CHAPTER 1

Industrial Policy and Productive Transformation: An Optimization Approach Based on Input–Output Analysis

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1.1 Introduction

The economic crisis of 2008, followed by a long period of recession, revealed the structural failings of many economies, creating the resurgence of interest in industrial policy. Much of the interest in industrial policy derives from its potential implications for solving dramatic socioeconomic problems, such as high unemployment rates, expanding trade imbalances, and poverty. Additionally, changes in the production systems

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due to the expansion of global value chains force countries to confront challenges arising from their level of integration within the new pattern of international trade (Di Tommaso et al., 2017). The rejuvenation (Stiglitz et al., 2013) or renaissance (Mazzucato et al., 2015; Savona, 2018) of industrial policy attracts several schools of thought in economics to a debate on the nature, the significance, the efficiency, and the instruments of industrial policy. The structural, the evolutionary, and, surprisingly, the neoclassical schools of thought all contribute to the debate, highlighting different perspectives and objectives as well as different directions for industrial policy.

The debate on industrial policy is not new. It can be traced back to the foundation of capitalism, with the controversy between two major theoretical streams of thought, mercantilism and liberalism (Maneschi, 1998). The neoclassical school of thought dominated the intense debate of academic and policy circles from the mid-1970s to the early 1980s. At that specific conjuncture, the majority of countries and world organizations adopted the position that the outcomes of industrial policy are limited, or even negative for the economies. Based on the neoclassical tradition, protectionism and infant-industry strategies only have adverse results and will probably lead to government failure. Thus, market-based strategies (liberalization, privatization, deregulation) and macroeconomic measures to ensure fiscal and financial stability were considered the only effective government policies (Chang & Andreoni, 2016; Rodrik, 2008). The neoclassical theoretical framework was strongly challenged by Chang (2002), who examined the economic history of developed economies and found no example of a country that developed following free-trade and market-based policies. On the contrary, all advanced countries developed on the basis of protectionism and infant-industry policies, the same policies which are rejected as ineffective and obsolete nowadays.

Based on the neoclassical agenda, industrial policy should only attempt to improve the business environment. Such interventions are commonly referred to as horizontal (also called functional) measures and include, among others, educational and training programs, R&D investments, FDI attraction, and infrastructures. In addition to horizontal measures, government interventions for overcoming market failures are accepted into the neoclassical school of thought. On the contrary, mainstream economists considered vertical industrial policies (also called selective) for the promotion of specific sectors or groups of sectors, or even for improving the supplementarity of the whole economic system, to be ineffective (Chang & Andreoni, 2019; Warwick, 2013). Salazar-Xirinachs et al. (2014, p. 20) identify a contradiction in the distinction between horizontal and vertical policy measures. They note that "the distinction between 'horizontal' measures (presumed to be neutral across sectors) and 'vertical' measures (supporting specific industries) is something of a false choice, as even the most 'general' policy measures favor some sectors over others". Even more, according to Stiglitz et al. (2013, p. 8), horizontal policy measures end up supporting "certain industries more than others and therefore shape the sector allocation of the economy". In reality, the only policies that can strictly be called horizontal are those concerning basic education and public health care. Nevertheless, referring to policy concerning these as industrial is "stretching the concept beyond reason" (Chang et al., 2016, p. 29).

The inability to develop a neutral, horizontal industrial policy does not mean that there is no difference between horizontal and vertical measures. Horizontal and vertical industrial policies have different objectives, and neutrality is only a part of the picture. Horizontal policies are consistent with improving the workings of markets and institutes, whereas vertical policies are consistent with the notion of structural change and the productive (or structural) transformation of the whole economy.

The term structural transformation refers to the "interrelated processes of structural change that accompany economic development" (Syrquin, 1988, p. 206). Advanced economies progressively shift their structure of production and exports to activities of higher value-added and more sophisticated products (Fortunato & Razo, 2014; Ocampo et al., 2009). The impact of the productive structure and its effects on economic development is frequently neglected by mainstream economics, despite its high relevance for development, international theory, and economic policy. As discussed by Rodrik (2009, p. 5), economic development "is fundamentally about structural change: it involves producing new goods with new technologies and transferring resources from the traditional activities to these new ones". The radical economic tradition offers significant contributions highlighting the fundamental role of changes in the composition of aggregate production and employment, and how they affect economic growth and development (Andreoni & Scazzieri, 2014; Hirschman, 1958; Kaldor, 1967; Prebisch, 1962; Robinson, 2016).

