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Structural economic dynamics in actual industrial economies

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ABSTRACT

Despite the tight articulation between Pasinetti's natural economic system and measurable inter-industry magnitudes, contributions inspired by his framework of structural economic dynamics have either focused on analytical developments or empirically implemented some of its features in isolation. To bridge the gap between theory and empirics, this paper introduces a computable formulation of Pasinetti's dual system of prices and quantities, including its natural configuration, starting from a set of inter-industry accounting identities. The analytical properties of the computable framework are discussed, using the logical structure of a closed Input–Output model. By articulating a dataset collating different OECD databases, the scheme is empirically implemented to explore the structural dynamics of six advanced industrial economies between 1995 and 2015. In particular, we quantify the required injection to close a country's unemployment gap via a public intervention, use the natural configuration of the economy to relate the evolution of demand, productivity, wages and the general price level, and compare the emerging trends of job creation and displacement across countries and hyper-integrated sectors.

1. Introduction

The framework of structural economic dynamics introduced by Pasinetti (1963, 1965, 1981, 1993) is a cornerstone of the literature on structural change. Not only for the (Cambridge) Keynesian tradition on which it is rooted, but also for alternative schools of economic thought. And for different reasons, as well. While Neoclassical contributions may consider it as a pioneering example to overcome balanced growth theory (Kongsamut et al., 2001, p. 869), Evolutionary contributions view it as a vehicle to overcome product life cycle bottlenecks through the creation of new sectors (Saviotti and Pyka, 2004).

At a foundational level, the framework has rendered crystal clear the contrast between approaches to economic analysis based on exchange relations with respect to those based on production requirements, prioritising reproduction and growth over scarcity for theorising about quantities and prices (Pasinetti, 1986b; Bortis, 2000).

At an analytical level, the scheme has been used to provide multisectoral foundations to Keynesian concepts, such as the multiplier (Trigg and Lee, 2005), to establish clear-cut distinctions between a 'vertical' and 'circular' description of productive relations (Landesmann and Scazzieri, 1993), as well as to analyse the co-ordination requirements to achieve a full employment situation in an economy undergoing structural transformation (Scazzieri, 2009).

But probably the deepest aspect of Pasinetti's framework is its innovative methodological standpoint for structural analysis, which may be summarised in four elements. First, there is a careful distinction between pre-institutional and behavioural relations (Pasinetti, 2007, pp. 36–7). A pre-institutional concept or relation is not one specified in an institutional *vacuum*, but one which "remains neutral with respect to the institutional organisation of society" (Pasinetti, 1981, p. 25). It is meaningful across institutional setups, e.g. a centrally planned, capitalist or mixed economy, but its realisation occurs within a well-specified set of rules, mechanisms and behaviours operating in an industrial society.[1]

Second, it adopts the (growing) subsystem (Sraffa, 1960, p. 89) — rather than the 'industry' — as its disaggregated unit of analysis. By logically repartitioning industries' labour inputs, means of production and gross outputs required to reproduce (and expand) each commodity in the net product, the economy is structured as a set of relatively autonomous circular flows. In this way, it is possible to analyse accumulation and technical change while preserving circularity. Each of these growing subsystems or vertically hyper-integrated sectors (Pasinetti, 1988) expands (or contracts) at a specific (steady) rate, challenging traditional dynamic Input–Output (I-O, hereinafter) analyses. And yet, this set of circular flows expanding at uneven rates is tied together by the *logic* of a closed I-O model (Pasinetti, 1981, pp. 30–3).

Third, it introduces a specific pre-institutional configuration of the economy labelled as 'natural', within which wages emerge as the income content of final consumption and profits as the income content of new investments. It represents a multisectoral formulation of the

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[1] See Garbellini and Wirkierman (2014b, section 2) for a discussion of the 'pre-institutional' character in Pasinetti's analyses.

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Keynesian distribution principle introduced by Kaldor (1955, p. 96): new investment *requirements* are given and equal to *natural* profits, so wages are a residual. In this way, the residual claimant in income is turned upside down with respect to Classical theory.

Fourth, in line with the stance taken by Domar (1946, p. 146), and *differently* from Kaldor, Pasinetti's natural economic system represents a *normative* configuration, with an implied set of measurable constraints that ought to be satisfied if full employment and full capacity utilisation are to be maintained (Pasinetti, 1981, Chapter VII). In fact, the specification of the natural economic system does not include the adjustment mechanism of profits to investment (or *viceversa*), which instead depends on the set of behavioural relations assumed.

Interestingly, though, despite the tight articulation between the natural economic system and measurable inter-industry magnitudes, contributions inspired by Pasinetti (1981, 1988, 1993) have either (i) kept the argument strictly within the realm of analytical developments (often intuitively explored through numerical simulations), or (ii) performed an empirical application based on a subset (often only one) of the features of the framework.

Within (i), Pasinetti's theoretical scheme has been generalised, extended and refined by Garbellini (2010) for the case of circulating capital inputs. Instead, specific theoretical applications of Pasinetti (1993) include: analysing the 'cost disease' argument (Baumol, 1967) arising from unbalanced productivity growth between manufacturing and services (Notarangelo, 1999), the employment consequences of demand saturation (Kurose, 2009), as well as balance-of-payments constrained growth (Araujo and Lima, 2007).

Within (ii), the subsystem approach has probably been the aspect of Pasinetti's framework most widely used. For example, in order to quantify productivity changes (Rampa, 1981a,b; Elmslie and Milberg, 1996; Garbellini and Wirkierman, 2014c), as well as (potential) changes in distributive possibilities due to technical progress (Marzi, 1994). Also, to measure the degree of outsourcing of business services from manufacturing industries throughout 'deindustrialisation' debates since the 1980s (Pasinetti, 1986a; Montresor and Vittucci Marzetti, 2011).

Empirical applications of the framework often mainly estimate a reduced form to capture conditional correlations *implied* by the model — such as in Milberg (1991, pp. 86–93) or Gouvea and Lima (2010, p. 181) — rather than the structural form of the model itself.

Therefore, to bridge the gap between theory and empirics, this paper introduces a computable formulation of Pasinetti's dual system of prices and quantities, including its natural configuration, starting from a set of inter-industry accounting identities, and implements the scheme to explore the structural dynamics of six advanced industrial economies — Germany (DEU), France (FRA), Italy (ITA), United Kingdom (GBR), Japan (JPN) and the United States (USA) — between 1995 and 2015.

A further original contribution of the paper is to show how the empirical implementation of Pasinetti's framework may be used to address policy-relevant questions for the countries and period considered. In particular, between 1995 and 2015, (at least) three processes have unfolded (to a different degree) across the six above-mentioned countries: (i) the implementation of fiscal consolidation policies by governments in the aftermath of the Global Financial Crisis of 2008/09 (Blanchard and Leigh, 2013), (ii) a decoupling between labour compensation and productivity growth (Paternesi Meloni and Stirati, 2022), (iii) increasing technological unemployment related to robotisation (Acemoglu and Restrepo, 2020).

In relation to (i), we ask: what is the required adjustment in government expenditure to reach full employment? In answering this question, we show how the inter-industry structure of government purchases becomes relevant to assess the potential aggregate effects of Keynesian expenditure policy. In relation to (ii), we ask: how may the wage–productivity growth gap be related to labour force, price and consumption dynamics? To answer this question, we develop a structural accounting framework alternative to 'growth accounting' exercises within the Neoclassical tradition (Hulten, 2010). Finally, in relation to (iii), we ask: which sectors are leading job creation/destruction trends? In answering this question, we shift the unit of analysis from the industry to the (hyper-)subsystem and uncover the interplay between (value-chain) productivity and (final) demand dynamics.

Following Pasinetti (1981, Chapter VI), empirical data is fitted into a vertically (hyper-)integrated model. However, rather than starting from model magnitudes and finding empirical *proxies*, the reverse route is taken. Successive layers of theoretical abstraction are superposed on fully fledged I-O tables, until the income and expenditure circuits obtained may be interpreted as price and quantity systems of a Pasinettian scheme of structural dynamics.

The advantage of this procedure is that it asserts beyond doubts that the coefficients in the model "must, therefore, be interpreted as representing those physical quantities which can actually be observed" (Pasinetti, 1981, p. 110). Given that I-O tables are compiled in nominal terms, one aspect to tackle is the consistent separation between price (indices) and volumes. More importantly, it becomes explicit that model coefficients do *not* represent a notion of *dominant* technique, but the medley of techniques in use within each industry.

Moreover, by starting from the full set of inter-industry accounting identities (which include, e.g., different taxes, imported inputs and inventories), it becomes transparent which elements are kept and which are progressively discarded to obtain the analytical model, rendering clear some potential limitations of the framework.

In order to establish a precise connection between empirical data and theoretical coefficients two compromises were reached. First, while we derive a set of *natural* prices to characterise the valuation side of the system, we work with an *effective* growth path, rather than a *normative* one, as regards physical quantities. This is due to the intrinsic difficulty in separating activity levels from technical change in empirical structures (Garbellini and Wirkierman, 2014c).

Second, and as a consequence of the previous point, in the formulation of a computable natural price system, the equality between profits and new investments is not obtained by equating a (subsystem-specific) *rate* of growth to a *rate* of profits, but by posing that the *mass* of profits equals the *total value* of new investments, at a sectoral level.

After this introduction, the rest of the paper is organised as follows. Section 2 derives an analytical framework of structural dynamics starting from a set of I-O accounting identities, discusses its properties and articulates a set of synthetic indicators. Section 3 performs an empirical exploration of the framework and discusses the results. Finally, Section 4 summarises main findings and concludes.

2. Structural economic dynamics: an Input–Output formulation

2.1. From accounting structures to price and quantity systems

Consider the set of expenditure and income *accounting* relations of a square, industry × industry Input–Output (I-O, hereinafter) system of n industries at current, basic prices, articulated as follows[2]:

$$\boldsymbol{x} \equiv \boldsymbol{X}\boldsymbol{e} + \boldsymbol{F}_k\boldsymbol{e} + \boldsymbol{f}_c + \boldsymbol{f}_z \tag{1}$$

$$\boldsymbol{x}^T = \boldsymbol{e}^T\hat{\boldsymbol{x}} \equiv \boldsymbol{e}^T\boldsymbol{X} + \boldsymbol{m}_x^T + \boldsymbol{\tau}^T + \boldsymbol{y}_l^T + \boldsymbol{y}_\pi^T \tag{2}$$

Eqs. (1) represent an expenditure system, whereas (2) an income system, where:

[2] The I-O tables generally available have been originally derived from a set of Supply-Use Tables (SUTs) using the fixed product sales structure assumption (EUROSTAT, 2008, p. 316). Magnitudes in the tables are expressed in 10^6 LCU, i.e., million units of each country's local currency unit (LCU). As regards notation, matrices are represented using boldface upper-case letters (e.g. $\boldsymbol{M}$), vectors with boldface lower-case letters (e.g. $\boldsymbol{v}$), all vectors are column vectors, and their transposition is explicitly indicated (e.g. $\boldsymbol{v}^T$). A vector with a hat (e.g. $\hat{\boldsymbol{v}}$) indicates a diagonal matrix with each element of the vector on the main diagonal. Vector $\boldsymbol{e} = [1, \ldots, 1]^T$ is a column vector of appropriate dimensions that sums across columns, while $\boldsymbol{e}_i = [0, \ldots, 0, 1, 0 \ldots, 0]^T$ is a vector that selects the ith column.

$\underset{(n\times1)}{\boldsymbol{x}}$	Vector of industry gross output;
$\underset{(n\times n)}{\boldsymbol{X}}$	Matrix of intermediate consumption domestically produced;
$\underset{(n\times n)}{\boldsymbol{F}_k}$	Matrix of capacity-generating gross fixed capital formation domestically produced;
$\underset{(n\times1)}{\boldsymbol{f}_c}$	Vector of final consumption and dwellings domestically produced;
$\underset{(n\times1)}{\boldsymbol{f}_z}$	Vector of other final uses;
$\underset{(n\times1)}{\boldsymbol{m}_x}$	Vector of imported intermediate inputs;
$\underset{(n\times1)}{\boldsymbol{\tau}}$	Vector of taxes net of subsidies on products and other net taxes on production;
$\underset{(n\times1)}{\boldsymbol{y}_l}$	Vector of labour compensation (including wages and salaries, as well as imputation for mixed income of self-employed);
$\underset{(n\times1)}{\boldsymbol{y}_\pi}$	Vector of gross operating surplus (net of imputation for mixed income of self-employed).

Final demand is split into three components: (i) a matrix of (capacity-generating) gross fixed capital formation by industry of origin *and* destination ($\boldsymbol{F}_k$), (ii) a vector of consumption and residential construction ($\boldsymbol{f}_c$),[3] and (iii) a vector of other final uses ($\boldsymbol{f}_z$), including exports and changes in inventories. The separation (i)-(iii) has analytical aims: capacity-generating fixed capital flows will be considered to be *induced* by gross output, each component of the final consumption vector will follow an exponential path, and other final uses will (purposely) not be included in the quantity system.[4]

By working with an I-O system at current prices, magnitudes in systems (1)–(2) can be interpreted in terms of the amount of physical output of the product of industry i that can be purchased with one monetary unit (Leontief, 1986, p. 22). This means that the price of gross output for each industry will be equal to *one*, as represented by vector $\boldsymbol{e}^T$ in equation system (2).[5] To obtain a supporting I-O price system with *only* gross operating surplus and labour compensation as *non-produced* inputs, we exclude $\boldsymbol{\tau}^T$ and $\boldsymbol{m}_x^T$ from income system (2):

$$\boldsymbol{\phi}^T\hat{\boldsymbol{x}} = \boldsymbol{\phi}^T\boldsymbol{X} + \boldsymbol{y}_\pi^T + \boldsymbol{y}_l^T \tag{3}$$

so that:

$$\boldsymbol{\phi}^T = \boldsymbol{\phi}^T\boldsymbol{A} + \boldsymbol{a}_\pi^T + \boldsymbol{a}_w^T \tag{4}$$

where $\boldsymbol{A} = \boldsymbol{X}\hat{\boldsymbol{x}}^{-1}$ is a matrix of domestically produced intermediate inputs per unit of gross output,[6] $\boldsymbol{a}_w^T = \boldsymbol{y}_l^T\hat{\boldsymbol{x}}^{-1}$ is a vector of labour compensation per unit of gross output and $\boldsymbol{a}_\pi^T = \boldsymbol{y}_\pi^T\hat{\boldsymbol{x}}^{-1}$ is a vector of gross operating surplus per unit of gross output. We then solve for $\boldsymbol{\phi}^T$:

$$\boldsymbol{\phi}^T = (\boldsymbol{a}_\pi^T + \boldsymbol{a}_w^T)(\boldsymbol{I} - \boldsymbol{A})^{-1} \tag{5}$$

Vector $\boldsymbol{\phi}^T$ represents a set of industry price *indices*, quantifying the relative deviation from observed, unit prices. However, in such a system gross operating surplus ($\boldsymbol{a}_\pi^T$) and labour compensation ($\boldsymbol{a}_w^T$) per unit of gross output are taken as given. In order to obtain a system of *natural* price indices, we need a theory for $\boldsymbol{a}_\pi^T$ and $\boldsymbol{a}_w^T$. In particular, gross operating surplus should allow to finance capacity-generating investment, whereas labour compensation should remunerate each unit of *homogeneous* labour with a *macroeconomic*, uniform wage rate (w):

$$\boldsymbol{\phi}_n^T = \boldsymbol{\phi}_n^T\boldsymbol{A} + \boldsymbol{\phi}_n^T\boldsymbol{A}_k + w\boldsymbol{a}_l^T \tag{6}$$

Eqs. (6) represent a system of *natural* (in the sense of Pasinetti, 1981, 1993) price *indices*, where $\boldsymbol{A}_k = \boldsymbol{F}_k\hat{\boldsymbol{x}}^{-1}$ is a matrix of domestically produced capacity-generating gross fixed capital formation per unit of gross output,[7] whilst $\boldsymbol{a}_l^T = \boldsymbol{l}^T\hat{\boldsymbol{x}}^{-1}$ is a vector of labour input requirements per unit of gross output.

The difference between price indices $\boldsymbol{\phi}^T$ and $\boldsymbol{\phi}_n^T$ can be grasped by comparing systems (4) and (6). If profits per unit of output were precisely those that finance the expansion of new vintages of fixed capital inputs ($\boldsymbol{a}_\pi^T = \boldsymbol{\phi}_n^T\boldsymbol{A}_k$) and labour compensation per unit of output corresponded to the associated labour requirement valued at an economy-wide wage rate ($\boldsymbol{a}_w^T = w\boldsymbol{a}_l^T$), then $\boldsymbol{\phi}^T = \boldsymbol{\phi}_n^T$.

