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An analysis of economic growth using input–output tables

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Abstract

Two perspectives on the analysis of economic growth have developed within the input–output framework. On the one hand, Leontief proposed a dynamic model, where investment supplies the necessary capital stock needed to produce future output. On the other hand, Structural Decomposition Analysis assumes that changes in the output level are dependent on the behaviour of the technological and final demand components. This paper examines the differences between input–output tables of different periods to explain growth, as well as the contribution of the final demand components in the phenomenon. Further, the article provides examples based on the coefficient tables of five OECD economies, between 1995 and 2011, to illustrate the relevance of the method proposed here.

Keywords: Microeconomic, Input–output tables and analysis, Multisector economic growth

JEL Classification: D5, D57, O41

1 Introduction

Leontief studied the economic system as a circular flow in his doctoral thesis (Leontief, 1928) and would depart from it to build the input–output (IO) model, which led him to characterize the economy as a closed system of production, distribution, and consumption among economic agents who relate to one another by means of the exchange of commodities (Leontief 1937). In such a system, the expenditure of one agent is the income of another. Thus, total income and total expenditure, or total supply and total demand, are pairs of equivalent variables, constructed in different ways that signify unequal concepts but amount to the same. The open IO model finds a solution as the transformation of the space of produced commodities into the space of produced commodities through final demand. Equivalently, such a transformation of the space of produced commodities into itself occurs through the agents' incomes (Aroche and Marquez 2020).

In order to analyse growth, Leontief (1970) proposes a dynamic model where capital stock expands in relation to investment; variation in output levels takes into account such changes and the behaviour of final demand. Nevertheless, the model easily becomes unstable, often under realistic assumptions (Blanc and Ramos, 2003; Heesterman 1990; Steenge 1990). The literature does not offer a solution to the dead end.

Several authors such as Kendrick (1972), Livesey (1973), and Luenberger and Arbel, (1977) diagnosed Leontief's (1970) dynamic model as inconsistent and irreducible, flaws which can be overcome only under balanced growth conditions (Schoonbeek 1990; Szyld 1985), where the technical and final demand coefficients remain stable. Even in the first version of the dynamic model, Leontief (1953) presents an optimal solution considering that the matrix of capital stock is strictly non-negative and irreducible. In the long run the model is consistent when there is substitutability between factors and produced inputs (Dantzig 1955).

Within the IO framework in an economy, growth has been treated empirically by means of comparative static methods using different IO tables (Dervis, et al. 1982; Leontief 1941). The output differential ($\Delta \boldsymbol{x} = \boldsymbol{x}^1 - \boldsymbol{x}^0$) and that of its components can be explained by two types of effects: (1) technological, reflected in the differential between the matrices of multipliers ($\Delta \boldsymbol{L} = \boldsymbol{L}^1 - \boldsymbol{L}^0$), and (2) final demand ($\Delta \boldsymbol{f} = \boldsymbol{f}^1 - \boldsymbol{f}^0$). If the latter changes, output will change as well, even if the inputs matrix remains the same. Various authors have developed so-called structural decomposition analysis (SDA) techniques (e.g., Miller and Blair 2009; Rose and Cassler 1996) to measure structural change, defined as the differential between values in two periods of time, e.g., current (1) and past (0). The different proposed techniques for analysing such differentials, however, arrive at different results even when using the same databases; nevertheless, they reach similar conclusions (Dietzenbacher and Los 1998).

SDA theoretical and methodological efforts have proven the nature of structural change and its intervening elements, such as final demand components, private consumption, exports, or investment, for example (Lin 2014; Portella 2016). Those methodologies have been applied on a regional level as well (Arto and Dietzenbacher 2014; Owen 2014) and also considering some variables related to the IO model, such as employment (Carrascal 2017; Portella 2016; Yang and Lahr 2010), the environment (Chang and Lahr 2016, Hoekstra et al. 2016; Lenzen et al 2012, Malik et al., 2016), and energy (Guevara and Rodrigues 2016; Kim and Heo 2016; Su and Ang 2012; Yamakawa and Peters 2011; Zhang and Lahr 2014). SDA has also been employed in combination with econometric techniques in relation to entropy (Fernández et al. 2008). Some authors suggest studying an alternative decomposition of the dynamic model (Dietzenbacher and Miller 2015; Miller & Blair 2009; 655), namely $\boldsymbol{x} = \boldsymbol{LBf}$ by means of analysing changes in the multipliers matrix ($\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$) and in the vector of final demand ($\mathbf{f}$) and their effects on the capital stock ($\mathbf{B}$).

In Leontief's IO model, output depends on final demand, when technology remains unchanged, as reflected in the multipliers matrix. In other words, output may vary if either of those two elements is altered. Sonis et al. (1996) suggest also taking into consideration the interrelation between technological effects and final demand. Parallel to the demand-driven model, in the supply-led model the exogenous variable is value-added; numerically, when it changes and the distribution coefficients remain, output changes. However, it is not easy to justify the stability of those relations (the willingness to consume determines supply) and it is not necessarily easy to follow the assumption that value-added determines output. Numerically speaking, however, both models are equivalent under certain conditions (Manresa and Sancho 2020) or similar (Aroche and Marquez 2020). Also, the differences between these two models can be analysed using the Laspeyres and Paasche indices, since "This difference is due to the assumptions of revenue maximization at the output side and cost minimization at the input side of the production unit" (Balk, 2016;19).

As implied above, SDA limits its scope to demand phenomena; its point of departure is Leontief's demand-sided model and then it has been used to study issues as deriving from final and intermediate demand. Yet, economic growth and structural change can also relate to supply-driven events. Admittedly, since the demand- and supply-determined models are similar, it should be possible to relate results on both models from that fact, but those will undoubtedly produce interesting insights on the analysis. Moreover, as already mentioned, SDA delivers multiple results for any database. It ought to be possible to propose alternative methods that avoid that.

The aim of this paper is threefold, first, to discuss an alternative method to SDA useful to analyse economic growth; second, to show that when comparing different IO tables of one economy it is possible to find the elements that contribute to growth from the supply side, namely, intermediate inputs and factors through a technical relationship and—from the demand side—intermediate consumption and final demand components. Thirdly, when a number of IO tables are available, it will be possible to find growth trajectories that economies follow, in order to analyse and compare the supply and demand balance.