As analytically discussed in Scazzieri (2018), the structural dynamics of an economic system can be used as the basis for determining different paths of structural changes. In this framework, the role emerges of industrial policy as a mechanism for detecting and selecting the path (or trajectory) toward specific macroeconomic targets (such as the attainment of a specific level of development, improvement of the exporting profile, unemployment reduction, trade deficits shrinkage, etc.) For the purposes of this research, industrial policy is defined as sector-specific interventions in an economic system toward productive transformation and the achievement of economic development. Thus, industrial policy has a mainly vertical character and systemic impact inasmuch it stimulates specific economic activities and promotes structural change (Rodrik, 2008).

Policy measures referred to in the literature as horizontal-type industrial policies, should not be neglected in the process of structural transformation. On the contrary, their implementation is complementary to an industrial policy strategy. Research and development (R&D) investment, environmental regulation, support for small and medium-sized enterprises, educational and training programs, infrastructure and measure ensuring financial stability are important aspects of the policy agenda worldwide. However, given their macroeconomic character, their inclusion in industrial policy is rather disorienting in terms of the industrial policy debate.

The design of an industrial policy plan requires an in-depth knowledge of the examined economy and the theoretical and empirical background to approach the complexity and complementarity of the different features of the economic system in question. Furthermore, determining the optimal industrial policy for an economic system should also consider the different challenges arising from the international economic environment and the evolution of technology.

The structure of the chapter is the following: Sect. 1.2 presents the link between production transformation and Input–Output analysis. Then Sect. 1.3 focuses on different aspects and prospects of productive transformation. The next Sect. 1.4 presents the methodological approach. In Sect. 1.5, the formulation of the mathematical model for the Greek economy is elaborated. Finally, Sect. 1.6 discusses the future directions of the research.

1.2 Productive Transformation and Input–Output Analysis

A productive transformation strategy requires a methodology that reflects the complexity and complementarity of the economy in question and can be used to formulate an optimization model for determining the optimal productive structure. To this end, Input–Output Analysis (Leontief, 1986) is employed in the literature. The reason for the extensive use of IOA in this type of problem is that it is essentially a methodology that provides a structural view of sectoral interlinkages. Therefore, understanding the underlying mechanisms and the drivers of structural transformation is a critical issue for industrial policy, and IOA is recognized as a suitable approach in this regard.

In IOA, the production of an economic system is disaggregated into $n$sectors of economic activity and the transactions of goods and services among them are determined. Each sector produces a single type of product (or service), and it is assumed that all producers within a sector employ the same production technology. Moreover, each sector absorbs inputs from the other sectors and provides its production as input to other sectors and to the final demand of the economic system. Thus, the production process of the whole system is articulated in a tabular form, i.e., the Input–Output table (IOT) of monetary values. The IOT describes the transactions between the different sectors (intersectoral flows) and the sectoral distribution of value-added and final demand. IOA focuses on the intersectoral flows of the IOT, a square table with dimensions nxn, depicting how intermediate products and services are combined in analogies defined by the production technology of each sector, to generate the sector's output. Analytically, a typical row of the square matrix represents the distribution of the output within the other sectors and a typical column of the square matrix reflects the composition of inputs demanded from other sectors for the specific sector's production. Thus, the typical element z_{ij} of IOT represents the i^{th} sector's output required by the j^{th} sector for the production of j^{th} sector's gross output. Furthermore, a typical technological coefficient a_{ij} represents the i^{th} sector's output required for a unit production of the j^{th} sector and a typical allocation coefficient b_{ij} represents the share of a unit production of the i^{th} sector used as intermediate input from the j^{th} sector (Miller & Blair, 2009). The matrices of the technological coefficients A_d (known as the Leontief approach) and allocation coefficients B_d (known as the Ghosh approach) provide a full view of the economic structure and are widely used for studying the economic effects of structural changes within an economy, both in sectoral and aggregate level. Particularly, the impact of structural shifts in final demand, in the Leontief model and value-added, in the Ghosh model, for the economic system can be simulated with the use of the A_d and B_d matrices, respectively (Ghosh, 1958; Miller & Blair, 2009; Belegri et al., 2011).

Nevertheless, a productive restructuring strategy requires the reverse process, i.e., the identification of the required shifts in production (expressed by final demand or value-added structure) for achieving macroeconomic targets under certain constraints. Thus, for addressing the productive transformation strategy, the macroeconomic objectives and constraints should be formulated into a constrained optimization model, the resolution of which will provide the optimal productive structure of the economic system.