As, in general, profits differ from capacity-generating investment, and wage rates differ across industries, $\boldsymbol{\phi}^T \neq \boldsymbol{\phi}_n^T$. Thus, the system of natural price indices (6) represents a *norm*. Its function is not to describe or predict the movement of market prices along a predefined time frame (be it short *or* long-period).[8] Instead, it is to define a valuation system that can be superposed to a set of commodity balances allowing for circulation and reproduction at an expanded scale. Moreover, note that fixed capital inputs in system (6) now became produced means of production, rather than a non-produced, primary input.

Given that gross operating surplus and labour compensation are the only price components beyond intermediate inputs in price system (6), a *compatible* commodity balance can be derived from expenditure accounting relations (1), by formulating:

$$\boldsymbol{x}_c = \boldsymbol{A}\boldsymbol{x}_c + \boldsymbol{A}_k\boldsymbol{x}_c + \boldsymbol{f}_c \tag{7}$$

The difference between *observed* gross outputs $\boldsymbol{x}$ in (1) and $\boldsymbol{x}_c$ in (7) consists in having excluded $\boldsymbol{f}_z$ from the commodity balance of the economy, re-proportioning activity levels to support the production of $\boldsymbol{f}_c$, i.e., final consumption and dwellings, as the only *final* uses of the system.[9]

However, magnitudes in expenditure system (7) are in current prices. In order to account for growth in volume terms, we may express them in (constant) prices of a base year (i.e., $t = 0$). Formally, this amounts to premultiplying each matrix or vector by a (reciprocal) price index diagonal matrix $\hat{\boldsymbol{\mu}}_0$, whose elements along the main diagonal contain the ratio between gross output at base-year and current

[3] The vector includes final consumption expenditure by households, general government and non-profit institutions serving households (NPISHs), as well as gross fixed capital formation devoted to dwellings.

[4] Some pointers on how to include foreign trade and formulate a *global* empirical scheme of structural dynamics may be found in the concluding section.

[5] Conceptually, we "redefine the physical units of measurement for each sector to be the amount that can be bought for \$1.00" (Miller and Blair, 2009, p. 42). Therefore, if the physical unit of measurement for the (composite) product(s) of industry i becomes $1/\text{price}_i$, the price of each of these redefined units is \$1. For example, if i was the steel industry (with its output normally measured in tons), *if* we knew that the price per ton was \$700, and output in monetary terms was x_i, we could interpret it as x_i 1/700th. tons of steel, each sold at \$1. Proceeding in this way for all industries, the price vector in current prices is the unit vector $\boldsymbol{e} = [1, \dots, 1]^T$.

[6] Each element a_{ij} from matrix $\boldsymbol{A} = [a_{ij}]$ represents the input requirements from industry i by industry j to produce a monetary unit of its gross output.

[7] Each element a_{ij}^k from matrix $\boldsymbol{A}_k = [a_{ij}^k]$ represents the gross fixed capital formation from industry i demanded by industry j, per monetary unit of its gross output.

[8] Even if the dynamics of *natural* prices may significantly predict that of *observed* prices, as will be seen below.

[9] Excluding $\boldsymbol{f}_z$ from (7) and $\boldsymbol{\tau}^T$ and $\boldsymbol{m}_x^T$ from (3) is motivated by the aim to get as close as possible to the framework specified by Pasinetti (1981, Chapter 2). In his setup, there is no foreign trade nor (net) taxes on products. In this sense, gross outputs in (7) are defined net of final uses other than consumption and dwellings, while price indices in (3) are defined net of taxes on products and imported intermediate inputs. Whilst including these components would render the analysis more comprehensive — and should be pursued as a direction of further research — we may take advantage of the fact that Pasinetti's scheme represents a *norm*. Thus, insights about the importance of the excluded components can be gained precisely by comparing gross output vector $\boldsymbol{x}_c$ with actual gross output vector $\boldsymbol{x}$ and assessing the deviation of price index vector $\boldsymbol{\phi}_n^T$ from $\boldsymbol{e}^T$. Comparisons along these lines are reported in Tables 5 and 9, as well as Figs. 2 and 3.

prices.[10] For gross output, intermediate and fixed capital inputs, we have, respectively:

$$\boldsymbol{x}_{(0)} = \widehat{\boldsymbol{\mu}}_0 \boldsymbol{x}, \qquad \boldsymbol{X}_{(0)} = \widehat{\boldsymbol{\mu}}_0 \boldsymbol{X}, \qquad \boldsymbol{F}_{k(0)} = \widehat{\boldsymbol{\mu}}_0 \boldsymbol{F}_k \tag{8}$$

Hence, using (8), we may define labour, intermediate and fixed capital input coefficients in constant prices, respectively, as:

$$\boldsymbol{a}_{l(0)}^T = \boldsymbol{l}^T \widehat{\boldsymbol{x}}_{(0)}^{-1} = \boldsymbol{l}^T \widehat{\boldsymbol{x}}^{-1} \widehat{\boldsymbol{\mu}}_0^{-1} = \boldsymbol{a}_l^T \widehat{\boldsymbol{\mu}}_0^{-1} \tag{9}$$

$$\boldsymbol{A}_{(0)} = \boldsymbol{X}_{(0)} \widehat{\boldsymbol{x}}_{(0)}^{-1} = \widehat{\boldsymbol{\mu}}_0 \boldsymbol{X} (\widehat{\boldsymbol{\mu}}_0 \widehat{\boldsymbol{x}})^{-1} = \widehat{\boldsymbol{\mu}}_0 \boldsymbol{X} \widehat{\boldsymbol{x}}^{-1} \widehat{\boldsymbol{\mu}}_0^{-1} = \widehat{\boldsymbol{\mu}}_0 \boldsymbol{A} \widehat{\boldsymbol{\mu}}_0^{-1} \tag{10}$$

$$\boldsymbol{A}_{k(0)} = \boldsymbol{F}_{k(0)} \widehat{\boldsymbol{x}}_{(0)}^{-1} = \widehat{\boldsymbol{\mu}}_0 \boldsymbol{F}_k (\widehat{\boldsymbol{\mu}}_0 \widehat{\boldsymbol{x}})^{-1} = \widehat{\boldsymbol{\mu}}_0 \boldsymbol{F}_k \widehat{\boldsymbol{x}}^{-1} \widehat{\boldsymbol{\mu}}_0^{-1} = \widehat{\boldsymbol{\mu}}_0 \boldsymbol{A}_k \widehat{\boldsymbol{\mu}}_0^{-1} \tag{11}$$

from where we see that constant and current price input matrices are similar (in the sense of Meyer, 2000, p. 255).

Premultiplying both sides of (7) by $\widehat{\boldsymbol{\mu}}_0$, noting that $\boldsymbol{I} = \widehat{\boldsymbol{e}} = \widehat{\boldsymbol{\mu}}_0^{-1} \widehat{\boldsymbol{\mu}}_0$ and using (10)–(11), we can express expenditure system (7) in constant prices:

$$\underbrace{\widehat{\boldsymbol{\mu}}_0 \boldsymbol{x}_c}_{\boldsymbol{x}_{c(0)}} = \underbrace{(\widehat{\boldsymbol{\mu}}_0 \boldsymbol{A} \widehat{\boldsymbol{\mu}}_0^{-1})}_{\boldsymbol{A}_{(0)}} \underbrace{(\widehat{\boldsymbol{\mu}}_0 \boldsymbol{x}_c)}_{\boldsymbol{x}_{c(0)}} + \underbrace{(\widehat{\boldsymbol{\mu}}_0 \boldsymbol{A}_k \widehat{\boldsymbol{\mu}}_0^{-1})}_{\boldsymbol{A}_{k(0)}} \underbrace{(\widehat{\boldsymbol{\mu}}_0 \boldsymbol{x}_c)}_{\boldsymbol{x}_{c(0)}} + \underbrace{\widehat{\boldsymbol{\mu}}_0 \boldsymbol{f}_c}_{\boldsymbol{f}_{c(0)}}$$

obtaining:

$$\boldsymbol{x}_{c(0)} = \boldsymbol{A}_{(0)} \boldsymbol{x}_{c(0)} + \boldsymbol{A}_{k(0)} \boldsymbol{x}_{c(0)} + \boldsymbol{f}_{c(0)} \tag{12}$$

Instead, *postmultiplying* price index system (6) by $\widehat{\boldsymbol{\mu}}_0^{-1}$ and using (9)–(11), we can compute a natural price index system in terms of constant price input coefficient matrices:

$$\underbrace{\boldsymbol{\phi}_n^T \widehat{\boldsymbol{\mu}}_0^{-1}}_{\boldsymbol{p}^T} = \underbrace{(\boldsymbol{\phi}_n^T \widehat{\boldsymbol{\mu}}_0^{-1})}_{\boldsymbol{p}^T} \underbrace{(\widehat{\boldsymbol{\mu}}_0 \boldsymbol{A} \widehat{\boldsymbol{\mu}}_0^{-1})}_{\boldsymbol{A}_{(0)}} + \underbrace{(\boldsymbol{\phi}_n^T \widehat{\boldsymbol{\mu}}_0^{-1})}_{\boldsymbol{p}^T} \underbrace{(\widehat{\boldsymbol{\mu}}_0 \boldsymbol{A}_k \widehat{\boldsymbol{\mu}}_0^{-1})}_{\boldsymbol{A}_{k(0)}} + w \underbrace{\boldsymbol{a}_l^T \widehat{\boldsymbol{\mu}}_0^{-1}}_{\boldsymbol{a}_{l(0)}^T}$$

obtaining:

$$\boldsymbol{p}^T = \boldsymbol{p}^T \boldsymbol{A}_{(0)} + \boldsymbol{p}^T \boldsymbol{A}_{k(0)} + w \boldsymbol{a}_{l(0)}^T \tag{13}$$

In order to separate the *scale* of activity from sectoral *proportions* in final uses, we define a vector of *per-capita* consumption coefficients:

$$\boldsymbol{c} = \frac{\boldsymbol{f}_{c(0)}}{\bar{N}} \tag{14}$$

where $\bar{N}$ stands for the labour force of the economy.[11]

The final step to obtain an analytical quantity system consists in acknowledging that the economy will reproduce gross outputs supporting final uses for those currently employed, rather than for the entire labour force:

$$\boldsymbol{q} = \boldsymbol{A}_{(0)} \boldsymbol{q} + \boldsymbol{A}_{k(0)} \boldsymbol{q} + \boldsymbol{c} N \tag{15}$$

Eqs. (15) represent a quantity system, where N stands for the quantity of labour effectively used in all production activities, i.e., employment. Note that, in general, $\boldsymbol{f}_{c(0)} \neq \boldsymbol{c} N$ unless $N = \bar{N}$, i.e., the labour force is fully employed.[12]

2.2. Duality and full-employment

Solving for $\boldsymbol{p}^T$ in (13) and for $\boldsymbol{q}$ in (15), allows to specify a *dual* set of (natural) price indices and quantities:

$$\boldsymbol{p}^T = w \boldsymbol{a}_{l(0)}^T (\boldsymbol{I} - \boldsymbol{A}_{(0)} - \boldsymbol{A}_{k(0)})^{-1} \tag{16}$$

$$\boldsymbol{q} = (\boldsymbol{I} - \boldsymbol{A}_{(0)} - \boldsymbol{A}_{k(0)})^{-1} \boldsymbol{c} N \tag{17}$$

Crucially, from (16) it is possible to define:

$$\boldsymbol{\eta}^T = \boldsymbol{a}_{l(0)}^T (\boldsymbol{I} - \boldsymbol{A}_{(0)} - \boldsymbol{A}_{k(0)})^{-1} \tag{18}$$

as a vector of vertically *hyper*-integrated labour coefficients, with each η_i synthesising the (concurrent and coexisting) labour requirements to reproduce a unit of consumption in sector i.[13]

In compact form, natural prices (16) and final outputs $\boldsymbol{f}$ compatible with gross output vector $\boldsymbol{q}$ — as determined by (17) — may be written as:

$$\boldsymbol{p}^T = w \boldsymbol{\eta}^T \tag{19}$$

$$\boldsymbol{f} = \boldsymbol{c} N \tag{20}$$

Equation systems (19)–(20) represent the valuation and reproduction aspects, respectively, for the same *structural* configuration of the economy. Their connection emerges when formulated as price and quantity sides of a *closed* I-O system (Leontief, 1937; Pasinetti, 1993):

$$\begin{bmatrix} \boldsymbol{p}^T & w \end{bmatrix} \begin{bmatrix} \widehat{\boldsymbol{0}} & \boldsymbol{c} \\ \boldsymbol{\eta}^T & 0 \end{bmatrix} = \begin{bmatrix} \boldsymbol{p}^T & w \end{bmatrix} \tag{21}$$

$$\begin{bmatrix} \widehat{\boldsymbol{0}} & \boldsymbol{c} \\ \boldsymbol{\eta}^T & 0 \end{bmatrix} \begin{bmatrix} \boldsymbol{f} \\ N \end{bmatrix} = \begin{bmatrix} \boldsymbol{f} \\ N \end{bmatrix} \tag{22}$$

Besides the relations expressed by (19)–(20), the last equation of system (21) is $w = \boldsymbol{p}^T \boldsymbol{c}$, requiring that the value of per-capita consumption equals the uniform wage rate of the economy, whilst the last equation of system (22) is $N = \boldsymbol{\eta}^T \boldsymbol{f}$, implying that the hyper-integrated labour content of final output coincides with the economy's employment. Note how the uniformity of wage rate w in price system (21) reflects "the basic principle of equal rewards for equal amounts of homogeneous labour" (Pasinetti, 1981, p. 132) at the core of Pasinetti's normative view.

While the structural configuration of the economy is given by the shared matrix of coefficients:

$$\boldsymbol{M} = \begin{bmatrix} \widehat{\boldsymbol{0}} & \boldsymbol{c} \\ \boldsymbol{\eta}^T & 0 \end{bmatrix} \tag{23}$$

to see the explicit connection between prices and quantities, it is necessary to solve dual systems (21)–(22). To understand the formal nature of the problem, it is useful to reorder terms in (21)–(22), expressing each as a system of linear homogeneous equations:

$$\begin{bmatrix} \boldsymbol{p}^T & w \end{bmatrix} \begin{bmatrix} \boldsymbol{I} & -\boldsymbol{c} \\ -\boldsymbol{\eta}^T & 1 \end{bmatrix} = \begin{bmatrix} \boldsymbol{0}^T & 0 \end{bmatrix} \tag{24}$$

$$\begin{bmatrix} \boldsymbol{I} & -\boldsymbol{c} \\ -\boldsymbol{\eta}^T & 1 \end{bmatrix} \begin{bmatrix} \boldsymbol{f} \\ N \end{bmatrix} = \begin{bmatrix} \boldsymbol{0} \\ 0 \end{bmatrix} \tag{25}$$

[10] In terms of the variables of the `STANI4_2016` database used for empirical computations (see Section 3 below), it amounts to computing `PRDK/PROD` for each industry as a diagonal element of $\widehat{\boldsymbol{\mu}}_0$.

[11] To simplify the analysis, we assume that total population coincides with the labour force.

[12] Please see Appendix A for a clarification of the relationship between quantity system (15) and a traditional dynamic I-O model.

[13] Strictly speaking, each element η_i of vector $\boldsymbol{\eta}^T$ will not, in general, correspond to hyper-integrated labour coefficient $l_i^{(i)}$ in Pasinetti (1988, pp. 127–8). Besides the treatment of fixed capital as a joint product in Pasinetti (1988), note that — using Pasinetti's notation — $l_i^{(i)} = \boldsymbol{a}_l^T (\boldsymbol{B} - (1+g+r_i)\boldsymbol{A})^{-1} \boldsymbol{e}_i$, represents the labour requirements to self-replace and expand the productive capacity of growing subsystem i at steady rate $g + r_i$. That is, whilst $l_i^{(i)}$ synthesises system-wide labour requirements (per unit of final uses) of a *normative* growth path, $\eta_i = \boldsymbol{a}_{l(0)}^T (\boldsymbol{I} - \boldsymbol{A}_{(0)} - \boldsymbol{A}_{k(0)})^{-1} \boldsymbol{e}_i$ captures comprehensive labour requirements (per unit of final uses) of an *effective* growth path. For details on this distinction, please see Garbellini and Wirkierman (2014c, section 2.2).