The paper is organized as follows: in the second section, I present the axiomatic properties of neoclassical economics that can be interpreted from IO tables and from the standpoint of the general and partial equilibrium in the economy. On those bases, I explain the price—cost and income—expenditure effects that define the contributions of the IO coefficients. In the third section, I examine the disequilibrium foundation of the IO tables and analyse it from the perspective of the growth contribution coefficients expression, in order to follow the trajectory of the supply and demand coefficients. In section four, I justify my choice of countries analysed and clarify some terms employed in this paper drawn from the IO tables. I then apply the suggested methodology to data for the largest OECD economies, namely the US, Germany, France, Japan, and the United Kingdom. The conclusions appear in the last section.

2 Neoclassical production and consumption theories from the IOT perspective

Beyond interesting theoretical discussions on whether the IO model is related to the Walrasian general equilibrium formulation (e.g., Leontief 1937; Lallement and Akhabar 2011), it is possible to understand Leontief's model from the basic principles of neoclassical production analysis (Rose and Casler 1996). The latter is a part of the axiomatic general equilibrium model—at least from a certain point of view. This model refers to economic agents who relate to sets of goods and sets of production technologies, by means of either production or utility functions. The neoclassical school demonstrates the necessary and sufficient conditions to ensure the existence of equilibrium, its stability and uniqueness (Debreu 1959). Walras and other neoclassical economists, together with the classics, acknowledge the circular flow on which Quesnay and Leontief lay their models of reproduction of the capitalist economy (Lallement and Akhabar 2011).

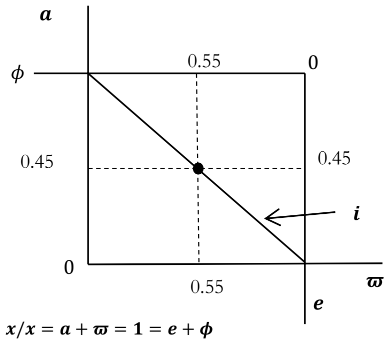

Fig. 1 General equilibrium from the 2011 USA input output table

If aggregated output is defined by the inner product of a price vector times a quantities vector (Debreu 1959),[1] the general properties of the neoclassical sets of production become specific; for example, when the production function is linear, with fixed-proportion, the isoquants are L-shaped, ipso facto excluding any possibility of a technical substitution relation between inputs. Leontief (1937) suggested that this is how the real world and the IO model function. The IO table assumes that the production value derives from the cost of inputs (cost elements), for a given level of both total purchases and output; likewise, revenues derive from sales of the goods produced to the various types of consumers at a given price level, as well as a given level of output. It is implicit that there are no continuous isoquants, or curves of supply or demand: there are only snapshots in the Cartesian space of commodities for every temporary observation. Indeed, technical change is ruled out of the model and comparative statics is the only possible approach to analysis involving more than one state of equilibrium. Below I develop a proposal to analyse output differentials between IO tables from separate periods which—as is well known—show different technical and distribution coefficients.

In the IO model, every industry shows linear production functions, and therefore the whole economy can be aggregated into a single sector; two equations may also represent the accounting of output: $\boldsymbol{i'Zi} + \boldsymbol{i'f} = \boldsymbol{i'x}$, on the one hand and $\boldsymbol{i'Zi} + \boldsymbol{v'i} = \boldsymbol{x'i}$, on the other, where Z is the intermediate transaction matrix, f is the final demand vector, v is the value-added vector, x is the gross value product, and i is the unit vector; considering the coefficients of these equations, they show a general equilibrium situation.

Figure 1 represents the Edgeworth box of the IOT of US economy in 2011 aggregated into one sector (see below for specifics of the database used in this paper). In this graph, the aggregated coefficients of intermediate consumption (a) as well as that of intermediate sales ($\boldsymbol{e}$) are 0.45, while the final demand coefficient (ϕ) and that of value-added (ϖ) are 0.55. The proportions refer to relative prices and quantities, respectively, so that the straight line represents the case when relative prices or relative quantities are equal to one.

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[1] Which is to say $px = \sum_{i=1}^{n} p_i y_i$, where p y is the general price level, x is total output, p_i is the price of the output of a branch or of economic activity and y_i is that same output.

Breaking up the economy into sectors or industries jeopardizes the general equilibrium, because—as we see in empirical IO tables—value-added may not equal final demand in every industry. Equations (1) and (2) below show the lack of equilibrium between supply and demand, splitting total purchases and offers by sectors:

$$x'\hat{x}^{-1} = i'A + \varpi' = i', \tag{1}$$

$$\hat{x}^{-1}x = Ei + \phi = i. \tag{2}$$

$\boldsymbol{i}$ is a unit vector, x is gross value product vector, ϖ is the value-added coefficient vector, ϕ the final demand coefficient vector, $\boldsymbol{A}$ is the technical coefficients matrix, and $\boldsymbol{E}$ is the distribution coefficients matrix. In both of the above expressions, the relative proportions add up to 1. These equations are alternatives for one another and correspond to the understanding of the IO table as either a supply or a demand array (they do not correspond to the IO model, but they correspond to a reading of the IO tables).

Reordering (1) and (2) in terms of vectors $\boldsymbol{i'}$ and $\boldsymbol{i}$, it is possible to find both the equilibrium price solution to the IO model (Leontief 1970) and that of quantities within Ghosh's (1958) methodology. Equations (3) and (4) below define the value of a unit output determined either by supply or demand. It has been shown that those models are similar and give way to two similar matrices ($\boldsymbol{L}$ and $\boldsymbol{G}$, respectively) that have been also interpreted as the multipliers matrices, both of which refer to equilibrium (Aroche & Marquez, 2020):

$$i' = \varpi'(I - A)^{(-1)} = \varpi'L, \tag{3}$$

$$i = (I - E)^{(-1)}\phi = G\phi. \tag{4}$$

In Eqs. (3) and (4), each equilibrium depends on coefficients ϖ and ϕ; if output increases, it is implied that final demand $(\boldsymbol{f})$ or value-added $(\boldsymbol{v})$—alternatively in each model—has changed. The equilibria reached in these expressions are optimum for the producer or the consumer independently, breaking up the general equilibrium environment.

2.1 The contribution of factors and components in the IOTs

In the open IO model, output levels are a monotonous function of fixed input coefficients and final demand variables. It is also true that when an input coefficient changes (either increases or decreases), at least one other will change in the opposite direction, so that output remains equal to 1. Jorgenson and Griliches (1967) discuss this issue measuring total factor productivity; such moves should be understood as the substitution effect between inputs, given an initial technology[2]. Figure 2A shows that effect for sector *j* described in the disaggregated analysis of total factor productivity and inputs (Miller and Blair 2009) in two different periods of time, 0 and 1. In the graph, the differential (Δ) between $\boldsymbol{x}_j^1$ and $\boldsymbol{x}_j^0$ is the

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[2] In the short term, the substitution effect results from changing relative prices, (Rose and Casler 1996: 53); however, the relation curve between equilibrium prices in one sector—as they appear in the I-O table—is a straight line with negative slope in the Cartesian plane. Such a function is not strictly convex.