Up to date, several studies have identified an economy's optimal productive structure. Most of these investigate the optimal structure of economic systems for addressing environmental pressures (such as greenhouse gas emissions and energy usage) and achieving macroeconomic objectives. Cho (1999) determined the optimal productive structure of the Chungbuk Province of Korea for addressing unemployment and resource scarcity. Oliveira and Antunes (2004) optimized the production structure of Portugal with a view to environmental (minimization of the acidification potential and the energy imports) and socioeconomic (maximization of employment and GDP) objectives. San Cristóbal (2010) defined the optimal structure of the Spanish economy when GDP is maximized and greenhouse gas emissions are minimized. Hristu-Varsakelis et al. (2010) used scenario analysis of GDP maximization and energy conservation to optimize the structure of Greece. Likewise, De Carvalho et al. (2015) approached the optimal productive structure of Brazil for different scenarios involving the maximization of GDP and employment and the minimization of greenhouse gas emissions and energy consumption. Chang (2015) investigated China and determined the optimal structure of the country when GDP is maximized and carbon dioxide emissions are minimized. Mi et al. (2015), in a regional study for Beijing, determined the productive structure of the city for maximum production and environmental objectives. In more recent studies, Tian et al. (2017) and Lin et al. (2019) investigated the optimal structure of China when GDP is maximized and energy consumption is minimized. Sánchez et al. (2019) found the optimal structure of Australia for the maximum GDP and employment and the minimum greenhouse gas emissions. Furthermore, in Papadakis and Markaki (2019), the optimal structure for the minimization of greenhouse gas emissions intensity is determined. Finally, Markaki and Papadakis (2021) identified the optimal structure of the Czech economy, ensuring that a decrease in global demand for vehicles will not affect the country's international competitiveness. In all cases, the optimal productive structure varies considerably from the current structure, highlighting the importance of productive transformation. Furthermore, the significant impact of a potential structural transformation on macroeconomic and/or environmental objectives in all the examined countries, constitutes a mutually reinforcing argument in favor of industrial policy strategies.

Although all the aforementioned studies successfully determine the optimal productive structure of the examined economic systems, they do not provide a robust methodological framework to explore different aspects of productive transformation. Moreover, the diversity of the set targets and the different types of constraints makes it difficult, in certain cases, even to recognize the common denominator in all the different approaches, i.e., the application of Input–Output Analysis. Consequently, there is a necessity for a robust methodological approach to productive transformation based on IOA, as support for different empirical applications. Such an approach will provide the tools to classify, compare, and evaluate different productive transformation plans.

1.3 Productive Transformation: Different Aspects and Prospects

A productive transformation that shifts production within different sectors through the reallocation of production factors, can address the structural weakness of the economy. Furthermore, such progress can increase aggregated production and exports, achieving significant improvements in the economy's level of development (Chang & Andreoni, 2016). Although the specific objectives and the restrictions of a productive transformation are country-specific, the broad outlines of an industrial policy toward a productive transformation can be drawn to derive factors that account for the main determinants. In this research, four structural economic factors are considered as a means of ensuring the effectiveness of productive transformation in an economic system. The share of manufacturing in production, the share of technologically advanced sectors, the strengths of intersectoral linkages, and the complexity of the economic system. The literature on industrial policy identifies these factors as crucial for the structural change of an economy from the supply side (Bresser-Pereira, 2016; Chang et al., 2013, 2016; Reinert, 2019). In this section, the role of each factor is discussed in terms of its contribution to growth and development.

1.3.1 Promoting Industrialization

Industrial policy is mainly associated with targeted interventions in specific industrial sectors (i.e., manufacturing, mining, utilities, and construction sectors), promoting industrialization in favor of an improved productive structure. However, the literature approaches the special role of industry in the process of structural transformation through several complementary aspects.

Firstly, industrial products, especially those sourcing from the core of industrial activities, i.e., manufacturing, have high tradability compared to the non-tradable character of most services activities (Rodrik, 2007; Stöllinger et al., 2013). Thus, industry products contribute to a favorable external balance of goods and services in the economy.

Secondly, as observed by Kaldor (1967, p. 8), there is a positive relationship between labor productivity growth rates and "the excess of the rate of growth of manufacturing production over the rate of growth of the economy as a whole". Thus, industry exhibits higher productivity gains than the rest of the economic system and promotes the aggregated labor productivity growth of the economy.