A necessary condition for the existence of non-trivial (i.e., different from zero) solutions for each system (24)–(25) is:

$$\det(\boldsymbol{I}-\boldsymbol{M}) = \det\begin{bmatrix}\boldsymbol{I} & -\boldsymbol{c}\\ -\boldsymbol{\eta}^T & 1\end{bmatrix} = 0 \tag{26}$$

i.e., the *same* condition is required for both price and quantity sides of this closed I-O scheme, and depends only on the *structural* configuration of the economy. Developing expression (26), we get:

$$\det(\boldsymbol{I})[1-(-\boldsymbol{\eta}^T)\boldsymbol{I}^{-1}(-\boldsymbol{c})] = 0$$

But given that $\det(\boldsymbol{I}) = 1^n \neq 0$, the condition requires that $\boldsymbol{\eta}^T\boldsymbol{c} - 1 = 0$, that is:

$$\boldsymbol{\eta}^T\boldsymbol{c} = \sum_{i=1}^{n}\eta_i c_i = 1 \tag{27}$$

Note, from (19), that natural prices are determined by hyper-integrated labour coefficients ($\boldsymbol{\eta}^T$), whilst the sectoral distribution of final outputs in (20) is determined by per-capita consumption coefficients ($\boldsymbol{c}$). Thus, expression (27) *binds* the key determinant of natural prices *to* that of final outputs in a precise way, in order to have non-trivial solutions for price and quantity systems (21)–(22).[14]

Moreover, given that the matrix of structural coefficients $\boldsymbol{M}$ in (23) is non-negative (as $\boldsymbol{c} > \boldsymbol{0}$ and $\boldsymbol{\eta}^T > \boldsymbol{0}^T$) and irreducible,[15] the duality between prices and quantities may be seen by noting that:

> "when condition [(26)] is satisfied [. . .], unity is an eigenvalue of the [non-negative] coefficients matrix of the two systems [(21)–(22)]"
>
> Pasinetti (1977, p. 59)

i.e., a solution for *positive* prices and quantities may be *computed* as the left and right eigenvectors, respectively, associated to the *unitary* eigenvalue of the *same* structural coefficient matrix $\boldsymbol{M}$, following the approach pioneered by Brody (1970).[16]

However, given that any scalar multiple of the obtained solutions for positive prices and quantities will also solve systems (21)–(22), only n elements of the $(n+1)$ vectors $\begin{bmatrix}\boldsymbol{p}^T & w\end{bmatrix}$ and $\begin{bmatrix}\boldsymbol{f} & N\end{bmatrix}^T$ are determined. Solutions for *relative* natural prices and final outputs are, thus, obtained. Following Pasinetti (1993, p. 18), we fix the available working population $N = \bar{N}$ and the money wage rate $w = \bar{w}$, implying that the physical quantities obtained should be compatible with the employment of the entire labour force, and commodity prices should be measured in terms of labour commanded.

Fixing $N = \bar{N}$ implies that the positive solution for final outputs in system (22) is the one compatible with full employment, so condition (27) is necessary to fulfil the full employment requirement of an *equilibrium situation* (Pasinetti, 1981, p. 48). Only if (27) is satisfied, the balance between final *output* and final *demand* in each (hyper-integrated) sector is compatible with the reproduction (and employment) of the given labour force $\bar{N}$.

In fact, each term $\eta_i c_i$ in (27) represents the *proportion* of the labour force required by the (hyper-integrated) production process of industry i. Crucially, it does not *only* concern employment of that industry, but of *all* industries (directly or indirectly) required to produce each unit of commodity i for consumption purposes. Thus, if (27) holds, the sum of these employment shares exhausts the labour force, obtaining full employment.

In this way, multiplying $\eta_i c_i$ by the size of the labour force gives us employment in (hyper-integrated) sector i:

$$E_i = \eta_i c_i \bar{N} \tag{28}$$

In general, though, the structural coefficients of matrix $\boldsymbol{M}$ in (23) are obtained from empirical data and, as such, need not (and probably will not) comply with condition (27). Thus, an equilibrium solution requires (27) to hold, but coefficients extracted from empirical data imply that (27) will hold only by a *fluke*. What is the way out of this *impasse*?

There are, at least, two routes.

On the one hand, *if* full employment is to be verified, then one of the *coefficients* of matrix $\boldsymbol{M}$ (23) becomes *endogenous*. For example, by choosing c_i such that:

$$c_i^* = \frac{1-\sum_{j\neq i}\eta_j c_j}{\eta_i} \tag{29}$$

(per-capita) consumption coefficient c_i is determined by all other *given* coefficients in order to comply with (27).

The intuition behind (29) may be seen by focusing on the formulation of the quantity side (22) as a set of linear *homogeneous* equations in (25): even when one degree of freedom has been granted (by taking the labour force as given), the structural matrix $(\boldsymbol{I}-\boldsymbol{M})$ cannot be of full rank (n+1), so one of the columns (or rows) must be linearly dependent. This implies that (at least) one of the coefficients becomes endogenous, to obtain a non-trivial solution that complies with full employment. Hence, if technical coefficients — captured by $\boldsymbol{\eta}^T$ in the first n columns — are given, then it will be the last column which will adjust:

> "This [$(n+1)$th.] column clearly can be linearly dependent on the others, since it contains a set of magnitudes concerning consumption, which are not technically given and which can be adjusted"
>
> Pasinetti (1977, p. 56)

Therefore, if empirical coefficients do not comply with (27), it is possible to select one final consumption coefficient, e.g. that corresponding to general government services, in order to see the required adjustment in public expenditure to reach full employment (Parrinello, 1966, p. 214).

On the other hand, *if* all technical and (per-capita) consumption coefficients are taken as given, non-fulfilment of (27) does not imply the non-existence of meaningful solutions. Due to the mathematical structure of the problem (Pasinetti, 1993, pp. 22–3), for given $N = \bar{N}$ and $w = \bar{w}$, expressions:

$$\boldsymbol{p}^T = \bar{w}\boldsymbol{\eta}^T \tag{30}$$

$$\boldsymbol{f} = \boldsymbol{c}\bar{N} \tag{31}$$

still provide meaningful solutions for prices and quantities, respectively.

Therefore, to quantify the distance between current expenditure and full employment income, we may compute the aggregate value of final output $\boldsymbol{f}$ in (31) using natural prices $\boldsymbol{p}^T$ in (30):

$$\boldsymbol{p}^T\boldsymbol{f} = \bar{w}\boldsymbol{\eta}^T\boldsymbol{c}\bar{N} = \boldsymbol{\eta}^T\boldsymbol{c}\cdot\bar{w}\bar{N}$$

which can be written as:

$$\frac{\text{Final expenditure}}{\text{Full employment income}} = \frac{\boldsymbol{p}^T\boldsymbol{f}}{\bar{w}\bar{N}} = \alpha \tag{32}$$

where $\alpha = \boldsymbol{\eta}^T\boldsymbol{c}$.

Coefficient α is an expenditure/full employment income gap. If $\alpha < 1$, final expenditure is short of full employment income, whereas the reverse occurs if $\alpha > 1$. Instead, when $\alpha = 1$, full employment condition (27) holds.

[14] The *economic* meaning of condition (27) is discussed below.

[15] The $(n+1)\times(n+1)$ matrix $\boldsymbol{M}$ is irreducible *if and only if* $(\boldsymbol{I}+\boldsymbol{M})^n > \boldsymbol{0}$ (Minc, 1988, p. 6). In this case:

$$(\boldsymbol{I}+\boldsymbol{M})^n = \begin{bmatrix}\boldsymbol{I}+\sum_{s=0}^{n-2}2^s\boldsymbol{c}\boldsymbol{\eta}^T & 2^{n-1}\boldsymbol{c}\\ 2^{n-1}\boldsymbol{\eta}^T & 2^{n-1}\end{bmatrix} > \boldsymbol{0}$$

as $\boldsymbol{c} > \boldsymbol{0}$ and $\boldsymbol{\eta}^T > \boldsymbol{0}^T$, so that also $\boldsymbol{c}\boldsymbol{\eta}^T > \boldsymbol{0}$.

[16] That is, eigenvectors $\boldsymbol{v}^T$ and $\boldsymbol{u}$ in eigensystems $\boldsymbol{v}^T\boldsymbol{M} = \lambda\boldsymbol{v}^T$ and $\boldsymbol{M}\boldsymbol{u} = \lambda\boldsymbol{u}$, for $\lambda = 1$, provide the solution for *positive* prices and quantities, respectively. This result is due to the Perron–Frobenius theorem (Meyer, 2000, p. 673).

2.3. Structural dynamics

The deeper implications and potential of the framework introduced by Pasinetti (1981, 1993) emerge in full when considering the time evolution of magnitudes. At this point, a methodological distinction between exogenous and endogenous elements of the system is needed. Pasinetti insightfully notes that:

> "[T]he distinction between unknowns and data does not coincide, and must not be confused with, the distinction between variables and constants. Unknowns may well be constant, in our theoretical scheme, and data may well be variables".
>
> Pasinetti (1981, p. 78)

For example, the money wage rate has been chosen as the numéraire of price system (21), and it will be exogenous (i.e., data), but changing through time (i.e., variable). The same applies to the evolution of the labour force, which sets the scale of quantity system (22). At a sectoral level, technical and (per-capita) consumption coefficients are assumed to change at given, *steady* but uneven rates.[17] Hence, structural dynamics of per-capita consumption coefficients and the labour force are given by:

$$c_i(t) = c_i(0)e^{r_i t} \tag{33}$$

$$\bar{N}(t) = \bar{N}(0)e^{gt} \tag{34}$$

where r_i is the rate of change in per-capita consumption of product i and g is the rate of change of the labour force. Instead, structural dynamics of (hyper-integrated) labour coefficients and the money wage rate are given by:

$$\eta_i(t) = \eta_i(0)e^{-\rho_i t} \tag{35}$$

$$\bar{w}(t) = \bar{w}(0)e^{\sigma_{\bar{w}} t} \tag{36}$$

where ρ_i is the rate of change of (hyper-integrated) labour productivity in sector i and $\sigma_{\bar{w}}$ is the rate of change of the (average) money wage rate.

With (33)–(36), we can substitute in (28), (30) and (31) to obtain solutions for the key three endogenous variables (i.e., unknowns) of the system, i.e., *natural* prices, final outputs and employment:

$$p_i(t) = \bar{w}(0)\eta_i(0)e^{(\sigma_{\bar{w}} - \rho_i)t} \tag{37}$$

$$f_i(t) = c_i(0)\bar{N}(0)e^{(g+r_i)t} \tag{38}$$

$$E_i(t) = \eta_i(0)c_i(0)\bar{N}(0)e^{(g+r_i-\rho_i)t} \tag{39}$$

In order to understand the implications of the process of structural dynamics unfolding in an industrial economy, Pasinetti focuses on the dynamic counterpart of (27), the macroeconomic condition for a *dynamic equilibrium* situation[18]:

$$\boldsymbol{\eta}^T(t)\boldsymbol{c}(t) = \sum_{i=1}^{n} \eta_i(0)c_i(0)e^{(r_i-\rho_i)t} = 1 \tag{40}$$

Expression (40) "represents the *effective demand condition* for keeping full employment through time" (Pasinetti, 1981, p. 86), and it summarises the job creation and displacement taking place across sectors of the economy. To see this, note that each term in (40) represents the (hyper-integrated) sector i's share of the labour force:

$$\lambda_i(t) = \frac{E_i(t)}{\bar{N}(t)} = \eta_i(t)c_i(t) \tag{41}$$

so that, even if there is full employment at $t = 0$, the passage of time for condition (40) implies[19]:

$$\frac{d}{dt}\left(\sum_{i=1}^{n} \lambda_i(t)\right) = \sum_{i=1}^{n} \dot{\lambda}_i(t) = \sum_{i=1}^{n} (r_i - \rho_i)\lambda_i(t) = \frac{d}{dt}(1) = 0$$

that is:

$$\sum_{i=1}^{n} (r_i - \rho_i)\lambda_i(t) = 0 \tag{42}$$

i.e., the share of employment in (hyper-integrated) sector i, $\lambda_i(t)$, will increase (decrease) when per-capita consumption demand is expanding faster (slower) than productivity, so that $r_i - \rho_i > 0$ ($r_i - \rho_i < 0$). Hence:

> "even if we start from the hypothesis that total full employment is in some way maintained over time [...] the maintenance of full employment at a global level requires a continuous process of re-proportioning of employment at the sectoral level"
>
> Pasinetti (1993, p. 51)

Therefore, the interplay between the structure of demand and productivity has far-reaching implications for *technological unemployment* in actual industrial economies: the fast pace of technological progress reflected in high values of ρ_i needs to be counteracted by corresponding increases in r_i, if (40) is to be maintained.

But *can* (40) be maintained for all time periods, *if* r_i and ρ_i are *steady*? In *exact* terms, it simply *cannot*. For if we assume (40) holds for time period t, in $t+1$ we would have:

$$\begin{aligned}\sum_{i=1}^{n} \lambda_i(t+1) &= \sum_{i=1}^{n} \eta_i(0)c_i(0)e^{(r_i-\rho_i)(t+1)} \\ &= \sum_{i=1}^{n} \lambda_i(t)e^{(r_i-\rho_i)} \\ &= \lambda_1(t)e^{(r_1-\rho_1)} + \cdots + \lambda_n(t)e^{(r_n-\rho_n)}\end{aligned}$$

For a sum of exponential functions to equal 1 (i.e., a constant) *across* time periods, we need $r_1 = \rho_1, \ldots, r_n = \rho_n$, so that each exponential becomes 1 (as each exponent equals 0) and $\lambda_1(t) + \cdots + \lambda_n(t) = 1$, which is precisely (40). Hence, only when there are *no* structural dynamics of employment (as $r_i = \rho_i$ for all i) a dynamic equilibrium may be maintained over time in *exact* terms (see also Cozzi, 1969, p. 45).

However, given that structural dynamics of employment is a pervasive feature of *actual* economies, condition (40) represents a *norm*, a benchmark path of full employment which will *not* be generally verified. Therefore, rather than focusing on $\lambda_i(t)$, we can define:

$$\theta_i(t) = \frac{\lambda_i(t)}{\sum_{j=1}^{n} \lambda_j(t)} \tag{43}$$

which represents the (hyper-integrated) sector i's share of total, *actual* employment in the economy. The sectoral gap between demand and productivity ($r_i - \rho_i$) will determine the changes in $\theta_i(t)$, which will increase (decrease) when sector i is expanding (contracting) its share of employment. Note that, by construction, $\sum_{i=1}^{n} \theta_i(t) = 1$.

Employment shares $\theta_i(t)$ in (43), together with rates of change ρ_i in (35), may be combined to define an economy-wide indicator of productivity performance:

$$\rho^*(t) = \sum_{i=1} \theta_i(t)\rho_i \tag{44}$$

which *resembles* Pasinetti's 'standard' rate of productivity growth (Pasinetti, 1981, pp. 101–4).[20]

[17] The assumption of steady rates of change is introduced to simplify the presentation. See the detailed discussion in Pasinetti (1981, pp. 81–3).

[18] Expression (40) can be obtained by combining (33) with (35), and summing across sectors.

[19] The time derivative of variable $x(t)$ is indicated by $\dot{x}(t) = dx(t)/dt$.

[20] Pasinetti defines ρ^* using $\lambda_i(t)$ in (41) — rather than $\theta_i(t)$ in (43) — as sectoral weights. In this way, "when effective demand condition [(40)] is

As a measure of productivity changes, ρ^* is different from other synthetic indicators. It aggregates across hyper-integrated sectors, rather than industries, as is the case for 'real' value added per unit of labour. It considers both labour *and* fixed-capital *flows* (which are vertically integrated in terms of labour requirements), so it is a 'total' productivity measure, such as Total Factor Productivity (TFP) growth. However, differently from TFP, ρ^* is obtained from the *expenditure* — rather than *income* — side of the system, and it considers fixed capital as produced means of production, rather than as a non-produced, primary factor (Rampa, 1981a,b).

Moreover, ρ^* may be used to evince the dynamic aspects of the duality between *natural* prices and outputs in Pasinetti's scheme. To see this, consider (37) to compute the rate of change of the natural price of product i:

$$\frac{\dot{p}_i(t)}{p_i(t)} = \sigma_{\bar{w}} - \rho_i$$

and combine these rates of change with the *same* weights (43) used to define ρ^* in (44). In this case, though, $\theta_i(t)$ represents the final expenditure share of product i in the wage rate.[21] Hence, a weighted average of price changes would be given by:

$$\begin{aligned}\sigma_A &= \sum_{i=1}^{n} \theta_i(t) \cdot (\sigma_{\bar{w}} - \rho_i) \\ &= \sum_{i=1}^{n} \theta_i(t)\sigma_{\bar{w}} - \sum_{i=1}^{n} \theta_i(t)\rho_i \\ &= \sigma_{\bar{w}} - \rho^* \end{aligned} \tag{45}$$

where σ_A represents the "general rate of [natural] price inflation" (Pasinetti, 1981, p. 164).