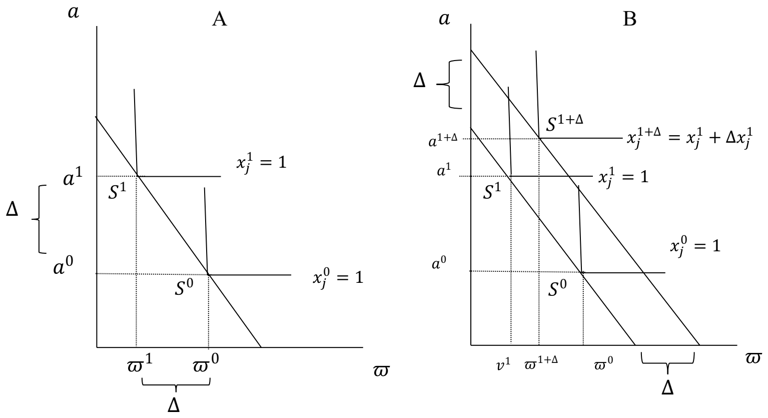

Fig. 2 A Substitution effect sector j, B price–cost effect to sector j

distance between S^1 and S^0; it is equal to zero, which means that the total sum of inputs (or the value of total output) in each period equals one $\left(\boldsymbol{x}_j^1 = \boldsymbol{x}_j^0 = \boldsymbol{i}\right)$ in this system of relative prices and quantities, where isoquants are semi-convex linear output functions. However, Δ should correspond to the direction that the output level would follow, so we can consider that it represents the real growth rate of each sector.

In comparative static analysis, the income effect is an instrument in Slutsky's equation (Gravelle and Rees 2004; Mas-Colell et al 1995) that will be adapted to the present proposal to show the transition between two equilibria in successive periods. First, let us assume that the economy grows with constant returns by adding inputs proportionally, in such a way that the isoquants have an "L" shape. Figure 2B again shows those two actual equilibria ($\boldsymbol{x}_j^1$ and $\boldsymbol{x}_j^0$) and a third hypothetical one $\left(\boldsymbol{x}_j^{1\Delta}\right)$ that would occur in the transit between them using the coefficients corresponding to time 1, yielding an output equal to $\boldsymbol{x}_j^0$. Economic growth experienced today in relation to the past is expressed by the hypothetical displacement from the latter point towards $\boldsymbol{x}_j^{1+\Delta}$, with coordinates $\left(\boldsymbol{a}^{1+\Delta}, \boldsymbol{\varpi}^{1+\Delta}\right)$, keeping the proportion between factors a^1 and $\boldsymbol{\varpi}^1$ at $\boldsymbol{x}_j^1$. In this case, we assume that $\Delta > 0$; therefore, $\boldsymbol{x}_j^{1+\Delta} > 1$, in terms of $\boldsymbol{x}_j^0 = 1$. In general, expanding output describes a ray where factors expand at a uniform rate, keeping the proportions between them, as shown in Fig. 2B as well.

Formally, Eq. (5) is defined assuming constant returns to scale (which means that $\Delta(\boldsymbol{A}^1, \varpi^1) = \boldsymbol{x}^1(\Delta\boldsymbol{A}^1, \Delta\varpi^1)$) and measures the output variation between two periods as the sum of the actual initial inputs plus the additions needed to support the increased output. The latter will equal the output growth rate ($\boldsymbol{\Delta}$) multiplied by today's production inputs:

$$i'^{1.+\Delta} = \left(i'A^1 + \varpi'^1\right) + \Delta\left(i'A^1 + \varpi'^1\right) = i'A^{1.+\Delta} + \varpi'^{1.+\Delta}. \tag{5}$$

Therefore, we can say that Eq. (5) describes a hypothetical output if constant returns to scale prevail, when output varies between dates 0 and 1, employing the technology of time 1. The balance between $\Delta\boldsymbol{x}^1$ and $\boldsymbol{x}^0$ is equivalent to the output growth rate, but expressed as the contributions of inputs ($\boldsymbol{A}^*$) and factors (ϖ^*):

$$\Delta' = i'^{1+\Delta} - i'^{0} = \left(i'A^{1.+\Delta} + \varpi'^{1.+\Delta}\right)\left(i'A^{0} + \varpi'^{0}\right) = i'A^{*} + \varpi'^{*} \tag{6}$$

On the demand side, Eqs. (5) and (6) explain the economy's growth trajectory based on the contributions of $\boldsymbol{A}*$ and $\varpi*$, so that they identify two theoretical hypotheses in this regard, (1) that the growth path can turn intensive in either intermediate inputs or factors—which is to say that the contribution of some of the factors to growth intensifies—or (2) that the proportions between the contributions of factors are constant along the path of growth.

In other words, the results of Eq. (6) can be positive, negative, or even null; growth can be explained by variations in either the value-added coefficient or the coefficient of intermediate inputs. Rearranging Eq. (6), we arrive at (7), which defines the rate of growth as the contribution of the increase of the value-added coefficients times the inverse Leontief matrix, which is also a matrix of "technical contribution" of the coefficients matrix $\left(\left(\boldsymbol{I} - \boldsymbol{A}^{\Delta}\right)^{-1}\right)$ to production. $\boldsymbol{A}^{\Delta} = \left(\widehat{\Delta'}^{-1}\boldsymbol{A}^{*}\right)$, i.e. the influence of variations in the technical coefficients on growth.

$$\begin{aligned} \Delta' &= i'A^{*} + \varpi'^{*} \rightarrow \Delta' - i'A^{*} = \varpi'^{*} \rightarrow \Delta'\left(I - \widehat{\Delta}'^{-1}A^{*}\right) \\ &= \varpi'^{*} \rightarrow \Delta' = \varpi'^{*}\left(I - A^{\Delta}\right)^{-1} \end{aligned} \tag{7}$$

Equation (8) is analogous to (7) on the demand side and can be developed from Eq. (4); it meets the properties of (5) and (6) as well.

$$\begin{aligned} \Delta &= E^{*}i + \phi^{*} \rightarrow \Delta - E^{*}i = \phi^{*} \rightarrow \Delta\left(I - E^{*}\hat{\Delta}'^{-1}\right) \\ &= \phi^{*} \rightarrow \Delta = \left(I - E^{\Delta}\right)^{-1}\phi^{*} \end{aligned} \tag{8}$$

In short, using the IO tables, growth can be analysed from the price–cost effect standpoint, for the supply side model, or from the income–expenditure standpoint for the demand version; also, growth can be characterized according to whether technology turns inputs or factors intensive or from the supply side, whether the economy turns intermediate or final sales intensive. Further, it is possible to find a growth rate similar to Leontief's prices model (Eq. 7) or one similar to Ghosh's proposal (Eq. 8), using the appropriate inverse matrices. This methodology does not assume equilibrium between supply and demand at every time in each industry. In the price–cost effect, the inverse matrix of the technical contribution coefficients determines growth depending on the factor contribution employed, as shown in Eq. (7). Equation (6) shows the contributions to growth that support the hypothesis developed in the IP analysis of growth, assuming changes in the demand components, which lead to structural changes, such as factors or inputs intensity (Aroche 2020).