Contrary to the traditional view that productivity gains cause economic growth, Ocampo (2005) revised the arrow of causality. He pointed out that the link between increased productivity and growth is two-way. The productivity gains increase economic growth and vice versa. The crucial point in his approach is that the quality of economic growth, as expressed in the country's macroeconomic performance, determines the level of productivity gains. Compared with a strong macroeconomic performance, poor performance is characterized by a substantial decline in the rate of productivity growth (see also Ocampo, 2014). As a result, an economy with poor macroeconomic performance is characterized by structural weakness, usually reflected in negative terms of trade and trade deficits

(Economakis et al., 2015). Thus, the role is emphasized of industrial policy in ensuring a strong macroeconomic performance.

Thirdly, in addition to the "great importance to the role of the manufacturing sector in overall economic activity, is its role as a driver of innovation and technological change… [as long as] the manufacturing sector still accounts for the bulk of business expenditure on R&D" (Pilat et al., 2006). The industrial sectors are a major source of technological progress for an economy, indicating that a country with a strong industrial base has the potential for technological upgrading. Even though industrial sectors are not homogenous in their technological level, industry significantly contributes to the diffusion of technology and, thus, operates as the "learning centre" of the economy (Baumol, 1967; Cardinale & Scazzieri, 2019; Chang et al., 2013). The constant renewal of manufacturing production (creation of new products or the improvement of the existing) is facilitated with innovations and modern technologies. In addition, industrial sectors' high capital accumulation level and higher capital intensity allow industrial products to embody state-of-art technologies (Szirmai, 2012).

Fourth, both backward and forward intersectoral linkages in the industry are much stronger than in services and agriculture. Stronger backward linkages indicate that the sector demonstrates high inputs from other sectors. Stronger forward linkages indicate that the sector is essential as a supplier of inputs required by other sectors (Dietzenbacher, 2002; Hirschman, 1958; Markaki & Papadakis, 2021). Strong linkages create a powerful spillover of knowledge and technology from industrial sectors to the rest of the economy. Sectors with strong interdependencies have a central role in economic activity, and their promotion provides extended effects to the economic system.

Fifth, from the demand side of the economy, the relative income elasticity of the demand for industrial (mainly manufacturing) products is higher than those from the primary and service sectors. This is because an increase in a country's income creates a higher demand for products of high-income elasticity of demand than those of low-income elasticity of demand, as a result of Engel's law. Thus, the inability of a non-industrialized economy to satisfy the increased demand for manufacturing products occurring as a result of economic growth will lead in the long run to the increase of imports and possible balance of payment problems (Economakis et al., 2018; Krugman, 1988).

The aspects of industry sectors discussed above stress the unique role that industry could play in the productive transformation of an economy. In the words of Cimoli et al. (2006), "an increase in the share of manufacturing in the overall economy would be required for activities with low productivity to converge upon high-productivity ones. The industry was seen as the main driver of productivity growth. [] …industrial development would generate the forward and backward linkages, spillover effects, capital accumulation and technological externalities needed to sustain increasing returns".

1.3.2 Promoting Product Sophistication and Diversification

Despite the undeniable contribution of industrial sectors to the process of productive transformation, the industry is not a homogenous group of sectors. Industrial sectors differ considerably in terms of, among others, capital and labor intensity, technological level, skills required, and productivity level. Industrial policy should provide the ground for developing a diversified economic base and, simultaneously, for upgrading production from simple to more sophisticated. On the one hand, productive diversification reduces the economy's vulnerability to external and internal shocks. On the other, technological progress is in line with the promotion of relatively sophisticated sectors (Lin, 2011). Empirical studies show that mature industrialized countries typically produce a wide range of goods, and the process of development is connected with a less concentrated (more diversified) productive structure (Economakis & Markaki, 2023; Imbs & Wacziarg, 2003; Markaki & Economakis, 2022).

Furthermore, Petralia et al. (2017) found that more developed countries tend to specialize in producing more diverse and valuable products by using more complex and less concentrated technologies compared to less developed countries. This finding supports the position of Lall (2000), who highlighted the importance of the technological structure of manufactured exports as an indicator of "quality" and the position of Rodrik (2009, p. 9) that "productive diversification is a key correlate of economic development".