Duality leads to using the same weights $\theta_i(t)$ to compute (44) and (45), representing employment and (per-capita) expenditure shares, respectively. Expression (45) connects productivity (ρ^*), inflation (σ_A) and distribution ($\sigma_{\bar{w}}$) in Pasinetti's scheme. If the average wage rate expanded vis-à-vis economy-wide productivity ($\sigma_{\bar{w}} = \rho^*$), there would be no inflation ($\sigma_A = 0$). Moreover, by taking $\sigma_{\bar{w}}$ as data in (36) and computing ρ^* from (44), it is possible to obtain σ_A from (45). Hence, wage rate and productivity dynamics *imply* an economy-wide rate of (natural) price inflation.

To complete the description of aggregate system evolution, interpreting weight $\theta_i(t)$ in (43) as the expenditure share of product i in the wage rate, we may define an economy-wide indicator of (per-capita) consumption dynamics:

$$r^*(t) = \sum_{i=1}^{n} \theta_i(t) r_i \tag{46}$$

which, *in general*, will not coincide with $\rho^*(t)$ in (44). However, inspecting the definition of (per-capita) consumption coefficients $\mathbf{c}$ in (14), note that they measure net output (final consumption expenditure) per unit of *system-wide* labour force. Hence, when aggregating across sectors, it *proxies* the concept of labour productivity. In fact, for a system which is *always* in a situation of full employment, $\rho^*(t) = r^*(t)$.[22]

under-satisfied, the proportion of the total labour force that remains unemployed is [...] attributed a zero rate of productivity growth" (Pasinetti, 1981, p. 104). Instead, in order to make cross-country comparisons, we prefer to distinguish between productivity changes of the *employed* labour force — in (44) — and the full employment gap in value terms, measured by α in (32), i.e., the difference between final expenditure and full-employment income.

[21] From (30), note that $p_i(t) = \bar{w}(t)\eta_i(t)$, so $\eta_i(t) = p_i(t)/\bar{w}(t)$. Substituting in (40) implies that: $\sum_{i=1}^{n} \frac{p_i(t)c_i(t)}{\bar{w}(t)} = 1$.

[22] Starting from (42), this can be seen by noting that: $\sum_{i=1}^{n} \lambda_i(t) r_i = \sum_{i=1}^{n} \lambda_i(t)\rho_i$, i.e., $r^*(t) = \rho^*(t)$ because $\theta_i(t) = \lambda_i(t)$ in a full employment situation.

Table 1
OECD Databases used to articulate a unified dataset.

OECD Code	Description
STANI4_2016	Structural Analysis Database (STAN) SNA08, ISIC Rev. 4 Edition
IOTS	Input–Output Tables (IOTs) Database, ISIC Rev. 3 Edition
IOTSI4_2018	Input–Output Tables (IOTs) Database, ISIC Rev. 4 Edition
ALFS	Annual Labour Force Statistics Database
Annual National Accounts Database:	
SNA_TABLE4	PPPs and exchange rates
SNA_TABLE8A	Capital Formation by Activity ISIC Rev. 4

Note: all OECD databases can be freely accessed at https://stats.oecd.org/.

Quite importantly, before heading into the empirical exploration, note that the synthetic productivity growth indicator $\rho^*(t)$ in (44) depends on the notion of net output adopted. In this case, this is given by final consumption. However, had net output also included elements from vector $\boldsymbol{f}_z$ in (1), then productivity would have changed, because the (hyper-integrated) labour content of (per-capita) final consumption tends to differ from the labour content of exports, for example.

2.4. An empirical roadmap

Starting from a set of inter-industry accounting identities, different aspects of Pasinetti's framework have been discussed. In Section 3 below, we illustrate how the framework may be applied to analyse the structural dynamics of actual industrial economies. In particular, we will:

(i) Compute the adjustment in the (per-capita) consumption coefficient (29) required to reach full employment, i.e., to comply with condition (27);
(ii) Quantify the gap between final expenditure and full employment income, measured by (32);
(iii) Provide a stylised *aggregate* account of the evolution of quantities and prices, using (34), (36) and (44)–(46);
(iv) Compare the emerging trends of job creation and displacement across countries and (hyper-integrated) sectors, by means of (42) and (43);
(v) Assess the correspondence between natural and observed *dynamics* of prices and outputs.

3. An empirical exploration

3.1. Dataset characteristics and preparation

The empirical application has considered six advanced industrial economies — Germany (DEU), France (FRA), Italy (ITA), United Kingdom (GBR), Japan (JPN) and the United States (USA) — between 1995 and 2015.[23] Table 1 enumerates different OECD databases that have been articulated to obtain a unified dataset.

The motivation to choose the 'Group of Six (G6)' is twofold. First, despite having lost 12.7 percentage points of their share in global income between 1995 and 2015, they still represented 43.4% of global value added in 2018.[24] Second, because of data (un)availability: it would have been relevant to include, for example, China, but this country is not amongst those in the STANI4_2016 database.

To operationalise the expenditure and income balances (1) and (2), respectively, a sequence of data preparation procedures has been

[23] Hereinafter, ISO3 country codes DEU, FRA, ITA, GBR, JPN and USA will be used when referring to each country.

[24] Measured at constant 2015 prices in USD. See, for example: https://unstats.un.org/unsd/snaama/.

carried out. First, a common minimum denominator to render compatible industry-level data across countries and OECD databases has been obtained. Table B.11 in Appendix B specifies the industry classification scheme adopted.

Second, missing values from the STANI4_2016 database for selected combinations of variables, industries and countries (GBR, USA and JPN, in particular) have been estimated, mostly by recourse to proportional methods applied on available data at a higher level of sectoral aggregation. Third, in order to separate residential construction from the rest of Gross Fixed Capital Formation (GFCF, hereinafter), the share of dwellings in GFCF has been estimated for each country and year. This allowed to complete vector $\boldsymbol{f}_c$ in (1).

Next, a series of matrices of domestically produced GFCF flows at basic prices by product of origin *and* industry of destination have been estimated using the RAS bi-proportional matrix updating method (Bacharach, 1965). Row and column margins from Input–Output (IOTS and IOTSI4_2018) and STANI4_2016 data have been used, as well as data on the row structure of transactions in (broad) fixed capital categories, extracted from the OECD 'Capital Formation by Activity' database. In this way, matrix $\boldsymbol{F}_k$ in (1) could be obtained. To render compatible IOTS, IOTSI4_2018 and STANI4_2016 databases, Input–Output tables have been adjusted to industry gross output and gross value added figures from the STANI4_2016 database, again using the RAS method.[25] Finally, current price matrices and vectors have been expressed in prices of a base year. For this, we have built time series of price indices for gross output by computing the ratio between variables PRDK and PROD from the STANI4_2016 database, for each country × year × industry combination.

As an outcome, we obtained a series of Input–Output matrices for domestic output at basic (constant, base-year) prices, disaggregated into $n = 27$ industries, including a matrix of GFCF flows (separating and adding dwellings to final uses) for each country × year combination.

As regards labour inputs, the vector of industry employment was obtained from the STANI4_2016 database, whereas the ratio between the aggregate labour force and total employment (measured in 10^3 persons) — extracted from the ALFS database — has been used to obtain an estimate of the labour force measured in 10^6 hours.

3.2. Equilibrium and distance to full employment income

As discussed in Section 2, empirical coefficients would satisfy full employment condition (27) only by a fluke. A first option is to compute the required adjustment in consumption according to (29).

To this end, we chose the consumption coefficient of public administration services. It may be conceived of as a *stabilising* demand source, measuring the required public expenditure to reach full employment (Parrinello, 1966, p. 214). In an economy facing unemployment, the implied adjustment will be an expansion of general government consumption. But the employment effects of such expansion will depend on the hyper-integrated labour coefficient of the public administration industry in each country. Hence, the inter-industry structure of government purchases becomes relevant to assess the potential aggregate effects of Keynesian expenditure policy. Moreover, given the hyper-integrated nature of the analysis, employment expansion will occur across *all* (direct and indirect) supplier industries.

This counterfactual clarifies why Pasinetti labelled condition (27) — and its dynamic counterpart (40) — as an "effective demand" condition: it is precisely when (27) is *not* satisfied that we can measure the required adjustment in final expenditure to reach full employment (Pasinetti, 1974, pp. 41–2), which renders explicit the fact that "production is, in this sense activated, or, as is also said, generated by effective demand" (Pasinetti, 1993, p. 20).

Table 2
Adjustment in consumption coefficient of government sector to reach full employment.
Source: Author's computation based on OECD Input–Output, STAN and National Accounts Databases.

(in base-year PPP-USD per hour)

ISO	Sector	1995		2015	
		c_i	c_i^*	c_i	c_i^*
DEU	84GOV	2.90	12.39	4.35	21.69
FRA	84GOV	4.36	14.48	4.51	19.68
GBR	84GOV	2.70	14.27	2.91	14.11
ITA	84GOV	3.48	18.22	3.13	20.60
JPN	84GOV	1.98	4.88	2.69	9.74
USA	84GOV	6.35	14.05	7.68	17.51

Notes: Base year is 2010. Exchange rate of the base year is the Purchasing Power Parity (PPP) for private consumption expenditure. Coefficient c_i is computed according to (14), c_i^* according to (29).

Table 2 reports the actual (c_i) and required (c_i^*) consumption coefficient of public administration services in order to reach full employment. The coefficient is measured in constant USD per (labour-force) hour, rendered comparable across countries and years using Purchasing Power Parities (PPP) for private consumption expenditure of the base year (2010).[26]

In all cases, actual government final consumption is *below* the level compatible with full employment. The USA is the country with the highest value of c_i across time, which points to the comparative importance of government in final consumption. Between 1995 and 2015, c_i increased in all countries but ITA, evincing its contraction of government expenditure per work hour in *real* terms. In contrast, DEU increased its *actual* value of c_i by almost 50%. ITA is also the country that requires the highest injection (measured by $c_i^* - c_i$) to close its unemployment gap via a public intervention, suggesting higher persistent unemployment and/or inter-industry requirements of public administration less conducive to employment creation. On the contrary, JPN and the USA are the economies requiring the *lowest* public injection to reach full employment, pointing to their *relative* autonomy in pursuing fiscal policy.

Notably, in all countries but GBR the size of the required expenditure expansion to reach full employment increased between 1995 and 2015, and it has raised the most in DEU and FRA. In fact, in order to close its unemployment gap, DEU would require a (per-capita) consumption coefficient of government services (c_i^*) higher than ITA, in absolute terms. How may this be possible, if DEU has had the *highest* increase in its *actual* value of c_i? The answer lies in the structural change of final uses between 1995 and 2015.

Table 3 reports the proportional distribution of final uses across countries. Recall from expenditure balance (1) that final uses consist of final consumption $\boldsymbol{f}_c$ (which includes consumption of durables and dwellings, i.e., residential construction) and other final uses $\boldsymbol{f}_z$ (including exports and changes in inventories).[27]

[25] Incidentally, this updating process implied approximating a translation from ISIC Rev. 3 to ISIC Rev. 4 industries in those Input–Output tables for years before 2005.

[26] Purchasing power parity (PPP) conversion rates have been applied to make constant local currency prices internationally comparable. Clearly, applying *scalar* rates of currency conversion to *sectoral* magnitudes is, at best, an approximation for the accurate comparison of value over space at a certain point in time. Ideally, solving for a system of endogenous conversion rates *and* world prices would have been preferable (Reich, 2001, p. 73), but data requirements to do so go beyond availability. At any rate, PPP imputations are an analytical device to avoid forces determining nominal exchange rates distort comparisons in *real* terms. However, PPPs are subject to stringent assumptions and limitations, e.g. commonly-priced products are not equally representative across countries (see EUROSTAT, 2012, for details).

[27] Recall that, in Pasinetti's scheme, capacity-generating investment in fixed assets, captured by matrix $\boldsymbol{F}_k$ in (1), are considered to be *induced* by the dynamics of final uses.

Table 3
Proportional distribution of final uses.
Source: Author's computation based on OECD Input–Output, STAN and National Accounts Databases.

(share of total final uses in %)

ISO	1995		2015	
	f_c	f_z	f_c	f_z
DEU	76.2	23.8	62.2	37.8
FRA	79.1	20.9	71.8	28.2
GBR	75.0	25.0	74.4	25.6
ITA	74.8	25.2	71.5	28.5
JPN	89.9	10.1	81.5	18.5
USA	90.0	10.0	86.7	13.3

Table 4
Final consumption expenditure to full employment income gap.
Source: Author's computation based on OECD Input–Output, STAN and National Accounts Databases.

(as a proportion of full employment income)

ISO	$\alpha(t)$	
	1995	2015
DEU	0.704	0.641
FRA	0.708	0.665
GBR	0.667	0.710
ITA	0.646	0.645
JPN	0.855	0.791
USA	0.836	0.833

Table 5
Distribution of employment by activating source of final demand and Employment-to-Labour-Force gap.
Source: Author's computation based on OECD Input–Output, STAN and National Accounts Databases.

(columns L_c/L and L_z/L as share of total employment in %; column L/N as share of total labour force in %)

ISO	1995			2015		
	L_c/L	L_z/L	L/N	L_c/L	L_z/L	L/N
DEU	77.4	22.6	90.9	67.3	32.7	95.4
FRA	78.3	21.7	90.4	74.2	25.8	89.6
GBR	73.0	27.0	91.4	75.0	25.0	94.7
ITA	73.2	26.8	88.3	73.2	26.8	88.1
JPN	88.3	11.7	96.9	81.9	18.1	96.6
USA	88.5	11.5	94.4	87.9	12.1	94.7

Table 6
Dynamics of the labour force, per-capita consumption, money wage rate, productivity and the general (natural) price level (1995–2015).
Source: Author's computation based on OECD Input–Output, STAN and National Accounts Databases.

(rates of change in average yearly percentage points)

ISO	g	r^*	$\sigma_{\bar{w}}$	ρ^*	σ_A
DEU	−0.16	0.95	2.03	1.42	0.61
FRA	0.51	0.66	2.49	0.99	1.50
GBR	0.58	1.27	3.31	0.98	2.33
ITA	0.18	0.51	2.55	0.52	2.03
JPN	−0.52	0.83	0.01	1.14	−1.14
USA	0.64	1.39	3.23	1.43	1.81

The most striking feature is the increasing reliance on exports as source of final demand by DEU, reaching almost 38% in 2015. This explains such a high value of c_i^* for DEU in 2015 reported in Table 2: the required size of the consumption coefficient of government services to reach full employment would need to substitute foreign for domestic demand, in order to employ the labour force currently producing output activated by exports.

The higher relative autonomy of JPN and the USA is confirmed by Table 3, as these countries have the lowest proportion of other final uses (though this has sharply increased for JPN between 1995 and 2015). The distribution between consumption and other final uses for GBR in 1995 and 2015 is practically the same, which is reflected in the relative stability of values for this country in Table 2.

Crucially, Table 2 illustrates how Pasinetti's framework of structural dynamics may be used to compare the order of magnitude of the public injection that would be required to reach full employment, had countries the possibility of activating gross output domestically.

A second option to approach the non-fulfilment of condition (27) is to measure the gap between actual final consumption expenditure and the full employment income benchmark, according to α in (32). Table 4 reports this gap.

Being measured as a proportion, $\alpha(t)$ may be directly compared across countries and time periods. In all countries the gap is smaller than one, meaning that final consumption expenditure falls short of full employment income. JPN was the country closest to its benchmark in 1995, but the USA has taken over in 2015. This may be explained by a sizeable *decrease* of $\alpha(t)$ in JPN, rather than the USA narrowing its gap. By 2015, DEU, FRA and ITA had converged towards a similar value of $\alpha(t)$: the gap has sharply widened in DEU and FRA, whilst it has remained almost constant in ITA. Instead, GBR has been the only country where the gap has considerably narrowed.

To better understand the changes in $\alpha(t)$, recalling (14) and (32), it may be decomposed as:

$$\alpha = \boldsymbol{\eta}^T \boldsymbol{c} = \frac{\boldsymbol{\eta}^T \boldsymbol{f}_c}{\bar{N}} = \frac{L_c}{L} \cdot \frac{L}{\bar{N}} \tag{47}$$

where $L_c = \boldsymbol{\eta}^T \boldsymbol{f}_c$ is the employment activated by final consumption expenditure and L represents economy-wide employment. Thus, the employment activated by other final uses will be given by $L_z = L - L_c$. Table 5 reports the elements of decomposition (47).