3 Analysis of the contribution of factors and inputs to growth

Figure 3 shows sector *j*'s equilibrium on the cartesian plane as a single producer at point S^0 and a single consumer at point D^0. Their coordinates are (1) the intermediate consumption and value-added coefficients and (2) the intermediate and final demand

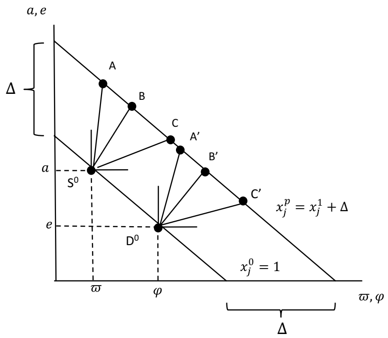

Fig. 3 Hypothesis of disequilibrium market to sector j

coefficients; the distance between those points is zero, as analysed in Fig. 2B, i.e. increasing the use of direct factors implies reducing intermediate inputs. Returning to Fig. 3, this is shown by segment S^0D^0; else, $(\boldsymbol{\varpi} - \boldsymbol{\phi}) = -(\boldsymbol{a} - \boldsymbol{e})$, showing the disequilibrium between supply and demand. Points *A*, *B*, and *C* correspond to the new technologies in relation to S^0. When output remains the same on two different dates, while technology differs, the contributions of each factor or input to output will also be dissimilar. Figure 3 also shows some possible growth trajectories of supply and demand, assuming equal technologies in segments S^0A, S^0B, and S^0C for the supply points and D^0A, D^0B', and D^0C' for demand.

On those trajectories three situations can emerge; first, the difference between *e* and *a* on S^0D^0 turns smaller than the difference between the points that correspond to segment AC', augmenting the disequilibrium. Under such circumstances, the prices and quantities models take different trajectories in the industry (for instance, segments S^0A and D^0C' in Fig. 3); second, the original disequilibrium remains, so the difference between *e* and *a* in segment S^0D^0 is the same as that in BB' and AA', which also means that the growth trajectories are parallel (for example on the trajectories S^0B and S^0B' or S^0A and DA'). Finally, that disequilibrium decreases, i.e. the differences between the coefficients at S^0D^0 are greater than that between the coefficients of the points in CA' (for example, trajectories AC and DA'); the models converge.

In one industry, the IO table shows the decomposition of one unit of output into internal and imported inputs (A^i, A^m), plus value-added per unit of output (ϖ), which in turn equals the sum of the compensation to capital (k) and labour (w), plus net taxes (g). On the income side, a unit of output in each industry comprises the distribution coefficients, both to the internal industries as well as exports of intermediates (E^i, E^x), plus the final demand coefficient (ϕ), equal to the sum of private consumption (c), government consumption (g), gross capital formation (π), and net exports (χ). It is also an accounting system where each demand account finds a counterpart on the supply side. Thus, Eq. (9) states that the distance between the supply- and demand-sided models is zero, while the sum of them is the null vector (o):

$$
\begin{aligned}
o' = {} & \left(i'A^{i} - \left(E^{i}i\right)'\right) + \left(i'A^{m} - (E)\right) + \left(K' - \pi'\right) + \left(w' - c'\right) \\
& + \left(\gamma' - g'\right) - \chi'
\end{aligned}
\tag{9}
$$

where $\left(\boldsymbol{i}'\boldsymbol{A}^{\boldsymbol{i}} - (\boldsymbol{E}^{\boldsymbol{i}}\boldsymbol{i})'\right)$ and $\left(\boldsymbol{i}'\boldsymbol{A}^{\boldsymbol{m}} - (\boldsymbol{E}^{\boldsymbol{x}}\boldsymbol{i})'\right)$ are the internal and external productive balances, which contain the financial $\left(\boldsymbol{k}' - \boldsymbol{\pi}'\right)$, private $\left(\boldsymbol{w}' - \boldsymbol{c}'\right)$, public $\left(\boldsymbol{\gamma}' - \boldsymbol{g}'\right)$, and external $\left(\boldsymbol{\chi}'\right)$ balances. The difference between savings and investment, measured as the difference between the gross operating margin and the gross capital formation, equals the disequilibrium in each sector equals the sum of the balances of the rest of the accounts.

Considering Eq. (6) and the balancing of expanding-shortening between inputs, the contribution of the latter when the technology changes may be positive or negative. The sign depends on the output variation, while the relation between those contributions may be also positive, negative, or null. As mentioned previously, points *A*, *B* and *C* in Fig. 3 correspond to new production forms in relation to $\boldsymbol{x}_{\boldsymbol{j}}^{0}$ and $\boldsymbol{x}_{\boldsymbol{j}}^{1}\left(\boldsymbol{x}_{\boldsymbol{j}}^{\boldsymbol{p}}\right)$. For each industry it is:

$$
x^{p\prime} = x^{1\prime} + \Delta' = i'A^{1} + \varpi^{1\prime} + (i\prime A^{*} + ?^{*\prime}) = i\prime A^{p} + \varpi^{p}
\tag{10}
$$

The relationship between factors and inputs for each industry in each period x^{p} is also different from $\boldsymbol{x}^{1}$ and $\boldsymbol{x}^{0}$, and corresponds to the growth trajectory of output.