The term economic complexity is introduced in the literature to express both diversification and sophistication of production. Economic complexity is assessed "based on the diversity of exports a country produces and their ubiquity, or the number of the countries able to produce them, and those countries' complexity. Countries that can sustain a diverse range of productive know-how, including sophisticated, unique know-how, can produce a wide diversity of goods, including complex products that few other countries can make" (Simoes & Hidalgo, 2011). Even though manufacturing sectors provide the ability to increase product diversification to a higher degree, by comparison to the primary and service sectors (Hausmann & Klinger, 2007), some service sectors could also promote diversification due to their knowledge intensity (Evans, 2008). By the term service sector, the relevant literature mainly refers to business services (such as transport, logistics, management, consulting, design, communications, warehousing) providing activities outsourced by manufacturing firms to the service sector. Business services are closely linked to manufacturing production, followed by wholesale and retail trade, financial intermediation, and transport (UNIDO, 2013). Thus, the procurements of business services depend on the manufacturing sectors; hence business services cannot operate optimally in an economy with a weak industrial base (Chang et al., 2016). Consequently, the expansion of service sectors which are strongly linked to manufacturing increases the diversification of the economy.

Thus, the process of productive transformation cannot only be expressed by the reallocation of production within the different sectors, but also as a process of diversification and technological updating of economic activities throughout the economy.

1.3.3 Promoting Interconnectedness

The structural weaknesses of an economic system resulting from a non-articulated economic structure act as an obstacle to structural change, even in diversifying and technologically advanced systems. Gains related to spillover effects "in terms of technology transfer and absorption" O'Donovan and Rios-Morales (2006, p. 55) reinforce productive activities, providing technologically advanced sectors are strongly linked to the rest of the economy. Otherwise, in the case of weak intersectoral linkages, diversification and sophistication of production will increase the demand for imported intermediate inputs, extending trade imbalances and slowing down industrialization and development.

Thus, the interconnectedness of the whole economic system is a crucial factor for the effectiveness of productive transformation. IOA describes the economy as a complex network of relationships between different activities, quantifying their interconnectedness by backward and forward linkages (Miller & Blair, 2009). For example, a developed industry is connected to a more complete and articulated economic structure (Leontief, 1986, pp. 169–170) with important productive linkages, spillover effects, capital accumulation, and technological externalities (see Cimoli et al., 2006; Hirschman, 1958). On the contrary, service sectors are more independent from other sectors by comparison to the manufacturing sector (Pilat et al., 2006).

Strengthening an economy's backward and forward linkages requires policy interventions focused on the increased portion of intermediate demand satisfied by domestic production. This intervention will empower economic activities both as a producer and a consumer of intermediate products and services. Import substitution policies targeting the intermediate productive structure, as it is expressed by the matrices of technological and allocation coefficients, is a one-way road toward addressing structural weaknesses sourcing from weak linkages.

1.3.4 Toward a Methodology for Productive Transformation

The approach to productive transformation adopted in this research builds on the position that to transform their production structure successfully, countries must undertake policies of diversification, interdependencies, and technological change simultaneously. Furthermore, this methodological approach stresses that productive transformation relies on both diversification and sophistication of production and that improving productive linkages is essential to sustain macroeconomic gains.

From the policy point of view, policies for diversification and technological upgrading, as well as import substitution policies focusing on both the final and the intermediate demand, could lead to an improvement of the country's external balance of goods and services and a reduction of the risk of adverse effect on production due to macroeconomic imbalances (Milberg et al., 2014). The combination of these types of policy interventions will enhance the potential for growth and development.

1.4 Productive Transformation and Industrial Policy: A Methodological Approach

In this research, a primary question is addressed: which sectors should a productive transformation strategy target to optimize the productive structure, satisfying specific macroeconomic targets in parallel? The term "productive transformation" is more accurate from the term "structural transformation", as the proposed methodology is quantified, focusing on the optimal distribution of production among the sectors, and not on all the interrelated aspects of the socioeconomic environment which the term structural transformation implicates. Section 1.5 provides the mathematical formulation of the proposed methodology for the Greek economy (Fig. 1.1).

The proposed methodology is structured in three stages:

In the first stage, the productive structure of the examined economy is expressed by the selected sectoral classification. The applied classification should be in line with the corresponding classification of the available input–output tables.

The second stage involves the determination of industrial policy target(s) and their mathematical modelling is built based on input–output analysis. Given that the proposed methodology has a strictly country-specific nature, the target(s) of different countries could be highly diverse, from macroeconomic to social, environmental, or any combination thereof. In this stage, taking in the advantage of the IOA to provide a mathematical model for the real-world economic system (Leontief, 1982), the target(s) of the industrial policy is expressed in connection with the productive structure of the examined economy at an analytical sectoral level.