The sizeable decrease of $\alpha(t)$ in JPN, DEU and FRA may be explained by the increasing weight of foreign demand as an activating source of employment (L_z/L in Table 5). In DEU, the decrease would have been even more pronounced had it not been for the narrowing gap between employment and the labour force (L/N in Table 5). A similar increase in L/N explains the transition to a higher value of $\alpha(t)$ in GBR.

Tables 4 and 5 convey a view of $\alpha(t)$ based on employment and the labour force. From (32), though, it may be seen that $\alpha = \boldsymbol{p}^T \boldsymbol{f}/\bar{w}\bar{N}$. Hence, being a summarising indicator of the effects of changes in the compositional structure of quantities $\boldsymbol{f}$ and (natural) prices $\boldsymbol{p}^T$, the labour force $\bar{N}$ and the average wage rate $\bar{w}$, α does not distinguish between these different sources. To distil these sources of change, aggregate dynamics for each component of $\alpha(t)$ are considered below.

3.3. Aggregate stylised dynamics

Collating the evolution of the labour force, g in (34), aggregate (per-capita) consumption, r^* in (46), the (average) money wage rate, $\sigma_{\bar{w}}$ in (36), (hyper-integrated) labour productivity, ρ^* in (44) and the general (natural) price level, σ_A in (45), Table 6 reports the aggregate outcomes emerging from the structural dynamics of quantities and prices.

While g and $\sigma_{\bar{w}}$ were directly obtained from aggregate data, economy-wide indicators ρ^* and r^* are weighted averages whose *theoretical* formulation — in (44) and (46) above — is in continuous terms. Thus, discrete-time approximations have been obtained by means of Törnqvist indices (Star and Hall, 1976, p. 259–60):

$$\rho^*(t) = \sum_{i=1}^{n} \frac{1}{2}(\theta_i(t) + \theta(0)) \cdot \frac{1}{t}(\ln \eta_i(t) - \ln \eta_i(0)) \tag{48}$$

$$r^*(t) = \sum_{i=1}^{n} \frac{1}{2}(\theta_i(t) + \theta(0)) \cdot \frac{1}{t}(\ln r_i(t) - \ln r_i(0)) \tag{49}$$

Finally, σ_A has been residually computed using (45).

The USA emerges as the economy with fastest expansion of productivity and (per-capita) final consumption (with almost equal growth rates). It represents the main consumption 'engine' of advanced industrial economies. While its labour force expands (and at the highest rate), so does its (average) wage rate. It may be considered as a useful benchmark, in order to compare the evolution of the other five countries in Table 6.

JPN is an ageing economy with a sharply decreasing labour force and deflationary trends. Final consumption expenditure lags behind high productivity growth. As the (average) money wage rate has remained practically constant, productivity increases have reduced the general (natural) price level. It is no surprise that, against this background, JPN was the country with the highest stock of operational industrial robots in the world economy by 2015 (UNCTAD, 2017, p. 47).

Table 6 hints at the variety of European growth regimes, when comparing the cases of GBR, DEU, FRA and ITA. GBR evinced a sustained expansion of final consumption expenditure, together with a sharp increase in its labour force *and* the fastest growth of its (average) money wage rate. Lagging productivity dynamics implied the highest (natural) price inflation rate.

The British growth trajectory contrasts with that followed by DEU, which showed a *contraction* of its labour force,[28] a productivity growth rate second only to the USA but a lagging dynamics of per-capita consumption vis-à-vis productivity, probably related to the sluggish expansion of its (average) money wage rate, resulting in the second lowest (natural) price inflation rate. Hence, as documented by Table 3, a growth path increasingly dependent on foreign demand.

The dynamics of FRA could be said to be half-way between GBR and DEU. While it showed an expansion of its labour force and productivity dynamics similar to that of GBR, its (average) money wage rate and (per-capita) consumption dynamics have been closer to that of DEU, evincing a shift towards foreign final demand as an activating source of output (as confirmed by Table 3). Hence, FRA is at the crossroads between alternative growth regimes.

Finally, the case of ITA depicts a stagnating economy in terms of labour force, productivity and (per-capita) final consumption, despite the relatively fast expansion pace of its (average) money wage rate. As may be seen from Table 3, ITA has *not* deepened its outward orientation (as DEU and FRA have). On the one hand, this points to the negative impact of the reduction of government expenditure in real terms (as reported in Table 2) and, on the other hand, suggests a short-circuit between (average) wage rate growth and final consumption dynamics. For example, wage rate increases might have been unevenly distributed across industries.[29]

In a nutshell, Table 6 illustrates how the empirical application of Pasinetti (1981, 1993) provides an alternative 'growth accounting' framework to traditional TFP growth exercises. However, one of the key features of Pasinetti's approach concerns the possibility of dwelling into the *structural* evolution underlying aggregate accounts.

3.4. Job creation and displacement: demand and productivity dynamics

The analysis of *potential* technological unemployment due to automation by means of dynamic I-O models pioneered by Leontief and Duchin (1986), and further refined — especially in terms of investment hypotheses — by Kalmbach and Kurz (1990), evince the importance of structural dynamics in projecting societal transformations.

A crucial point that Pasinetti's framework brings into the picture is the *unit of analysis* to disaggregate job displacement trends. Each productivity growth coefficient ρ_i in (35) summarises the changes in labour content of all industries (directly and/or indirectly) required to reproduce and expand (or contract) the production of final commodity i. That is, to study the comprehensive — though disaggregated — labour displacement (and creation) effects of technical change "one ought to be concerned with the vertically [hyper-]integrated labour coefficients and how they develop over time" (Kurz et al., 2018, p. 566).

The growth of (per-capita) final consumption at rate r_i in (33) is the force counteracting the labour-saving nature of productivity increases. Recall that, in accordance with (1), final consumption in this context includes consumption by households, general government expenditure and dwellings, i.e., residential construction (which is a component of investment in national accounts).

Thus, as shown in (42), by comparing r_i with ρ_i for each hyper-integrated sector, it is possible to quantify the changes in sectoral employment *shares* triggered by the shifting compositional structure of final consumption and the pace of productivity growth.

Table 7 reports the detailed changes in per-capita consumption and productivity coefficients between 1995 and 2015, whereas Fig. 1 plots the cross-country (simple) average of r_i and ρ_i to visually grasp central tendencies in demand and productivity for each sector.

Fig. 1 hints at several trends. First, in line with Baumol (1967), productivity growth in manufacturing is, with few exceptions, higher than in service sectors. In particular, the fastest pace of productivity increases occurred in Information and Communications Technology (ICT, hereinafter) equipment (26CEQ), electrical equipment (27ELQ), transport equipment (29T30MTR) and Information Technology (IT, hereinafter) and Telecommunication services (58T63ITS). These sectors are both digitally intensive (Calvino et al., 2018) and R&D intensive (Galindo-Rueda and Verger, 2016). Moreover, manufacturing sectors 26CEQ, 27ELQ and 29T30MTR have been increasingly organised as internationally fragmented production processes (Guilhoto et al., 2019, p. 26), which further contributes to accelerating the pace of *domestic* productivity performance.[30]

Second, and as a counterpart to productivity developments, (per-capita) final consumption expenditure (in real terms) has been expanding in (almost all) service products and contracting across most manufacturing ones. In particular, the fastest expansion rates occurred in ICT and electrical equipment (26CEQ and 27ELQ), business services (69T82OBZ), IT and Telecommunication services (58T63ITS), as well as transportation and storage services (49T53TRN). Expanding demand for 26CEQ, 27ELQ and 58T63ITS reflects increasing societal digitalisation between 1995 and 2015, with the associated revolution in logistics (49T53TRN) to supply digitally ordered — but physically delivered — goods.[31]

Changing consumption patterns for *domestic* final output implicitly reflects the relatively higher tradability of manufacturing products with respect to services, in the context of deepening global trade. For example, the sharp decline in (per-capita) consumption of domestically produced textiles and wearing apparel (15T15TEX) hints at the shifting patterns of international specialisation: as one of the most interna-

[28] Even though the labour force *and* employment in DEU expanded in terms of number of persons engaged, the total number of hours worked between 1995 and 2015 remained *almost* constant (an increase of 0.08% per year). Hence, the sharp decline in the average hours worked per person employed and the relatively slower expansion of the labour force vis-à-vis employment (measured in 10^3 persons), implied a *decreasing* (estimated) labour force when measured in 10^6 hours.

[29] Between 1995 and 2002, the dispersion of (conditional) inter-industry wage-rate differentials increased in ITA (Du Caju et al., 2010, p. 6).

[30] Hyper-integrated labour coefficient η_i in (18) quantifies the comprehensive *domestic* labour content of final consumption. Hence, if a firm organises production by *importing* labour through intermediate imports, this will reduce the domestic labour content, increasing productivity.

[31] The increase in the *final* consumption of *business* services (which is, to a greater extent, an intermediate input) deserves to be further explored.

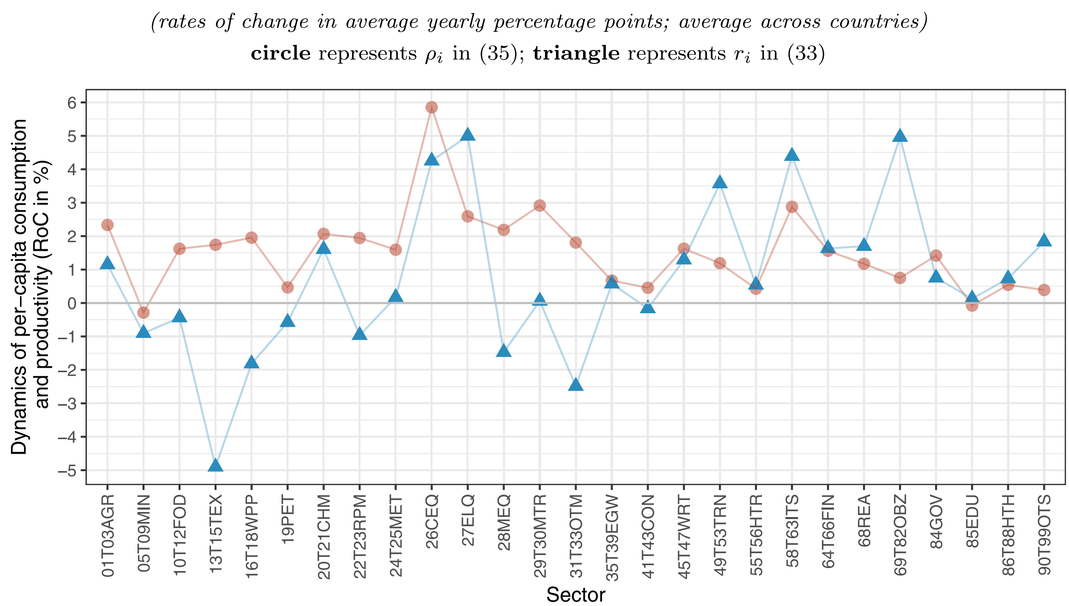

Fig. 1. Per-capita consumption and hyper-integrated labour productivity dynamics (1995–2015).
Notes: Detailed description of sector labels is reported in Table B.11 of Appendix B.
Precise figures plotted correspond to columns 'Mean' of Table 7.
Source: Author's computation based on OECD Input–Output, STAN and National Accounts Databases.

tionally fragmented sectors (Guilhoto et al., 2019, p. 26), advanced industrial economies have been increasingly importing final products from 15T15TEX.

But to what extent demand and productivity dynamics netted each other out? Amongst those subsystems with fastest productivity increases, electrical equipment (27ELQ) and IT services/Telecommunications (58T63ITS) evinced also an even greater expansion of (per-capita) consumption, increasing their employment share. On the contrary, demand expansion for ICT equipment (26CEQ) fell short of productivity growth, and this job displacement gap has been particularly large in transport equipment (29T30MTR). Thus, the accelerating labour-saving trend across the production chain of motor vehicles occurred in a context of stagnating demand. This is particularly relevant, as the automotive industry has so far had the fastest industrial robot deployment in the world economy (UNCTAD, 2017, p. 48).

In sum, Fig. 1 suggests: (i) relatively faster productivity growth across manufacturing sectors coupled with a decrease in their (per-capita) consumption demand, (ii) more sluggish productivity dynamics of services coupled with an increasing consumption demand. Hence, (i) and (ii) imply a structural dynamics of employment in which manufacturing hyper-integrated sectors expel jobs and service subsystems absorb them.

What should be clear, though, is that the employment changes occur at the hyper-integrated level. Hence, jobs expelled from manufacturing sectors concern those in *both* manufacturing and service participating *industries*. Sectoral employment changes reflect the comprehensive outcome for the whole production chain, rather than for the originating industry.

Country-level differences emerge by inspecting Table 7. Consider demand dynamics first. In some sectors, such as electrical equipment (27ELQ) and business services (69T82OBZ), the expansion rate of JPN explains the order of magnitude of the average growth rate.[32]

The notorious growth in (per-capita) consumption of ICT equipment (26CEQ) for DEU and USA contrasts with the relatively slower evolution in ITA and GBR. The expansion of final demand for transportation and storage services (49T53TRN) in FRA and GBR has been markedly faster than in other countries, whilst ITA was the least dynamic country in terms of IT services and Telecommunications (58T63ITS). Coupled with its relatively slower demand for 26CEQ, it suggests an increasing digitalisation gap in ITA. Moreover, the demand expansion for financial services (64T66FIN) in DEU and JPN, real estate services (68REA) in GBR and health services (86T88HTH) in GBR and USA, points to relevant processes of structural transformation of consumption in these countries.

When it comes to productivity growth differentials, cross-country dispersion is smaller than for (per-capita) final consumption dynamics in almost every sector.[33]

Given that each productivity growth rate ρ_i in (35) is a weighted average of changes in the labour content across *all* industries (directly or indirectly) participating in hyper-integrated sector i, it is expected that cross-country differences would be relatively tamed, in comparison to product-specific consumption patterns.

In three subsystems with the fastest pace of productivity increases — 26CEQ, 29T30MTR and 58T63ITS — the USA and DEU have an above-average performance, as opposed to ITA, which has had a below-average expansion rate. For GBR, the fastest productivity growth in 29T30MTR contrasts with the sluggish growth in 26CEQ. Instead, business services (69T82OBZ) have been particularly dynamic in GBR and JPN, but with a sharply declining productivity in ITA.

Interestingly, these results suggest that, even if subsystems 26CEQ, 29T30MTR and 58T63ITS have a relatively small share of employment (see Table 8), countries particularly dynamic in these digital and R&D intensive sectors have the fastest *aggregate* rate of productivity growth (see Table 6).

[32] Note that (per-capita) consumption coefficients in (14) have the labour force $\tilde{N}$ in the denominator. Hence, given that the Japanese labour force has contracted sharply, consumption coefficients are likely to increase, even when domestic final demand is stagnating.

[33] Cross-country dispersion in the growth rates of (per-capita) consumption and hyper-integrated productivity coefficients for each sector i may be obtained by computing the standard deviation of country values r_i and ρ_i, respectively, for each row of Table 7 (excluding the 'Mean' column).

Table 7
Dynamics of per-capita consumption and hyper-integrated labour productivity (1995–2015).
Source: Author's computation based on OECD Input–Output, STAN and National Accounts Databases.