It is possible to infer that $\boldsymbol{x}^{\boldsymbol{p}}\prime = \boldsymbol{x}^{\boldsymbol{p}}$ implies that $\boldsymbol{x}^{\boldsymbol{p}}\prime - (\boldsymbol{x}^{\boldsymbol{p}})\prime = \delta\prime$, δ is the null vector. Hence, such equality may be expressed as Eq. (9), where $\boldsymbol{\delta}$ is equal to the sum of each balance between factor components' growth contributions so that, reordering in terms of the financial balance, Eq. (10) shows that a deficit signifies that such contributions to capital payments are greater than investment outlays, a situation which in turn is explained by a deficit between******* revenues and expenditures.

$$
\begin{aligned}
-(k'^{t\Delta} - \pi'^{t\Delta}) = {} & \left(i'A^{it\Delta} - \left(E'^{t\Delta}i\right)'\right) + \left(i'A^{m\Delta} - \left(E^{x\Delta}i\right)'\right) + \left(w\prime^{t\Delta} - c\prime^{t\Delta}\right) \\
& + \left(\gamma\prime^{t\Delta} - g\prime^{t\Delta}\right) - \left(\chi^{t\Delta}\right)'
\end{aligned}
\tag{11}
$$

Equation (11) shows that each balance has a counterpart within the economy between internal supply and demand (except for trade in final goods); thus, a deficit can be explained by another surplus such as a productive one, whether private or public. However, the results of the balance may fulfil various cases, as shown in Fig. 3, which allows measuring the disequilibrium as the distance between every pair of points. Comparing the balances will yield deeper insights for the analysis of growth. Considering that the savings-investment accounts are the basis of the process of growth, when the balance between them is zero, there will be price stability, as well as increasing wealth and a better distribution (Harrod 1939). Thus, this will be a favourable scenario for growth.

Table 1 Decomposition of the growth of the economy by supply and demand coefficients according to the IOT of 1995 and 2011

	***Ai*∗**	***Am*∗**	***k*∗**	***w*∗**	**γ∗**	**Δ**	***Ei*∗**	***Ex*∗**	***c*∗**	**π∗**	***g*∗**	**χ∗**
France	1.5	2.7	− 1.5	− 0.5	− 0.4	1.8	1.5	2.7	− 1	1.2	0	− 2.6
Germany	0.9	5.4	− 0.3	− 2.6	-2	1.4	0.9	5.4	− 2.7	− 3.2	− 1.1	2.3
Japan	− 1.1	3.4	0.4	− 0.6	− 1.4	0.8	− 1.1	3.4	1.7	− 4.7	2.7	− 1.3
UK	− 2	2.4	− 0.4	2.1	0	2.1	− 2	2.4	1.7	− 1	2.1	− 1.1
US	− 1	1.8	0.4	0.6	0.6	2.5	− 1	1.8	2.9	− 1.3	1.7	− 1.6

***Ai*∗**: contribution domestic technical coefficients

***Am*∗**: contribution import technical coefficients

***k*∗**: contribution compensation to capital coefficients

***w*∗**: contribution labour coefficients

γ∗: contribution plus net taxes coefficients

Δ: annual rate growth

***Ei*∗**: contribution internal intermediate deliveries coefficients

***Ex*∗**: contribution external intermediate deliveries coefficients

***c*∗**: contribution private consumption coefficients

π∗: contribution gross capital formation coefficients

***g*∗**: contribution public consumption coefficients

χ∗: contribution net exports coefficients

Source: Own preparation with the IOT of the OECD publication 1995 and 2011 rev. 3

4 Database

In order to analyse growth and its characteristics empirically,[3] we take data for the five largest OECD economies (the United States, Germany, Japan, France, and the United Kingdom), which also have the largest populations and are among the group of countries with the highest human development indices (UNDP, 2011). OECD (stats.oecd.org) publishes the IO tables for those countries at current prices; the World Bank database (datos.bancomundial.org) includes variables such as gross domestic product for each country from 1995 to 2011 at constant (2010) prices. Those values are used to estimate the rates of growth of the gross output values by industry.

Aggregated value-added and final demand accounts in the IOT are also part of the database as follows: net taxes includes every row vector that refers to taxes and subsidies in the original tables; the consumption account aggregates the sum of households' final consumption expenditures, direct purchases abroad by residents (imports), and direct purchases by non-residents (exports); government consumption totals the demand of non-profit institutions serving households; the sum of gross fixed capital formation also accounts for changes in inventories, as the investment account.

5 Empirical example

According to the World Bank, between 1995 and 2011 the world economy grew 3% per annum on average, at 2010 prices, which means that production grew from 42.2 trillion dollars in 1995 to 68 trillion dollars in 2011. That growth was due to total factor productivity, and that of labour (Badunenko et al., 2013, Jorgenson et al. 2007).

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[3] The present analysis includes the domestic economy only and excludes every aspect that may involve any effect of trade or exchanges between countries. As a result, the exercises presented here do not use any multiregional IO tables.

Nevertheless, the former has not been growing in the OECD economies (Balk 2014; Marattin and Salotti 2011), as their contribution to the World output has declined from 77% in 1995 to 66.8% in 2011 and non-member countries have increased their share of World output due to expanding capital investments (Badunenko et al., 2013). The average growth rate of OECD member states was 2.2% during that same period.

Table 1 also presents rates of Gross Domestic Product (GDP) growth between 1995 and 2011 for the countries included in this paper. The United States grew at 2.5% (Δ) per annum on average, following a value-added intensive path, particularly in the contribution of labour compensation coefficients ($\boldsymbol{w}^{*}$) and those of net taxes ($\boldsymbol{\gamma}^{*}$). These calculations also show that US growth depends more on the productivity of labour than of capital, with the UK presenting a similar case. Just as neoclassical theory has shown, growth for this country derives from increased human capital, which explains the increasing wages account (Barro 1991; Mankiw et al. 1992; O'Mahony and Timmer 2009; Solow 1956). Recently, Torres and Yang (2019) have demonstrated that the empirical distribution of the technical coefficients matrix in the US is symmetric and unimodal, which means that the distribution of input coefficients has persisted for a long period of time, despite major technical and institutional transformations and changes in the organization of production. Nonetheless, these results show that within growth inter-industry relations due to external input requirements are more beneficial than internal ones. On the demand side, growth was intensive in the coefficient of private ($\boldsymbol{c}^{*}$) and public ($\boldsymbol{g}^{*}$) consumption, which has been the result of a policy of public debt (Streeck 2013). These results indicate that the strategy practised in the US in recent years has favoured growth but eroded investment.

Germany, France, and Japan followed paths of growth that were more intensive in intermediate inputs $\left(\boldsymbol{A}^{*}\right)$, on the one hand, and were value-added intensive ($\boldsymbol{\varpi}^{*}$), on the other. Nevertheless, intermediate inputs have contributed in the growth process in the whole set of economies considered (O'Mahony and Timmer 2009). It is interesting to note in which countries imported inputs $\left(\boldsymbol{A}^{m*}\right)$ have contributed to growth in higher proportions than domestically produced inputs. In other words, today international value chains play a decisive role in economic development; as a result, they have undergone a process of productive fragmentation that has made companies more profitable, like those in the automotive industry on the strength of which the manufacturing industry was built in the United States (Feenstra 1998).