In the third stage, potential constraints are considered. Potential constraints could guide the transformation process in order not to inhibit the effectiveness of industrial policy measures. They are determined based

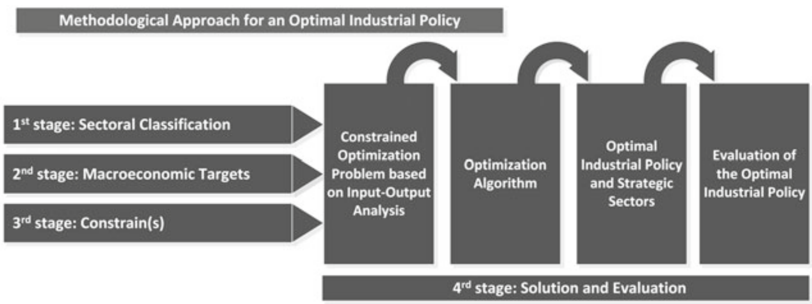

Fig. 1.1 The methodological approach of productive transformation (*Source* Authors' creation)

on economic and social features (such as technology, resources, skill level) of the economy examined.

Finally, the fourth stage includes the solution of the constrained optimization problem and evaluating the optimal economic structure. During the evaluation stage of the methodology, it is critical to investigate the optimal productive structure against socioeconomic aspects not included in the constraints in order to identify possible adverse effects. A revision of the 2nd and the 3rd stage is possible. New constraints could be included in order to prevent or counteract adverse effects.

1.5 The Formulation of the Mathematical Model for Greece

This section provides the background required for the formulation of productive transformation as a constraint optimization problem for the case of Greece. The productive transformation aims to reduce the trade balance deficits once macroeconomic targets (GDP growth rate and economic complexity) are achieved. The GDP growth rate is determined based on the projections of Oxford Economics (2020), while this growth rate should be linked to the increased complexity of the economy. GDP growth rate and economic complexity are constraints in the optimization process. The optimal productive structure should be determined for minimizing the trade balance deficits when GDP growth rates and economic activity reach specific values. The process of productive transformation concerns two aspects of the economic system: the decision variables.

The first aspect is the sectoral allocation of the value-added. The GDP share of each sector, expressed in the form of a vector, is the first decision variable of the model. The literature provides two alternatives for the determination of the decision variable. The first alternative is the use of value-added allocation (Mi et al., 2015; Oliveira & Antunes, 2004; Tian et al., 2017; Yu et al., 2016) and the second one is the use of the sectoral distribution of final demand (De Carvalho et al., 2015; Sanchez et al., 2019). The selection of the sectoral allocation of the value-added as a decision variable is due to the importance of the GDP growth rate constraint. GDP is the summation of value-added across the sector; thus, the first decision variable is directly connected with a constraint.

The second aspect is the distribution coefficients. Following an approach proposed by Papadakis and Markaki (2019), the network of sectoral interlinkages is optimized using the import substitution processes of imported intermediate inputs. The matrix of the distribution coefficient is used as the second decision variable, as an expression of the sectoral linkages. The use of the distribution coefficient instead of the technological coefficients is due to the origin of the first in the Ghosh approach, as discussed later in this section. In the Ghosh approach, value-added is considered exogenous; thus, both decision variables coexist in the Ghosh model and their impact on the objective function can be directly assessed.

The novelty of this approach is that it captures the full economic potential of productive transformation. The assumption that the economic system linkages will remain stable after a productive transformation cannot be valid. The promotion of a sector is connected with its ability to produce to satisfy both intermediate and final demand. Without capturing the improved position of a sector as a potential intermediate producer, a crucial segment of the economy is omitted. Thus, an in-depth productive transformation should simultaneously consider the reallocation of production among the sectors and the substitution of imported intermediate inputs with domestic production (Fig. 1.2).

This section provides the background required for formulating productive transformation as a constraint optimization problem. The approach of this research requires the expression of the objective function (trade balance deficit) and the restrictions (GDP and economic complexity) as a function of the decision variables (the structure of the value-added and the distribution coefficients of the sectors). To this end, firstly, the basic input–output model is described in matrix formation and, secondly,

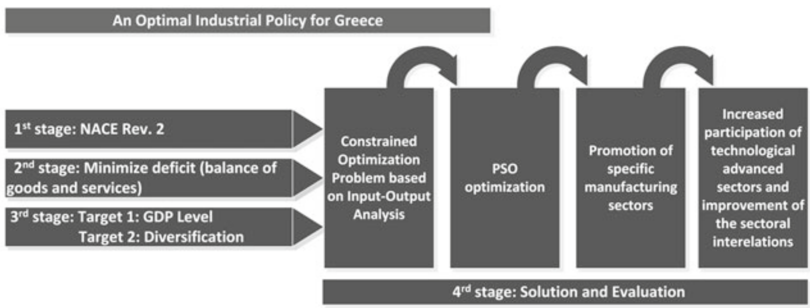

Fig. 1.2 An optimal industrial policy for Greece (*Source* Authors' creation)

the domestic content of exports and the GDP are defined in connection with the decision variables. An analytical description of the structural weaknesses of the Greek economy and the requirements of a productive transformation process is included in Chapter 2 of this volume.