(rates of change in average yearly percentage points)

Sector		Per-capita consumption dynamics (r_i)							Productivity dynamics (ρ_i)						
ISO	Descriptor	DEU	FRA	GBR	ITA	JPN	USA	Mean	DEU	FRA	GBR	ITA	JPN	USA	Mean
01T03AGR	Agriculture	0.13	0.08	4.16	1.41	−0.83	1.97	1.15	1.88	2.40	4.07	1.70	2.05	1.91	2.34
05T09MIN	Mining	−8.77	−7.61	1.98	7.03	0.00	1.96	−0.90	1.68	0.64	−3.88	0.09	−0.21	−0.04	−0.29
10T12FOD	Food products	−1.64	−0.61	1.29	−0.42	−1.43	0.20	−0.44	1.91	1.53	2.34	1.49	1.09	1.38	1.62
13T15TEX	Textiles and Apparel	−2.99	−5.45	−4.45	−1.30	−10.11	−5.11	−4.90	2.23	2.43	2.06	1.81	−0.69	2.60	1.74
16T18WPP	Wood products	−3.39	−2.42	−2.90	−4.24	3.65	−1.58	−1.81	2.55	2.40	1.95	1.87	0.67	2.30	1.95
19PET	Refined petroleum	−0.13	−0.95	0.29	−0.23	−1.92	−0.51	−0.58	2.50	0.60	0.31	0.97	−2.69	1.11	0.47
20T21CHM	Chemicals and Pharma	−0.85	−0.70	2.73	1.16	4.43	2.88	1.61	2.48	2.26	3.32	2.30	0.60	1.43	2.07
22T23RPM	Non-metal mineral prod.	−1.10	−1.12	−2.18	−0.58	−2.57	1.76	−0.96	2.20	2.04	2.21	1.46	1.95	1.81	1.94
24T25MET	Metal products	−0.77	−0.42	0.36	0.29	−0.31	1.87	0.17	1.70	1.53	2.58	1.63	0.34	1.79	1.59
26CEQ	ICT equipment	6.65	3.47	1.23	2.88	3.46	7.81	4.25	6.75	5.95	3.18	2.50	7.19	9.55	5.85
27ELQ	Electrical equipment	4.52	−0.29	3.14	4.33	18.90	−0.62	4.99	2.45	2.29	2.85	2.60	3.19	2.19	2.59
28MEQ	Machinery equipment	−3.75	−12.20	−4.03	−4.17	15.90	−0.58	−1.47	1.81	2.80	2.75	1.67	2.10	1.99	2.19
29T30MTR	Transport equipment	1.49	−0.40	0.95	0.68	−1.78	−0.57	0.06	3.40	3.11	4.03	2.01	1.68	3.25	2.92
31T33OTM	Other manufacturing	−2.18	−5.46	−4.64	−3.42	−0.41	1.18	−2.49	2.35	2.67	1.63	1.27	0.20	2.72	1.81
35T39EGW	Energy services	2.50	−0.38	0.57	−0.23	1.73	−0.73	0.58	2.57	0.10	−0.16	−0.10	1.70	−0.10	0.67
41T43CON	Construction	−0.57	0.89	0.17	−0.28	−1.34	0.14	−0.17	0.86	0.30	0.56	−0.16	0.64	0.54	0.46
45T47WRT	Trade	0.54	0.82	2.48	0.57	1.18	2.18	1.29	2.10	1.24	1.49	0.81	1.37	2.74	1.63
49T53TRN	Transport and Logistics	3.43	4.73	5.74	2.81	1.14	3.57	3.57	2.30	1.00	1.74	0.34	0.54	1.23	1.19
55T56HTR	Accommodation and Food	−0.63	0.79	−1.25	2.21	0.34	1.78	0.54	0.46	0.44	0.09	0.08	0.45	1.04	0.43
58T63ITS	ITS and Telecomm.	5.49	5.22	4.86	2.53	4.86	3.40	4.39	3.65	2.09	3.49	1.57	3.02	3.44	2.88
64T66FIN	Finance	3.45	1.14	1.82	−0.93	3.03	1.27	1.63	1.41	1.73	1.47	0.58	1.35	2.82	1.56
68REA	Real estate	1.81	0.87	3.71	1.39	1.85	0.56	1.70	1.96	0.57	1.99	−1.06	1.27	2.30	1.17
69T82OBZ	Business services	3.52	4.95	0.38	2.99	14.70	3.24	4.96	−0.43	0.20	2.10	−1.42	2.65	1.39	0.75
84GOV	Public Admin.	2.02	0.17	0.36	−0.54	1.54	0.95	0.75	2.06	1.34	0.53	0.84	2.61	1.14	1.42
85EDU	Education	0.56	−0.22	0.09	−0.41	0.38	0.37	0.13	−0.39	−0.37	−1.71	−0.13	1.88	0.26	−0.08
86T88HTH	Health	0.53	0.16	2.04	−0.27	−0.18	2.12	0.73	0.87	0.67	1.32	−0.09	−0.28	0.77	0.54
90T99OTS	Other services	2.27	2.83	0.50	2.35	0.54	2.50	1.83	0.44	1.05	−0.18	0.04	0.10	0.89	0.39

The combination of demand and productivity dynamics in (42) results in changes in hyper-integrated employment shares. But the order of magnitude of these changes crucially depends on weights $\theta_i(t)$ in (43). Table 8 reports these weights, i.e., the hyper-integrated sectoral shares in total employment. Thus, the time average and difference between initial and final years quantify the structural configuration and dynamics of employment, respectively.

Focusing on cross-country averages (columns under the 'Mean' heading in Table 8), the most outstanding aspect is the concentration trends in employment. In 2015, the 5 sectors with highest share — health (86T88HTH), public administration (84GOV), trade (45T47WRT), personal (90T99OTS) and education (85EDU) services — accumulate 54% of economy-wide employment. To interpret these figures, it is crucial to recall that these are *subsystem* shares, i.e., it is the employment activated across all industries by the domestic final demand for the sector's product. Hence, the 14.12% of employment in the hyper-integrated health sector corresponds to jobs in health services, but also across its supplier industries (such as the pharmaceutical industry, transport services and manufacturing of biomedical equipment).[34]

This, however, evinces the prominent role of service industries in articulating the division of labour in advanced industrial societies. In fact, the 13 sectors with highest share concentrate more than 90% of total employment and, out of these, only food products (10T12FOD) is a primary or manufacturing sector. Thus, the long period trend indicates that manufacturing has become functional to produce consumable services, rather than the reverse.

This sharp concentration of weights also suggests that *aggregate* indicators ρ^* and r^* in (48) and (49), respectively, may be highly sensitive to the performance of hyper-integrated service sectors with high shares in employment. In fact, combining the information from Tables 7 and 8, it emerges that between 28% (for GBR) and 47% (for USA and FRA) of the value of ρ^* and between 40% (for JPN) and 64% (for DEU and USA) of the value of r^* are determined by the 5 sectors with highest (cross-country) employment shares.

As regards the evolution of employment shares, focusing on Table 8, differences in cross-country averages between 1995 and 2015 indicate that 6 hyper-integrated sectors account for over 88% of job absorption: personal (90T99OTS), transport and logistics (49T53TRN), business (69T82OBZ), health (86T88HTH), education (85EDU) and IT and Telecommunication (58T63ITS) services.

Correspondingly, 6 sectors account for over 77% of job displacement: food products (10T12FOD), textiles and apparel (13T15TEX), public administration (84GOV), furniture and other manufacturing (31T33OTM), transport equipment (29T30MTR) and construction (41T43CON).

This pattern reinforces the trend towards a prominent role of service subsystems in articulating employment across production chains of the economy. But it also warns about the directionality of labour-saving innovations: food products (10T12FOD), textiles and apparel (13T15TEX) and transport equipment (29T30MTR) are the three industries with the highest 'routine-task intensity' across OECD countries (Marcolin et al., 2016, p. 17). Hence, from a technological point of view, they have the highest potential for deepening automation.

3.5. Natural and observed dynamics

The focus so far has been on the dynamics of gross output activated by final consumption and *natural* prices. But how do these movements compare to the dynamics of *actual*, observed gross outputs and prices?

Formally, to what extent the sectoral rates of change of $\boldsymbol{q}$ in (15) correspond to those of $\boldsymbol{x}$ in (1), and to what extent rates of change

[34] Garbellini and Wirkierman (2014a) provide a framework to analyse the interaction between industry employment and subsystem labour.

Table 8
Hyper-integrated sectoral shares in total employment (1995 and 2015).
Source: Author's computation based on OECD Input–Output, STAN and National Accounts Databases.
(in % of economy-wide employment activated by final consumption demand for the industry's product; column total equals 100%)

Sector		DEU		FRA		GBR		ITA		JPN		USA		Mean	
		1995	2015	1995	2015	1995	2015	1995	2015	1995	2015	1995	2015	1995	2015
01T03AGR	Agriculture	1.57	1.21	3.63	2.43	1.55	1.48	4.39	4.14	3.12	1.89	1.10	1.12	2.56	2.05
05T09MIN	Mining	0.26	0.03	0.03	0.01	0.06	0.17	0.01	0.03	0.00	0.03	0.04	0.06	0.06	0.05
10T12FOD	Food products	7.00	3.78	7.14	4.95	5.22	3.97	8.81	6.02	8.52	5.56	5.31	4.21	7.00	4.75
13T15TEX	Textiles and Apparel	1.22	0.47	1.66	0.37	1.81	0.46	4.61	2.48	2.52	0.42	2.00	0.43	2.30	0.77
16T18WPP	Wood products	1.12	0.38	0.75	0.31	0.95	0.34	1.42	0.42	0.10	0.19	1.03	0.47	0.90	0.35
19PET	Refined petroleum	0.55	0.36	0.35	0.27	0.25	0.24	0.42	0.33	0.27	0.34	0.58	0.42	0.40	0.33
20T21CHM	Chemicals and Pharma	1.43	0.80	0.97	0.57	0.67	0.56	1.07	0.85	0.68	1.59	1.07	1.43	0.98	0.97
22T23RPM	Non-metal mineral prod.	0.76	0.43	0.37	0.21	0.60	0.24	0.62	0.41	0.78	0.34	0.35	0.35	0.58	0.33
24T25MET	Metal products	0.50	0.34	0.17	0.12	0.37	0.22	0.45	0.35	0.22	0.21	0.19	0.19	0.32	0.24
26CEQ	ICT equipment	0.40	0.43	0.34	0.22	0.25	0.16	0.22	0.23	2.16	1.11	0.54	0.38	0.65	0.42
27ELQ	Electrical equipment	0.22	0.37	0.14	0.09	0.11	0.11	0.15	0.21	0.03	0.82	0.26	0.15	0.15	0.29
28MEQ	Machinery equipment	0.69	0.25	0.24	0.01	0.44	0.11	0.59	0.18	0.02	0.29	0.20	0.12	0.36	0.16
29T30MTR	Transport equipment	2.15	1.61	1.34	0.71	1.35	0.68	1.11	0.86	2.46	1.33	2.17	1.02	1.76	1.03
31T33OTM	Other manufacturing	2.44	1.08	2.19	0.46	1.98	0.53	2.24	0.88	0.47	0.45	1.49	1.10	1.80	0.75
35T39EGW	Energy services	2.45	2.64	1.77	1.71	2.04	2.22	2.04	1.99	2.60	2.83	1.28	1.13	2.03	2.09
41T43CON	Construction	8.85	7.30	6.67	7.99	5.68	4.94	7.60	7.44	7.65	5.56	4.76	4.41	6.87	6.27
45T47WRT	Trade	10.15	8.15	8.77	8.57	12.35	14.14	11.04	10.55	8.29	8.62	10.99	9.85	10.26	9.98
49T53TRN	Transport and Logistics	3.92	5.40	2.09	4.68	2.48	5.18	3.57	5.86	5.14	6.27	1.95	3.13	3.19	5.09
55T56HTR	Accommodation and Food	5.29	4.66	4.49	5.12	9.21	6.61	5.43	8.35	7.87	8.32	7.12	8.29	6.57	6.89
58T63ITS	ITS and Telecomm.	1.49	2.36	1.25	2.49	2.00	2.47	1.55	1.88	2.03	3.16	2.69	2.68	1.83	2.51
64T66FIN	Finance	2.21	3.64	3.01	2.85	3.94	3.98	2.40	1.78	2.01	3.03	4.86	3.58	3.07	3.14
68REA	Real estate	3.79	4.04	4.06	4.58	5.34	7.07	1.74	2.85	4.58	5.56	4.02	2.85	3.92	4.49
69T82OBZ	Business services	1.27	3.07	1.60	4.40	1.79	1.19	1.55	3.76	0.27	3.27	1.75	2.54	1.37	3.04
84GOV	Public Admin.	12.90	14.05	17.80	15.01	11.65	10.59	12.95	9.86	11.54	10.06	16.23	15.69	13.84	12.54
85EDU	Education	7.10	9.42	7.88	8.63	8.14	10.94	6.09	5.78	5.13	4.11	9.47	9.71	7.30	8.10
86T88HTH	Health	14.92	15.29	16.38	15.76	14.01	15.18	9.56	9.24	10.08	11.11	13.80	18.13	13.13	14.12
90T99OTS	Other services	5.35	8.46	4.91	7.47	5.78	6.22	8.34	13.27	11.45	13.53	4.75	6.57	6.76	9.25

of $\boldsymbol{p}^T$ in (30) correspond to those implied by gross output price deflators.[35]

In the case of quantities, the key difference between $\boldsymbol{q}$ and $\boldsymbol{x}$ is that the latter also includes other final uses vector $\boldsymbol{f}_z$ in (1). Instead, $\boldsymbol{q}$ includes only final consumption $\boldsymbol{c}N$ in (15). Hence, differences are expected to be larger for those sectors which heavily depend on foreign final demand as an activating source of output (as exports are the main component of $\boldsymbol{f}_z$). However, given that both $\boldsymbol{q}$ and $\boldsymbol{x}$ consider an *effective* growth path, dynamics should not be dissimilar.

Instead, more caution is required to assert that *natural* prices (Pasinetti, 1981, 1993) and actual price indices move in the same direction. The dynamics of natural price $p_i(t)$ in (37) is determined by the evolution of the (average) money wage rate $\sigma_{\bar{w}}$ net of hyper-integrated productivity growth ρ_i. The movement of actual prices may reflect other forces at work. For example, *changes* in inter-industry wage rate differentials would distort a depiction based on the dynamics of the *average* wage rate applied to all sectors.

In essence, the question is whether the theory of value implied by computable price system (21) provides an adequate approximation to the *dynamics* of *actual* prices in advanced industrial economies.

Table 9 reports the Pearson correlation coefficient for each country across sectors between natural vs. observed prices and quantities.

As expected, the correlation between the dynamics of $\boldsymbol{q}$ in (15) and $\boldsymbol{x}$ in (1) is above 0.76 across countries and lower than 0.90 only in ITA and FRA. To visualise the sectoral details of this correspondence, Fig. 2 plots the dynamics of gross output activated by final consumption (x-axis) vis-à-vis that of observed gross output (y-axis) for every sector, in a separate panel for each country.

In particular, for those sectors to the *left* of zero on the x-axis and *above* zero on the y-axis, domestic final consumption in 2015 failed to activate a higher level of gross output than in 1995. These points correspond precisely to activities that by 2015 heavily relied on foreign demand as an activating source of output (and income). For the cases of FRA and ITA (but also DEU), these are (mostly) the same manufacturing sectors: chemicals and pharmaceuticals (20T21CHM), metal products (24T25MET), electrical equipment (27ELQ) and mechanical machinery (28MEQ).

Table 9
Price and Quantity dynamics in the natural and observed systems: Correlation coefficients.
Source: Author's computation based on OECD Input–Output, STAN and National Accounts Databases.
(Pearson correlation coefficient for each country across sectors)

ISO	Natural vs. Observed	
	Prices	Quantities
DEU	0.71	0.91
FRA	0.83	0.76
GBR	0.90	0.93
ITA	0.67	0.85
JPN	0.90	0.97
USA	0.94	0.99

Notably, from the first column of Table 9, it may be seen that the correlation between natural and observed prices is at least 0.90 for GBR, JPN and the USA and, in any case, above 0.67 for all countries. To visualise the sectoral details of this correspondence, Fig. 3 plots natural (x-axis) vis-à-vis observed (y-axis) price dynamics for every sector, in a separate panel for each country.

Inspecting Fig. 3, it emerges that outliers most often correspond to natural-resource-based sectors: mining (05T09MIN), refined petroleum (19PET) and energy services (35T39EGW), in which: (i) the process of product *pricing* involves the valuation of available natural resources and/or (ii) they are imported commodities. Both (i) and (ii) are not directly considered in the set of computable prices derived from (21).

[35] Gross output price indices may be obtained from variables `PROD` and `PRDK` of the `STANI4_2016` database (see Table 1).

