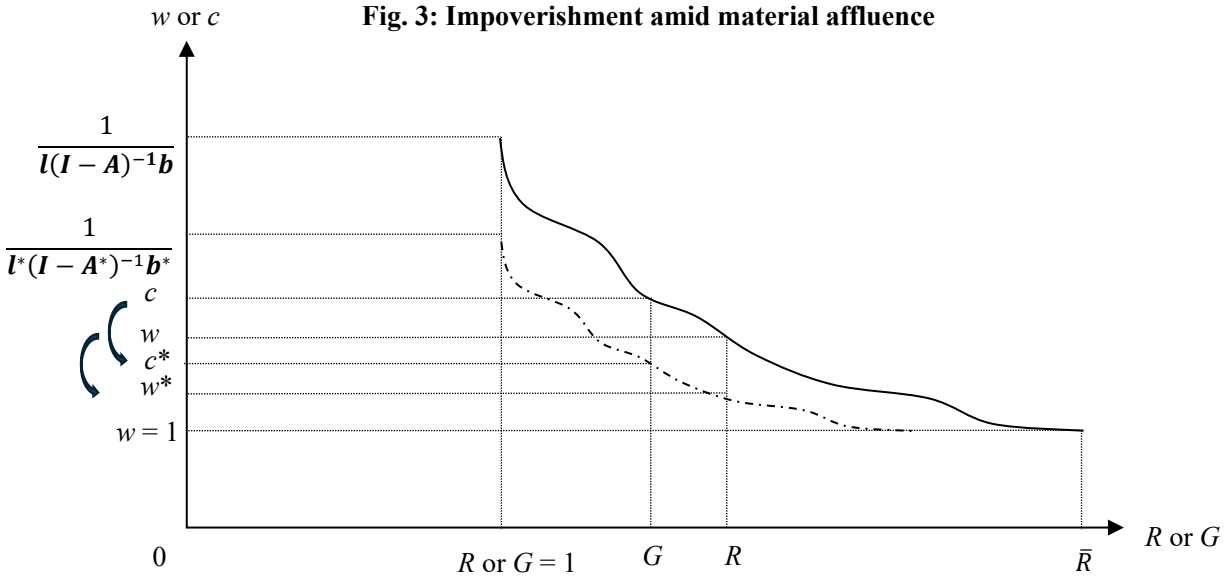


Fig. 3: Impoverishment amid material affluence

The mechanism examined above makes it possible to understand impoverishment in modern society amid affluence of goods and services. The complexity of a highly developed affluent society necessitates as well as enables ever-increasing consumption of goods and services, resulting in impoverishment unless being compensated for by radical improvement of technique *and* income distribution in favor of workers. This reveals the reason why we almost constantly cherish the feeling of ever-deteriorating psychological hunger and thirst amid material affluence. It may continuously influence workers' family life over decades, depriving them of desire to form a family with several children, since raising children incurs substantial expansion of $\boldsymbol{b}^*$ which is expected to annoy parents in the long term ahead.

Conclusions

Our answer to the question "What is wealth and how to measure it?" is thoroughly grounded on Smith's concept of wealth, i.e., "necessaries, conveniencies, and amusements of human life," which is developed into the macrodynamic measurement units of wealth, technique, and productivity. The unified classical approach embedded in the dual equation made it possible to measure and compare techniques and productivity in terms of unique scalar values, regardless of ever-changing engineering techniques and minimum consumption baskets over time and space.

A corollary of our argument was offered about the possibility of poverty and impoverishment amid affluence of modern society, which may explain a declining birthrate and an aging population, coupled

with exacerbating psychological uneasiness among the population.

The article intended to make one step closer to achieving the "dynamics of the wealth of nations," Pasinetti's dream inscribed in the subtitle of Pasinetti (1981) and further pursued in Pasinetti (1993), if not thoroughly successful. The macrodynamic extension of the dual equation allows parameters $\boldsymbol{A}$, $\boldsymbol{l}$, and $\boldsymbol{b}$ to vary as well as variables *r*, *w*, *g*, and *c*, which accommodates his intension of dynamizing the wealth of nations.

Appendix:

Firstly, multiply $\boldsymbol{q}$ by $\boldsymbol{p}$, and we get:

$$\boldsymbol{pq} = (1+g)(\boldsymbol{pAq} + c\boldsymbol{pb})$$

Since $\boldsymbol{pb} = 1$ and $k = \boldsymbol{pAq}$,

$$\boldsymbol{pq} = (1+g)(k+c)$$

Since *y* is defined as

$$y = \boldsymbol{p}(\boldsymbol{I}-\boldsymbol{A})\boldsymbol{q}$$
$$y + k = \boldsymbol{pq}$$

Therefore,

$$y + k = (1+g)(k+c)$$
$$y = g(k+c) + c$$

Secondly, multiply $\boldsymbol{p}$ by $\boldsymbol{q}$, and we get:

$$\boldsymbol{pq} = (1+r)(\boldsymbol{pAq} + w\boldsymbol{lq})$$

Since $k = \boldsymbol{pAq}$ and $\boldsymbol{lq} = 1$,

$$\boldsymbol{pq} = (1+r)(k+w)$$
$$y + k = (1+r)(k+w)$$

Therefore,

$$y = r(k+w) + w$$

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