1.5.1 The Leontief Model

In an economy with $n$sectors of economic activity, the total output of each sector i, x_i expresses the total level of production by an economic sector, which covers both intermediate and final demand. Given a vector $\boldsymbol{x} \in \mathbb{R}^{n \times 1}$ denoting the total output by sector of economic activity, the distribution of output is expressed by Eq. 1.1.

$$\boldsymbol{x} = \boldsymbol{Z}_d \cdot 1_{\boldsymbol{n}} + \boldsymbol{f}_{\boldsymbol{d}} \tag{1.1}$$

where,

$\boldsymbol{Z}_d \in \mathbb{R}^{n \times n}$ represents the matrix of domestically produced intermediate demand. The typical element z_{ij} of $\boldsymbol{Z}_d$ represents the production of sector i, which is used as an intermediate input by sector j.

$\boldsymbol{f}_d \in \mathbb{R}^{n \times 1}$ is the vector of the final demand components (analytically exports, public and private consumption, gross capital formation, and change in inventories), which are domestically produced.

$1_n \in \mathbb{R}^{n \times 1}$ is an n-dimensional vector, each element of which equals one.

As discussed in Leontief (1991), $\boldsymbol{Z}_d$ is a share of the economy's total output $\boldsymbol{x}$. Dividing the typical element of $\boldsymbol{Z}_d$, z_{dij} by the total output of sector j, the technological coefficient $a_{ij} = z_{ij}/x_j$ is defined. The technological coefficient a_{ij} represents the direct requirement of sector i's output, needed to produce one unit of sector j's output. The matrix of technological coefficients $\boldsymbol{A}_d \in \mathbb{R}^{n \times n}$ (or the matrix of direct requirements) is defined as:

$$\boldsymbol{A}_{\boldsymbol{d}} = \boldsymbol{Z}_{\boldsymbol{d}} \cdot \hat{\boldsymbol{X}}^{-1} \Rightarrow \boldsymbol{Z}_{\boldsymbol{d}} = \boldsymbol{A}_{\boldsymbol{d}} \cdot \hat{\boldsymbol{X}} \tag{1.2}$$

where and $\hat{\boldsymbol{X}} \in \mathbb{R}^{n \times n}$, a diagonal matrix whose diagonal elements are the elements of vector $\boldsymbol{x}$.

Taking into account Eq. 1.2, Eq. 1.1 is transformed to:

$$\boldsymbol{x} = \boldsymbol{A}_{\boldsymbol{d}} \cdot \boldsymbol{x} + \boldsymbol{f}_{\boldsymbol{d}} \Rightarrow \boldsymbol{x} = (\boldsymbol{I}_{\boldsymbol{n}} - \boldsymbol{A}_{\boldsymbol{d}})^{-1} \cdot \boldsymbol{f}_{\boldsymbol{d}} \tag{1.3}$$

The matrix $(\boldsymbol{I}_n - \boldsymbol{A}_d)^{-1}$ is the well-known Leontief inverse matrix (Miller & Blair, 2009). A typical element $i, j \in [1, n]$ of the Leontief inverse matrix shows the sector's-i product, which is required, directly and indirectly, for the production of one unit of the final demand of the sector's-j output.

Consider a vector $\boldsymbol{v_a} \in \mathbb{R}^{n\times 1}$. A specific element of $\boldsymbol{v_a}$ represents the value-added of a particular sector. Given a vector $\boldsymbol{v} \in \mathbb{R}^{n\times 1}$ representing the intensity of employment by sector of economic activity, then $\boldsymbol{v}$, can be computed by Eq. 1.4:

$$\boldsymbol{v} = \hat{\boldsymbol{X}}^{-1} \cdot \boldsymbol{v_a} \tag{1.4}$$

A typical diagonal element of $\boldsymbol{v}$ represents the value-added by unit of a sector's output.