(rates of change in average yearly percentage points)

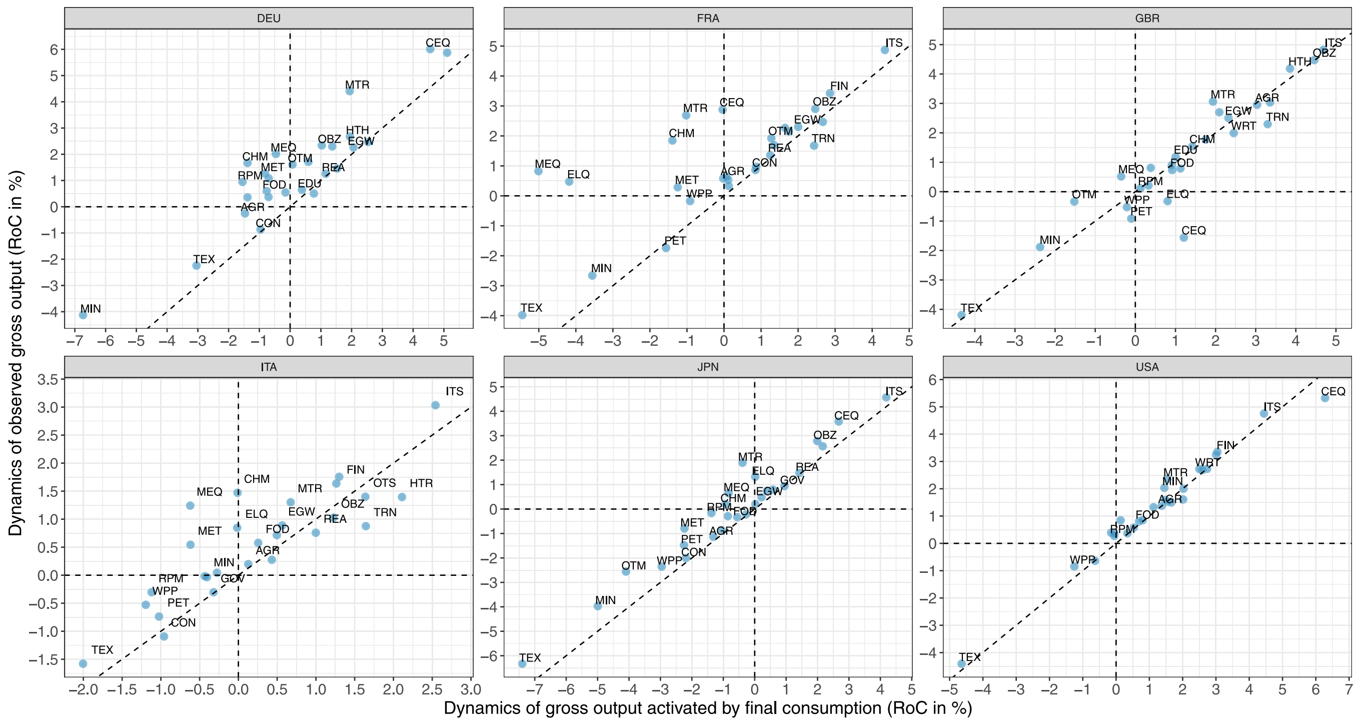

Fig. 2. Gross output dynamics: activated by final consumption vs. observed.
Notes: Detailed description of sector labels is reported in Table B.11 of Appendix B.
Source: Author's computation based on OECD Input–Output, STAN and National Accounts Databases.

(rates of change in average yearly percentage points)

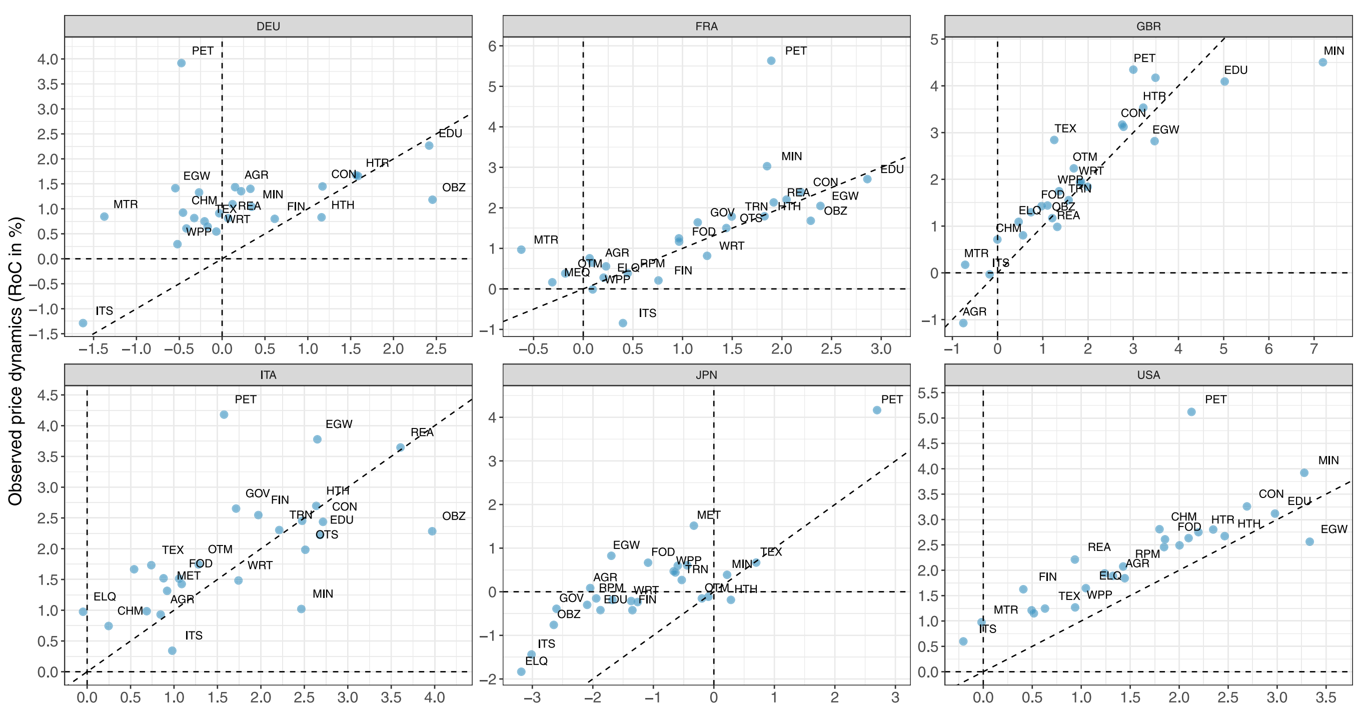

Fig. 3. Natural vs. Observed Price Dynamics.
Notes: Detailed description of sector labels is reported in Table B.11 of Appendix B.
Source: Source: Author's computation based on OECD Input–Output, STAN and National Accounts Databases.

Table 10
Observed price dynamics compared to direct labour costs and natural prices: Correlation coefficients.
Source: Author's computation based on OECD Input–Output, STAN and National Accounts Databases.

(Pearson correlation coefficient for each country across sectors)

ISO	Direct labour	Natural price
DEU	0.69	0.71
FRA	0.78	0.83
GBR	0.81	0.90
ITA	0.48	0.67
JPN	0.76	0.90
USA	0.88	0.94

Notes: Columns 'Direct Labour' and 'Natural Price' report the correlation coefficient between observed price dynamics and (i) direct labour cost dynamics, (ii) natural price dynamics, respectively.

But one may wonder: is this strong and positive correlation between natural and actual price dynamics mainly due to the evolution of each industry's *direct* labour content valued at the (average) wage rate (a notion of 'unit labour cost'), or does accounting for productive interdependencies by means of hyper-integrated sectors also play a role?

As Table 10 reports, for *all* countries, considering the dynamics of natural price ($p_i = \bar{w}\eta_i$) improves the strength of the linear association with observed price dynamics with respect to using direct labour costs ($\bar{w}a_{li}$). And in the cases of GBR, ITA and JPN, there is a sizeable increase in the correlation coefficient.

Based on the results of Table 10, an interesting direction for further research would consist in comparing how natural prices differ from prices determined by vertically hyper-integrated labour valued at *sector-specific* wage rates, bringing institutional elements into the analysis.

4. Summary of findings and concluding remarks

Starting from a set of Input–Output (I-O, hereinafter) accounting identities, this paper has derived a computable implementation of Pasinetti's framework of structural economic dynamics. Rather than adapting the theoretical scheme to empirical data, the reverse route has been taken, allowing to precisely map the correspondence between magnitudes in Pasinetti (1981, 1993) and actual inter-industry tables.

Taking advantage of the logical structure of a closed I-O model, the connection between theoretical magnitudes and actual data evinced that the condition for the solution of prices and quantities complying with an *equilibrium situation* may only hold by a *fluke*, when model equations were filled in with empirical coefficients.

Two routes out of this *impasse* were explored. First, by allowing final consumption of (at least) one product to become *endogenous*, adjusting to match technological possibilities. Second, by computing non-equilibrium solutions from empirical coefficients in order to quantify the distance from a full employment situation. In each case, empirical indicators have been proposed to reflect the solution path followed.

Inspecting the effective demand condition in Pasinetti (1993, p. 50), it could be seen that if *steady* — albeit uneven — sectoral growth rates are assumed, the condition simply cannot hold for *all* time periods. Hence, as final expenditure falls short of full employment income, the economy is bound to generate technological unemployment.

Moreover, by exploiting the duality of prices and quantities at a *given* point in time, Pasinetti's *natural* configuration may be interpreted as a structural accounting framework, connecting the evolution of natural prices, technical progress, outputs and the labour force. Such a framework has been empirically implemented as an alternative to aggregate TFP growth accounting exercises.

Empirically, the paper explored the structural dynamics of six advanced industrial economies — Germany (DEU), France (FRA), Italy (ITA), United Kingdom (GBR), Japan (JPN) and the United States (USA) — between 1995 and 2015, by articulating an integrated dataset collating different OECD databases.

By choosing the consumption coefficient of public administration services as a stabilising demand source, we quantified the required injection to close a country's unemployment gap via a public intervention. This injection is highest in ITA, and lowest in the USA and JPN (in per-capita terms). Moreover, the sizeable increase in the final consumption expenditure to full employment income gap in JPN, DEU and FRA may be explained by the increasing weight of foreign demand as an activating source of employment in these countries.

Applying the structural accounting framework introduced, USA and GBR emerge as consumption 'engines' amongst advanced industrial economies, whereas the pace of productivity growth has been fastest in USA and DEU. JPN confirms its path as an ageing economy with a sharply decreasing labour force and deflationary trends. The dynamics of FRA was found to be half-way between GBR and DEU, being at the crossroads between alternative growth regimes. Finally, the stagnating character of ITA suggests a negative impact of the reduction of government expenditure in real terms, as well as a short-circuit between (average) wage rate growth and final consumption dynamics.

A crucial point of Pasinetti's framework is that sectoral productivity trends and employment shares are measured using hyper-integrated labour coefficients, i.e., the labour content across all industries (directly and/or indirectly) required to reproduce and expand (or contract) the production of the final commodity of a given industry. Hence, sectoral dynamics convey the comprehensive effects of technical progress along an entire production chain.

Our findings suggest a relatively faster (slower) productivity growth across manufacturing (service) sectors coupled with a decrease (an increase) in their per-capita consumption demand. Thus, manufacturing hyper-integrated sectors expel jobs and service subsystems absorb them. Moreover, employment concentration trends hint at a structural configuration in which manufacturing has become functional to produce consumable services, rather than the reverse.

Furthermore, the correlation coefficient between the dynamics of natural and observed prices is, at least, 0.90 for GBR, JPN and the USA and, in any case, above 0.67 for all countries, suggesting that the computable price system derived from Pasinetti (1981, 1993) in Section 2 provides an adequate *approximation* to the *dynamics* of actual prices in advanced industrial economies.

Limitations of the present analysis point to directions for further research.

First and foremost, the need to 'open' the framework to foreign trade. As the cases of FRA, DEU and JPN have showed, an increasing share of gross output is activated by exports. Moreover, the empirical mismatch in the dynamics between natural and observed prices for natural-resource-based sectors, suggests that imported inputs play a relevant role in the specification of a computable natural price system.

The point is how to formulate an open-economy scheme of structural dynamics. Rather than an analytical extension towards the cases of a small-open economy or a two-region model (Araujo and Teixeira, 2003), we believe the extension should consider a *global* economic system. The world is a *closed* economy. In such a system, global final consumption would *coincide* with global gross value added. Only in this way we may simultaneously achieve an accurate *disaggregated* separation between prices and quantities *and* apply the circular logic of a *closed* I-O model. Both aspects are required by Pasinetti's framework. There is great potential for such analytical *and* empirical scheme. For example, the contrast between *international* productivity and *national* competitiveness could be analysed. Also the required coordination of national expansion rates to reflate a depressed world economy could be quantified. And the determinants of trade patterns in the spirit of Pasinetti (1981, Chapter XI) may be further explored.

A second limitation of the present analysis is that of focusing on an *effective* growth path, rather than estimating a *normative* growth trajectory, based on the expansion (or contraction) of means of production according to subsystem-specific exponential rates (as in Pasinetti, 1988). Here, a key challenge lies in setting up a bridge between the theoretical conceptualisation and empirical implementation of the separation between growth and technical change, especially as regards *fixed* capital inputs (Garbellini and Wirkierman, 2014c, p. 162). In essence, while the device of treating fixed capital as a joint product allows for a straightforward *analytical* separation between activity levels and the technique in use, available empirical data prevent us from implementing such a scheme, in general terms. At any rate, further efforts to formulate empirically tractable schemes of structural dynamics involving fixed capital are needed to quantify the mismatch between new investment requirements and *actual* capital accumulation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Relationship with a dynamic Input–Output model

The aim of this appendix is to clarify the relationship of quantity system (15) with the formulation of a *simplified* dynamic Input–Output (I-O, hereinafter) model inspired by, for example, Leontief and Duchin (1986, p. 134).

Reconsider the expenditure system (1) and express all magnitudes in prices of a base year:[36]

$$\boldsymbol{x}_{(0)} = \boldsymbol{X}_{(0)}\boldsymbol{e} + \boldsymbol{F}_{k(0)}\boldsymbol{e} + \boldsymbol{f}_{c(0)} + \boldsymbol{f}_{z(0)} \tag{A.1}$$

To derive a dynamic I-O model from expression (A.1), we need to specify the analytical separation between growth and the technique in use, both for circulating — captured by matrix $\boldsymbol{X}_{(0)}$ — as well as gross fixed — captured by matrix $\boldsymbol{F}_{k(0)}$ — capital transactions. For example, we may formulate the following relations:

$$\boldsymbol{X}_{(0)}\hat{\boldsymbol{x}}_{(0)}^{-1} = \boldsymbol{A}_{(0)}(\boldsymbol{I} + \hat{\boldsymbol{g}}) \tag{A.2}$$

$$\boldsymbol{F}_{k(0)}\hat{\boldsymbol{x}}_{(0)}^{-1} = \boldsymbol{R}_{k(0)} + \boldsymbol{K}_{(0)}\hat{\boldsymbol{g}} \tag{A.3}$$

$$\hat{\boldsymbol{g}} = (\Delta\hat{\boldsymbol{x}}_{(0)})\hat{\boldsymbol{x}}_{(0)}^{-1} \tag{A.4}$$

where $\boldsymbol{A}_{(0)}$ is a matrix of coefficients of circulating capital inputs per unit of gross output of the purchasing industry, $\boldsymbol{R}_{k(0)}$ is a matrix of fixed capital replacements per unit of gross output of the purchasing industry, $\boldsymbol{K}_{(0)}$ is a matrix of coefficients of fixed capital stocks per unit of gross output of the purchasing industry and $\hat{\boldsymbol{g}}$ is a diagonal matrix with proportional growth rates of industry gross output along the main diagonal.

Expression (A.2) suggests that current inputs are met from past outputs with a one-period production lag (Lager, 2000, p. 250). Hence, to increase output in the next period, we need to expand circulating capital inputs in the current one (through term $\boldsymbol{A}_{(0)}\hat{\boldsymbol{g}}$). But if we assume that production and productive consumption of circulating capital occurs within the same accounting period, then (A.2) becomes:

$$\boldsymbol{X}_{(0)}\hat{\boldsymbol{x}}_{(0)}^{-1} = \boldsymbol{A}_{(0)} \tag{A.5}$$

Moreover, under constant returns to scale, if fixed capital is infinitely durable, so that gross fixed capital formation equals *new* investments (i.e., $\boldsymbol{R}_{k(0)} = \boldsymbol{0}$):

$$\boldsymbol{F}_{k(0)}\hat{\boldsymbol{x}}_{(0)}^{-1} = \boldsymbol{K}_{(0)}\hat{\boldsymbol{g}} \tag{A.6}$$

which, using (A.4), implies that:

$$\boldsymbol{K}_{(0)} = \boldsymbol{F}_{k(0)}(\Delta\hat{\boldsymbol{x}}_{(0)})^{-1} \tag{A.7}$$

i.e., average capital-stock/output ratios — in matrix $\boldsymbol{K}_{(0)}$ — coincide with investment/(change-in-output) ratios (Green, 1975, p. 20).

By introducing (A.5) and (A.6) into (A.1), and noting that $\boldsymbol{F}_{k(0)}\boldsymbol{e} = (\boldsymbol{F}_{k(0)}\hat{\boldsymbol{x}}_{(0)}^{-1})\boldsymbol{x}_{(0)} = \boldsymbol{K}_{(0)}\hat{\boldsymbol{g}}\boldsymbol{x}_{(0)} = \boldsymbol{K}_{(0)}\Delta\boldsymbol{x}_{(0)}$, we obtain:

$$\boldsymbol{x}_{(0)} = \boldsymbol{A}_{(0)}\boldsymbol{x}_{(0)} + \boldsymbol{K}_{(0)}\Delta\boldsymbol{x}_{(0)} + \boldsymbol{f}_{c(0)} + \boldsymbol{f}_{z(0)} \tag{A.8}$$

which resembles — albeit in simplified form — the model introduced in Leontief and Duchin (1986, p. 134). A key point in (A.8) is the fact that new (fixed capital) investment is related to changes in gross output via an accelerator mechanism.