At the sector level, the average shares of each one in total output, according to IOT for each country, show that service sector activities contribute the most to output, as happens in the more developed countries (Palma 2005; Szirmai 2012). For example, in both Germany and Japan the service sector's share surpasses 50% of GDP, while in the other countries it exceeds 60%. These industries, however, are not necessarily the ones that grow fastest; wholesale, retail, and repairs account for 10% of total production value in the 6 economies; however, this branch's average growth rate in this set of countries is only 1.2%.

The results in Table 2 show the contribution to growth of the various components in four sectors, using the coefficients matrices, as explained above. Table 3 shows whether growth in each sector is intermediate or final demand (on the one hand) or inputs- or factors-intensive (on the other), when the absolute difference between coefficients is greater than 1. Growth can also maintain its character when that difference is equal to or less than 1.

Table 2 Decomposition supply and demand coefficients according to the IOT of 1995 and 2011

Countries	Coefficients	Coke, refined petroleum products and nuclear fuel	TX computer, electronic and optical equipment	Motor vehicles, trailers and semi-trailers	Computer and related activities
France	$Ai*$	−10.7	5.9	3.7	13.2
	$Am*$:	36.1	1.9	6.2	1.6
	$k*$	−9.1	−0.9	−2.9	7.3
	$w*$	−3.7	−8.3	−4.7	−17.3
	$\gamma*$	−6.0	−0.9	−1.2	0.1
	Δ	6.6	−2.3	1.1	4.9
	Ei	−4.3	−12.0	−5.4	−9.4
	Ex	12.0	18.6	0.3	1.8
	$c*$	11.5	14.4	5.2	−7.4
	$\pi*$	−1.2	−1.4	9.4	22.4
	$g*$	0.0	−2.2	0.0	0.0
	$\chi*$	−11.4	−19.7	−8.4	−2.5
Germany	$Ai*$	−24.1	−3.7	3.6	1.6
	$Am*$:	36.1	3.8	6.6	4.5
	$k*$	−0.2	3.2	−0.3	−14.0
	$w*$	−2.1	1.1	−2.8	−0.3
	$\gamma*$	−2.1	−2.2	−2.2	13.7
	Δ	7.6	2.2	4.9	5.5
	Ei	10.2	−3.1	11.5	3.1
	Ex	18.1	−0.8	4.2	18.2
	$c*$	−1.7	−3.5	−11.3	2.7
	$\pi*$	−3.9	−16.8	−6.4	−7.5
	$g*$	−0.4	−2.0	0.0	0.0
	$\chi*$	−14.7	28.4	6.9	−11.0
Japan	$Ai*$	−4.1	−6.4	3.1	−3.1
	$Am*$:	34.3	6.3	2.0	0.4
	$k*$	−9.8	1.7	−2.8	11.8
	$w*$	−11.9	−0.4	−1.6	4.8
	$\gamma*$	−1.6	−1.8	1.2	−7.0
	Δ	6.9	−0.6	1.9	6.9
	Ei	−1.1	−3.7	2.2	13.9
	Ex	3.9	8.0	0.4	0.5
	$c*$	4.2	2.1	−7.5	−3.6
	$\pi*$	2.9	−2.1	−0.8	−4.0
	$g*$	0.0	0.0	0.0	0.0
	$\chi*$	−3.0	−4.9	7.6	0.1
UK	$Ai*$	−12.8	−11.9	−7.0	5.4
	$Am*$:	32.4	−0.1	13.3	2.0
	$k*$	−9.8	0.6	−1.2	−2.2
	$w*$	−2.6	7.7	−4.7	2.8
	$\gamma*$	−2.1	−0.1	−0.1	−0.6
	Δ	5.1	−3.8	0.3	7.4
	Ei	−10.9	−2.7	−7.4	7.0
	Ex	24.4	34.0	7.2	1.4
	$c*$	5.7	22.9	15.8	1.3
	$\pi*$	−0.1	−0.5	−10.0	0.9

Table 2 (continued)

Countries	Coefficients	Coke, refined petroleum products and nuclear fuel	TX computer, electronic and optical equipment	Motor vehicles, trailers and semi-trailers	Computer and related activities
	g ∗	0.0	0.0	0.0	0.3
	χ∗	− 14.1	− 57.5	− 5.3	− 3.5
US	***Ai*** ∗	− 2.3	− 24.1	− 1.4	8.0
	Am ∗:	10.0	− 5.1	9.9	2.0
	k ∗	2.7	7.8	− 0.7	2.7
	w ∗	1.5	13.6	− 4.3	− 1.4
	γ∗	− 1.2	5.8	− 3.4	− 4.2
	Δ	10.7	− 2.0	0.1	7.1
	Ei	− 5.5	− 12.7	− 4.4	16.2
	Ex	2.4	17.8	7.1	3.9
	c ∗	6.6	16.4	1.3	1.2
	π∗	0.0	23.2	5.8	− 9.6
	g ∗	0.0	0.0	0.0	0.1
	χ∗	7.2	− 46.7	− 9.7	− 4.7

Ai ∗: contribution domestic technical coefficients

Am ∗: contribution import technical coefficients

k ∗: contribution compensation to capital coefficients

w ∗: contribution labour coefficients

γ∗: contribution plus net taxes coefficients

Δ: annual rate growth

Ei ∗: contribution internal intermediate deliveries coefficients

Ex ∗: contribution external intermediate deliveries coefficients

c ∗: contribution private consumption coefficients

π∗: contribution gross capital formation coefficients

g ∗: contribution public consumption coefficients

χ∗: contribution net exports coefficients

Source: Own preparation with the IOT of the OECD publication 1995 and 2011 rev. 3

Growth in the chosen economies has been already characterized; nevertheless, sectoral behaviour need not follow the aggregated pattern. France, Germany, and Japan have 17 industries intensive in demand for intermediate inputs, whereas in the delivery of such elements each economy has 14, 15, and 13 sectors. In the UK there are 14 and 13 branches intensive in the demand and delivery of intermediate inputs, while in the US there are 17 and 9. Japan and the UK have more value-added intensive sectors (10 and 13) compared to France, Germany, or the US (4, 8, and 7), while each country has some branches intensive in final demand components, like Japan (14), the UK (13), the US (16), and 9 in France and Germany.

Table 3 shows that the sectors with balanced contributions between the four components are more abundant on the supply side in France and the US (14 and 15), but 9 such industries are found in Germany and 7 in Japan and the UK. On the demand side, there are 11 balanced industries in France, 10 in Germany, 9 in the US, and 8 in Japan and the UK.

Sectors can show different contributions to growth on the supply or demand side. For example, coke, refined petroleum products, and nuclear fuel in Germany is

Table 3 Characterizing of the growth paths

Industry	France		Germany		Japan		UK		US	
	Supply	Demand	Supply	Demand	Supply	Demand	Supply	Demand	Supply	Demand
Agriculture, hunting, forestry and fishing	S	S	S	S	S	S	VA	E	VA	S
Mining and quarrying	S	S	VA	S	VA	DF	VA	E	A	E
Food products, beverages and tobacco	S	S	S	S	S	S	A	S	A	DF
Textiles, textile products, leather and footwear	VA	DF	VA	DF	A	DF	S	DF	A	DF
Wood and products of wood and cork	S	S	S	S	A	DF	VA	E	A	E
Pulp, paper, paper products, printing and publishing	VA	E	S	E	A	E	VA	E	S	DF
Coke, refined petroleum products and nuclear fuel	A	E	A	E	A	DF	A	E	A	DF
Chemicals and chemical products	A	DF	A	S	A	E	S	S	A	DF
Rubber and plastics products	S	S	A	DF	S	S	VA	DF	S	S
Other non-metallic mineral products	S	S	A	S	A	E	VA	DF	S	S
Basic metals	VA	E	A	E	A	DF	VA	DF	A	E
Fabricated metal products	S	S	A	DF	VA	DF	S	DF	S	S
Machinery and equipment, nec	S	S	A	E	A	DF	VA	DF	S	S
TX computer, electronic and optical equipment	VA	DF	VA	DF	S	S	A	DF	A	DF
Electrical machinery and apparatus, nec	S	S	A	DF	VA	DF	VA	DF	S	DF
Motor vehicles, trailers and semi-trailers	A	DF	A	E	A	DF	S	S	S	S
Other transport equipment	A	E	A	E	VA	DF	A	DF	VA	DF
Manufacturing nec; recycling	S	S	S	S	A	DF	S	S	S	S
Electricity, gas and water supply	A	E	A	E	A	E	A	E	VA	DF
Construction	A	DF	VA	DF	A	DF	VA	E	S	S
Wholesale and retail trade; repairs	A	E	S	S	S	S	A	S	A	DF
Hotels and restaurants	A	DF	VA	E	A	DF	VA	E	VA	DF
Transport and storage	A	E	A	E	S	E	A	S	VA	E
Post and telecommunications	A	DF	S	DF	A	DF	A	DF	A	DF
Financial intermediation	A	E	A	DF	VA	S	S	DF	A	E

Table 3 (continued)

Industry	France		Germany		Japan		UK		US	
	Supply	**Demand**	**Supply**	**Demand**	**Supply**	**Demand**	**Supply**	**Demand**	**Supply**	**Demand**
Real estate activities	S	E	VA	S	A	DF	A	DF	A	E
Renting of machinery and equipment	A	E	VA	E	VA	DF	VA	E	A	E
Computer and related activities	A	DF	A	E	VA	E	A	E	A	E
R&D and other business activities	A	E	A	E	VA	DF	A	DF	VA	E
Public administration and defence; compulsory social security	S	E	S	E	A	DF	A	E	A	DF
Education	A	E	A	E	A	S	A	E	A	DF
Health and social work	S	DF	VA	E	VA	DF	A	E	A	DF
Other community, social and personal services	A	E	A	DF	VA	E	VA	S	VA	DF
Private households with employed persons	S	S	S	S	S	S	S	S	S	S
Output	A	E	A	E	A	E	VA	DF	VA	DF

A: technical coefficients

DF: final demand coefficients

E: delivery coefficients

S: balanced or Similar contributions

VA: valued add

Source: Own preparation with the IOT of the OECD publication 1995 and 2011 rev. 3

Table 4 Financial balance in the IOT 1995—2011

Industry	France		Germany		Japan		UK		US	
	1995	**2011**	**1995**	**2011**	**1995**	**2011**	**1995**	**2011**	**1995**	**2011**
Coke, refined petroleum products and nuclear fuel	0.10	− 0.05	0.00	0.05	0.46	0.07	0.11	− 0.10	0.16	0.20
TX computer, electronic and optical equipment	− 0.15	0.08	− 0.14	0.23	− 0.18	− 0.08	− 0.14	− 0.13	− 0.04	− 0.27
Motor vehicles, trailers and semi-trailers	− 0.11	− 0.09	− 0.01	0.08	− 0.05	− 0.11	− 0.21	− 0.04	− 0.05	− 0.19
Computer and related activities	− 0.23	− 0.10	− 0.03	− 0.03	− 0.19	0.22	− 0.10	− 0.14	− 0.22	0.05

Source: Own preparation with the IOT of the OECD publication 1995 and 2011 rev. 3

intensive in the delivery of intermediate inputs; in the UK food products, beverages, and tobacco are intensive in factors on the supply side but on the demand side their contributions to output are similar.

As mentioned above, the IOT as a whole fulfils the general equilibrium conditions, but individual sectors need not do so, as intermediate demand and intermediate consumption, or final demand and value-added are often different. As shown in Fig. 3, one wonders about the sectoral equilibria, i.e. the distance between the equilibrium points (S^0 and D^0), which can also be identified as the differences between the investment and savings coefficients.

Table 4 shows the distance between such components in 1995 according to the IOT in the energy, transport, and communications sectors. The sign of the balance indicates whether the disequilibrium is stronger on the supply or demand sides, when it is positive or negative, respectively. In France such branches show lower values on balance in 2011, even if savings coefficients in coke, refined petroleum products, and nuclear fuel in 1995 were greater than coefficients of investment, contrary to results in 2011, while the rest of the industries show higher investment than savings coefficients.

In Germany, savings coefficients increased over investments between 1995 and 2011, except in computer and related activities, which maintained its balance. In Japan, the sector coke, refined petroleum products, and nuclear fuel was the only one with a greater investment coefficient than savings, but the general tendency is to balance disequilibria between 1995 and 2011.

Table 4 shows that the savings coefficients have surpassed those of investment, except in computer and related activities, where the 1995 balance remains in 2011. In the former year in Japan, coke, refined petroleum products, and nuclear fuel was the only industry where the savings coefficients were higher than the investment coefficients; towards 2011 they tended to converge, but their difference kept the same sign. Other activities in Japan had opposite results, even as disequilibria diminished in computer, electronic, and optical equipment, but increased in motor vehicles, trailers, and semi-trailers, as well as in computer and related activities, which changed sign.