From system (A.8), there are at least two possibilities to pursue further analysis. We may either interpret the term $\Delta\boldsymbol{x}_{(0)}$ as a connection between gross output of different (accounting) periods, creating an inter-temporal equation system (as done in Leontief, 1970), *or* we may write $\boldsymbol{K}_{(0)}\Delta\boldsymbol{x}_{(0)}$ in (A.8) as $\boldsymbol{K}_{(0)}\hat{\boldsymbol{g}}\boldsymbol{x}_{(0)}$ and assume that yearly gross output growth rates by *industry* – $\hat{\boldsymbol{g}}$ – are exogenously given. But if we follow this latter route, and assume that both *trend* industry growth rates and matrix $\boldsymbol{K}_{(0)}$ are *independent* data to our problem, expression (A.6) is unlikely to hold, because the empirically available magnitudes in the left-hand side of (A.6) determine $\boldsymbol{K}_{(0)}$ and $\hat{\boldsymbol{g}}$ *jointly*.

Therefore, instead of making an explicit separation between the technique in use (matrix $\boldsymbol{K}_{(0)}$) and growth (matrix $\hat{\boldsymbol{g}}$) within a given time period, we assume that "in each year, the gross investment undertaken by each industry represents the flow of capital goods required to maintain the industry on its current growth path" (Peterson, 1979, p. 220). This amounts to defining $\boldsymbol{A}_{k(0)} = \boldsymbol{F}_{k(0)}\hat{\boldsymbol{x}}_{(0)}^{-1}$, as is done in the main text of the paper.[37]

Finally, by solving (A.8) for the gross output supporting final consumption of those employed ($c N$ rather than $\boldsymbol{f}_{c(0)} + \boldsymbol{f}_{z(0)}$), we obtain quantity system (15) in the main text.

To sum up, in the approach taken in the paper, we aim to stay as close as possible to observed (intra-period) gross outputs, specifying a structural accounting framework which reflects effective magnitudes by using matrix $\boldsymbol{A}_{k(0)}$. With matrix $\boldsymbol{A}_{k(0)} = \boldsymbol{F}_{k(0)}\hat{\boldsymbol{x}}_{(0)}^{-1} = \boldsymbol{K}_{(0)}\hat{\boldsymbol{g}}$, we do not make an analytical separation between the technique in use and expansion requirements ($\boldsymbol{K}_{(0)}\hat{\boldsymbol{g}}$ are determined jointly), having an effective rather than normative path for (intra-period) gross outputs. Were we to separate the technique in use from expansion requirements, the analytical formulation of $\boldsymbol{K}_{(0)}$ and $\hat{\boldsymbol{g}}$ presented here would be (implicitly) assuming that gross fixed capital formation equals new investments, therefore, sectoral (fixed) capital stocks are infinitely durable (as there are no replacement requirements).

Appendix B. Additional tables

See Table B.11.

[36] As described in the main text, constant price magnitudes may be obtained by premultiplying vectors and matrices by a diagonal matrix of (reciprocal) price indices $\hat{\boldsymbol{\mu}}_0$. In what follows, all magnitudes with subindex (0) indicate that they are expressed in constant prices.

[37] A similar approach may be found in Ghosh (1964, p. 97).

Table B.11
Sectoral Classification: Correspondence with OECD Input–Output and STAN Databases based on ISIC Rev. 4 and ISIC Rev. 3.
Source: Own elaboration based on OECD Input–Output and STAN Databases.

Sector			OECD classification based on	
Label	Descriptor	ISO	ISIC Rev. 4	ISIC Rev. 3
01T03AGR	Agriculture	AGR	D01T03	C01T05
05T09MIN	Mining	MIN	D05T06, D07T08, D09	C10T14
10T12FOD	Food products	FOD	D10T12	C15T16
13T15TEX	Textiles and Apparel	TEX	D13T15	C17T19
16T18WPP	Wood products	WPP	D16, D17T18	C20, C21T22
19PET	Refined petroleum	PET	D19	C23
20T21CHM	Chemicals and Pharma	CHM	D20T21	C24
22T23RPM	Non-metal mineral prod.	RPM	D22, D23	C25, C26
24T25MET	Metal products	MET	D24, D25	C27, C28
26CEQ	ICT equipment	ICT	D26	C30T33X
27ELQ	Electrical equipment	ELQ	D27	C31
28MEQ	Machinery equipment	MEQ	D28	C29
29T30MTR	Transport equipment	MTR	D29, D30	C34, C35
31T33OTM	Other manufacturing	OTM	D31T33	C36T37
35T39EGW	Energy services	EGW	D35T39	C40T41
41T43CON	Construction	CON	D41T43	C45
45T47WRT	Trade	WRT	D45T47	C50T52
49T53TRN	Transport and Logistics	TRN	D49T53	C60T63
55T56HTR	Accomodation and Food	HTR	D55T56	C55
58T63ITS	ITS and Telecomm.	ITS	D58T60, D61, D62T63	C64, C72
64T66FIN	Finance	FIN	D64T66	C65T67
68REA	Real estate	REA	D68	C70
69T82OBZ	Business services	OBZ	D69T82	C71, C73T74
84GOV	Public Admin.	GOV	D84	C75
85EDU	Education	EDU	D85	C80
86T88HTH	Health	HTH	D86T88	C85
90T99OTS	Other services	OTS	D90T96, D97T98	C90T93, C95

References

Acemoglu, D., Restrepo, P., 2020. Robots and jobs: Evidence from US labor markets. J. Polit. Econ. 128 (6), 2188–2244.

Araujo, R.A., Lima, G.T., 2007. A structural economic dynamics approach to balance-of-payments-constrained growth. Cambr. J. Econ. 31 (5), 755–774.

Araujo, R.A., Teixeira, J.R., 2003. An extension of the structural change model to international economic relations. Metroeconomica 54 (4), 458–473.

Bacharach, M., 1965. Estimating nonnegative matrices from marginal data. Internat. Econom. Rev. 6 (3), 294–310.

Baumol, W.J., 1967. Macroeconomics of unbalanced growth: The anatomy of urban crisis. Am. Econ. Rev. 57 (3), 415–426.

Blanchard, O.J., Leigh, D., 2013. Growth forecast errors and fiscal multipliers. Amer. Econ. Rev. 103 (3), 117–120.

Bortis, H., 2000. Some considerations on structure and change. Struct. Change Econ. Dyn. 11 (1–2), 185–195.

Brody, A., 1970. Prices, Proportions and Planning – A Mathematical Restatement of the Labor Theory of Value. Akademiai Kiado, Budapest.

Calvino, F., Criscuolo, C., Marcolin, L., Squicciarini, M., 2018. A Taxonomy of Digital Intensive Sectors. OECD Science, Technology and Industry Working Papers 2018/14, OECD.

Cozzi, T., 1969. Sviluppo e Stabilita' dell'Economia. Fondazione Luigi Einaudi, Torino.

Domar, E.D., 1946. Capital expansion, rate of growth, and employment. Econometrica 14 (2), 137–147.

Du Caju, P., Kátay, G., Lamo, A., Nicolitsas, D., Poelhekke, S., 2010. Inter-Industry Wage Differentials in EU Countries: What Do Cross-Country Time Varying Data Add to the Picture? Working Paper Series No. 1182, April 2010, European Central Bank (ECB).

Elmslie, B., Milberg, W., 1996. The productivity convergence debate: a theoretical and methodological reconsideration. Cambr. J. Econ. 20, 153–182.

EUROSTAT, 2008. Eurostat Manual of Supply, Use and Input-Output Tables. Office for Official Publications of the European Communities, European Commission, Luxembourg.

EUROSTAT, 2012. Eurostat-OECD Methodological Manual on Purchasing Power Parities. Office for Official Publications of the European Communities, European Commission, Luxembourg.

Galindo-Rueda, F., Verger, F., 2016. OECD Taxonomy of Economic Activities Based on R&D Intensity. OECD Science, Technology and Industry Working Papers 2016/04, OECD.

Garbellini, N., 2010. Essays on the Theory of Structural Economic Dynamics: Technical Progress, Growth, and Effective Demand (Ph.D. thesis). Universita' Cattolica del Sacro Cuore, XXIII cycle, A.Y. 2009/10, Milano.

Garbellini, N., Wirkierman, A.L., 2014a. Blocks and circularity in labour requirements: An interplay between clusters and subsystems in the EU. Struct. Change Econ. Dyn. 28, 60–74.

Garbellini, N., Wirkierman, A.L., 2014b. Pasinetti's 'Structural Change and Economic Growth': A Conceptual Excursus. Rev. Polit. Economy 26 (2), 234–257.

Garbellini, N., Wirkierman, A.L., 2014c. Productivity accounting in vertically (hyper-) integrated terms: Bridging the gap between theory and empirics. Metroeconomica 65 (1), 154–190.

Ghosh, A., 1964. Experiments with Input-Output Models. Cambridge University Press, Cambridge.

Gouvea, R.R., Lima, G.T., 2010. Structural change, balance-of-payments constraint, and economic growth: evidence from the multisectoral Thirlwall's law. J. Post Keynes. Econ. 33 (1), 169–204.

Green, M.J., 1975. Investment matrices for the United Kingdom; their structure and use in forecasting. In: Gossling, W.F. (Ed.), Capital Coefficients and Dynamic Input-Output Models. Input-Output Publishing Company, London, pp. 14–35.

Guilhoto, J., Hewings, G., Johnstone, N., Webb, C., Yamano, N., 2019. Exploring Changes in World Production and Trade: Insights from the 2018 Update of OECD's ICIO/TIVA Database. OECD Science, Technology and Industry Working Papers 2019/04, OECD.

Hulten, C.R., 2010. Growth accounting. In: Hall, B.H., Rosenberg, N. (Eds.), Handbook of the Economics of Innovation, Vol. 2. Elsevier, pp. 987–1031.

Kaldor, N., 1955. Alternative theories of distribution. Rev. Econom. Stud. 23 (2), 83–100.

Kalmbach, P., Kurz, H.D., 1990. Micro-electronics and employment: a dynamic input-output study of the West German economy. Struct. Change Econ. Dyn. 1 (2), 371–386.

Kongsamut, P., Rebelo, S., Xie, D., 2001. Beyond balanced growth. Rev. Econom. Stud. 68 (4), 869–882.

Kurose, K., 2009. The relation between the speed of demand saturation and the dynamism of the labour market. Struct. Change Econ. Dyn. 20 (2), 151–159.

Kurz, H.D., Schütz, M., Strohmaier, R., Zilian, S., 2018. Riding a new wave of innovations — A long-term view at the current process of creative destruction. Wirtschaft Gesellschaft 44 (4), 545–583.

Lager, C., 2000. Production, prices and time: a comparison of some alternative concepts. Econ. Syst. Res. 12 (2), 231–253.

Landesmann, M.A., Scazzieri, R., 1993. Commodity flows and productive subsystems: An essay in the analysis of structural change. In: Baranzini, M., Harcourt, G.C. (Eds.), The Dynamics of the Wealth of Nations — Growth, Distribution and Structural Change, Essays in Honour of Luigi Pasinetti. St. Martin's Press, New York.

Leontief, W.W., 1937. Interrelation of Prices, Output, Savings, and Investment. Rev. Econ. Stat. 19 (3), 109–132.

Leontief, W.W., 1970. The Dynamic Inverse. In: Carter, A.P., Bródy, A. (Eds.), Contributions to Input-Output Analysis. North Holland Publishing Company, pp. 17–46.

Leontief, W.W., 1986. Input-Output Economics, Second Ed. Oxford University Press, New York.

Leontief, W., Duchin, F., 1986. The Future Impact of Automation on Workers. Oxford University Press, New York.
Marcolin, L., Miroudot, S., Squicciarini, M., 2016. The Routine Content Of Occupations: New Cross-Country Measures Based On PIAAC. OECD Trade Policy Papers No. 188, OECD.
Marzi, G., 1994. Vertically integrated sectors and the empirics of structural change. Struct. Change Econ. Dyn. 5 (1), 155–175.
Meyer, C.D., 2000. Matrix Analysis and Applied Linear Algebra. SIAM, Philadelphia.
Milberg, W.S., 1991. Structural change and international competitiveness in Canada: an alternative approach. Int. Rev. Appl. Econ. 5 (1), 77–99.
Miller, R.E., Blair, P.D., 2009. Input-Output Analysis — Foundations and Extensions, Second Ed. Cambridge University Press, Cambridge.
Minc, H., 1988. Nonnegative Matrices. John Wiley & Sons.
Montresor, S., Vittucci Marzetti, G., 2011. The deindustrialisation/tertiarisation hypothesis reconsidered: a subsystem application to the OECD7. Cambr. J. Econ. 35 (2), 401–421.
Notarangelo, M., 1999. Unbalanced growth: a case of structural dynamics. Struct. Change Econ. Dyn. 10 (2), 209–223.
Parrinello, S., 1966. Alcune implicazioni della diffusione del progresso tecnologico in uno schema classico di crescita economica. Metroeconomica 18 (3), 198–238.
Pasinetti, L.L., 1963. A Multi-Sector Model of Economic Growth. King's College, Cambridge.
Pasinetti, L.L., 1965. A New Theoretical Approach to the Problem of Economic Growth. In: The Econometric Approach To Development Planning. Pontificia Academia Scientiarvm, Citta' del Vaticano.
Pasinetti, L.L., 1974. Growth and Income Distribution — Essays in Economic Theory. Cambridge University Press, Cambridge.
Pasinetti, L.L., 1977. Lectures on the Theory of Production. Columbia University Press, New York.
Pasinetti, L.L., 1981. Structural Change and Economic Growth: A Theoretical Essay on the Dynamics of the Wealth of Nations. Cambridge University Press, Cambridge.
Pasinetti, L.L., 1986a. Introduzione. In: Pasinetti, L.L. (Ed.), Mutamenti Strutturali Del Sistema Produttivo — Integrazione Tra Industria E Settore Terziario. Il Mulino, Bologna, pp. 7–11.
Pasinetti, L.L., 1986b. Theory of Value — A Source of Alternative Paradigms in Economic Analysis. In: Baranzini, M., Scazzieri, R. (Eds.), Foundations of Economics. Structures of Enquiry and Economic Theory. Basil Blackwell, Oxford, pp. 409–431.
Pasinetti, L.L., 1988. Growing subsystems, vertically hyper-integrated sectors and the labour theory of value. Cambr. J. Econ. 12 (1), 125–134.
Pasinetti, L.L., 1993. Structural Economic Dyanmics: A Theory of the Economic Consequences of Human Learning. Cambridge University Press, Cambridge.
Pasinetti, L.L., 2007. Keynes and the Cambridge Keynesians — A 'Revolution in Economics' to be Accomplished. Cambridge University Press, Cambridge.
Paternesi Meloni, W., Stirati, A., 2022. The decoupling between labour compensation and productivity in high-income countries: Why is the nexus broken? Br. J. Ind. Relat. 1–39.
Peterson, W., 1979. Total factor productivity in the UK: A disaggregated analysis. In: Patterson, K.D., Schott, K. (Eds.), The Measurement of Capital. Theory and Practice. Macmillan, London.
Rampa, G., 1981a. Concetto e misrua della producttività in uno schema input-output. Ann. Fondazione Luigi Einaudi XV, 107–127.
Rampa, G., 1981b. The Concept and Measurement of Productivity in an Input-Output Framework. Research Paper N. 18, Faculty of Economics and Politics, University of Cambridge.
Reich, U.-P., 2001. National Accounts and Economic Value — a Study in Concepts. Palgrave, New York.
Saviotti, P.P., Pyka, A., 2004. Economic development, qualitative change and employment creation. Struct. Change Econ. Dyn. 15 (3), 265–287.
Scazzieri, R., 2009. Structural economic dynamics: Looking back and forging ahead. Econ. Polit. 26 (3), 531–558.
Sraffa, P., 1960. Production of Commodities by Means of Commodities. Cambridge University Press, Cambridge.
Star, S., Hall, R.E., 1976. An Approximate Divisia Index of Total Factor Productivity. Econometrica 44 (2), 257–263.
Trigg, A.B., Lee, F.S., 2005. Pasinetti, Keynes and the multiplier. Rev. Polit. Econ. 17 (1), 29–43.
UNCTAD, 2017. Trade and Development Report 2017: Beyond Austerity: Towards a Global New Deal. United Nations Conference on Trade and Development, UNCTAD/TDR/2017, New York and Geneva.