Based on the results in Table 4, savings coefficients have increased in excess of savings coefficients in Germany, except in computer and related activities, which have the same balance in 1995 and 2011. In that year, in Japan, coke, refined petroleum products, and nuclear fuel was the only branch where savings coefficients were higher than investment coefficients and they tended to converge showing equal signs, so that the balances were close to nil. The rest of the Japanese sectors had opposite results, even as the balance shrank in computer, electronic, and optical equipment, rising in motor vehicles, trailers, and semi-trailers as well as in computer and related activities, where the balance changed sign.

Table 5 gathers results obtained from comparing the neoclassical financial disequilibrium referred to the financial balance in 1995 and those drawn from the 2011 IO table, based on contribution to growth, as defined in this paper. In France, as well as in the UK, there are 17 branches where disequilibrium converges, in Germany 13, and 11 in both Japan and the US. As regards sectors where components follow parallel paths, preserving disequilibria, the US presents 9, Japan and the UK 7, while in Germany there are 6 and in France 5. Finally, there are 17 sectors where the trajectories diverge

Table 5 Neoclassical financial disequilibrium 1995—2011

Industry	France	Germany	Japan	UK	US
Agriculture, hunting, forestry and fishing	D	D	C	C	C
Mining and quarrying	P	C	D	D	D
Food products, beverages and tobacco	C	C	D	C	P
Textiles, textile products, leather and footwear	C	C	P	C	D
Wood and products of wood and cork	D	C	D	C	C
Pulp, paper, paper products, printing and publishing	D	P	D	P	D
Coke, refined petroleum products and nuclear fuel	C	D	C	P	D
Chemicals and chemical products	C	D	C	D	D
Rubber and plastics products	D	P	P	C	P
Other non-metallic mineral products	C	C	D	C	C
Basic metals	D	C	C	D	C
Fabricated metal products	D	D	P	P	C
Machinery and equipment, nec	C	D	P	D	P
TX Computer, Electronic and optical equipment	C	D	C	P	D
Electrical machinery and apparatus, nec	P	D	C	D	D
Motor vehicles, trailers and semi-trailers	C	D	D	C	D
Other transport equipment	P	D	C	D	C
Manufacturing nec; recycling	D	D	D	P	D
Electricity, gas and water supply	C	C	C	C	P
Construction	C	C	C	C	C
Wholesale and retail trade; repairs	C	P	D	C	D
Hotels and restaurants	C	D	D	P	D
Transport and storage	C	D	D	C	D
Post and telecommunications	D	C	P	C	C
Financial intermediation	C	C	D	P	C
Real estate activities	C	D	C	C	C
Renting of machinery and equipment	C	D	D	C	C
Computer and related activities	C	P	D	D	C
R&D and other business activities	D	C	P	C	D
Public administration and defence; compulsory social security	D	P	D	D	P
Education	D	P	C	D	P
Health and social work	D	D	D	C	P
Other community, social and personal services	P	C	C	C	P
Private households with employed persons	P	C	P	P	P
Output	C	C	C	P	D

C: convergence

D: divergence

P: parallel

Source: Own preparation with the IOT of the OECD publication 1995 and 2011 rev. 3

in Germany and Japan, 13 in the US, 12 in France, and 9 in the UK. In the aggregate, France, Germany, and Japan converge to equilibrium, whereas in the UK disequilibrium is stable and it is expanding in the US.

Coke, refined petroleum products, and nuclear fuel, as well as computer, electronic, and optical equipment, fulfil the three hypotheses on the disequilibrium trajectories in different economies; they diverge in Germany and the US, converge in France and Japan, and hold stable in the UK. The disequilibrium trajectories in motor vehicles, trailers, and semi-trailers converge in France and Japan and diverge in Germany, the UK, and the US. In computer and related activities services, the disequilibrium between supply and demand is stable in Germany, convergent in France, and divergent in the US.

6 Discussion

Leontief's conception of the circular flow within the economic system, as expressed in the IOT, allowed him (Leontief 1937 and 1944) to analyse how changes on the demand side influence supply accounts (and vice versa), ultimately defining the output value.

The table and the models that derive from it do not belong to the general equilibrium environment. Rather, they express independent equilibria for the producer and the consumer of intermediate and final goods. The IO model and the IO table implicitly assume that each agent optimizes her linear objective function independently, so that the IO framework yields an equilibrium demand model. Moreover, the components of the expenditure accounts in each industry (the agent in the model) are different from those in the income account; therefore, each branch can show disequilibrium in some of its partial accounts. Normalizing the demand model, each column will total 1; independently, the rows in the supply model will also total 1 (gross output). Industries reach equilibrium, together with the economic system. Equilibrium is not Walrasian in nature.

Since economic growth is seldom balanced, it causes modifications in intersectoral relationships, including final demand and value-added components. Breaking down changes into the income–expenditure framework, on the one hand, and the price–cost scheme, on the other, allows us to measure the contributions of the different components of supply and demand to growth, which will become clear when operating with the coefficient tables, rather than with absolute figures.

7 Conclusions

The IO tables can be read from the perspective of economic theory; in the aggregate, they can be understood as a general equilibrium result, based upon the producers' model, while the consumer side is exogenous. Structural analysis is also focused on the disaggregation of economic activity and the interdependence between the different parts of the system, as Leontief repeatedly stated, particularly in his earlier articles. Nevertheless, this falls outside the scope of the neoclassical school of thought. The fundamentals of the latter, analysed together through exercises of comparative statics, allow us to understand the contribution each input coefficient makes to economic growth and to find the trajectory of growth followed by the system.

This paper has evaluated economic growth in Germany, France, Japan, the UK, and the US, identifying the elements that contribute to that process, as well as the trajectories followed by the supply and demand accounts. In the first three countries, the sales and purchases coefficients of intermediate inputs have determined that the disequilibria between supply and demand tend to converge, while in the UK the contributions of final demand and value-added have stabilized disequilibria. In the US, larger divergences between supply and demand result from the contributions of labour to growth. In short, the German, French, and Japanese economies have outperformed those of the US and the UK.

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Author contributions
MAMM performed all the work, studied the references related to the study of change using input–output tables, and reinterpreted the tables with the help of economic theory.

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The data were obtained from the OECD website, and it is the 2015 edition. They are available at the following link: https://stats.oecd.org/Index.aspx?DataSetCode=IOTS_2021.

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Ethics approval and consent to participate
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