1.5.2 The Ghosh Model

Ghosh (1958) suggested an alternative interpretation of the Leontief model where gross output equals the primary inputs entering the economic system, expressed by Eq. 1.5.

$$\boldsymbol{x} = 1_{\boldsymbol{n}} \cdot \boldsymbol{Z_d} + 1_{\boldsymbol{n}}{}' \cdot \boldsymbol{Z}_m + \boldsymbol{v_a} = 1_{\boldsymbol{n}}{}' \cdot \boldsymbol{Z} + \boldsymbol{v_a} \tag{1.5}$$

where, $\boldsymbol{Z_m} \in \mathbb{R}^{n\times n}$ represents the matrix of imported intermediate demand and $\boldsymbol{Z} \in \mathbb{R}^{n\times n}$ represents the matrix of the total intermediate demand, both domestic and foreign. The typical element z_{ij} of $\boldsymbol{Z} = \boldsymbol{Z_d} + \boldsymbol{Z_m}$ represents the total production of sector i (domestic and foreign) needed for the production of the sector j.

Following the Ghosh approach, the matrix $\boldsymbol{B_d} \in \mathbb{R}^{n\times n}$ of the distribution coefficients of domestic intermediate inputs is defined as:

$$\boldsymbol{B_d} = \hat{\boldsymbol{X}}^{-1} \cdot \boldsymbol{Z_d} \Rightarrow \boldsymbol{Z_d} = \hat{\boldsymbol{X}} \cdot \boldsymbol{B_d} \tag{1.6}$$

The matrix $\boldsymbol{B_m} \in \mathbb{R}^{n\times n}$ of the distribution coefficients of imported intermediate inputs is defined as:

$$\boldsymbol{B_m} = \hat{\boldsymbol{X}}^{-1} \cdot \boldsymbol{Z_m} \Rightarrow \boldsymbol{Z_m} = \hat{\boldsymbol{X}} \cdot \boldsymbol{B_m} \tag{1.7}$$

And from Eq. 1.6 and Eq. 1.7:

$$\boldsymbol{Z} = \boldsymbol{Z_d} + \boldsymbol{Z_m} = \hat{\boldsymbol{X}} \cdot (\boldsymbol{B_d} + \boldsymbol{B_m}) = \hat{\boldsymbol{X}} \cdot \boldsymbol{B} \tag{1.8}$$

where, $\boldsymbol{B} \in \mathbb{R}^{n \times n}$ and $\boldsymbol{B} = \boldsymbol{B_d} + \boldsymbol{B_m} => \boldsymbol{B_m} = \boldsymbol{B} - \boldsymbol{B_d}$.

Based on Eq. 1.8, Eq. 1.5 is transformed to:

$$\begin{aligned} \boldsymbol{x} = \boldsymbol{x} \cdot \boldsymbol{B} + \boldsymbol{v_a} &\Leftrightarrow \boldsymbol{x^T} = \boldsymbol{v_a^T} \cdot \boldsymbol{v_a}(1 - \boldsymbol{B})^{-1} \\ &\Leftrightarrow \boldsymbol{x} = ((1 - \boldsymbol{B})^{-1})' \cdot \boldsymbol{v_a} \end{aligned} \tag{1.9}$$

In an effort to link the mathematical formulation of the Leontief and the Ghosh model, Miller and Blair (2009, pp. 547–548) show that the matrices of technological coefficients ($\boldsymbol{A_d}$) and distribution coefficients ($\boldsymbol{B_d}$) are similar. Thus,

$$\boldsymbol{A_d} = \hat{X} \cdot \boldsymbol{B_d} \cdot \hat{X}^{-1} \Leftrightarrow \boldsymbol{B_d} = \hat{X}^{-1} \cdot \boldsymbol{A_d} \cdot \hat{X} \tag{1.10}$$

1.5.3 Objective Functions and Constraints

The optimization problem's objective function expresses the trade balance's deficit. The balance of goods and services *balance* $\in \mathbb{R}^{1 \times 1}$ of an economy is expressed by Eq. 1.11

$$\text{balance} = 1_{\boldsymbol{n}}^{\boldsymbol{T}} \cdot (\boldsymbol{ex} - \boldsymbol{im}) \tag{1.11}$$

The components of final demand $\boldsymbol{f_d}$, are the vectors $\boldsymbol{ex} \in \mathbb{R}^{n \times 1}$,$\boldsymbol{c_d} \in \mathbb{R}^{n \times 1}$, and $\boldsymbol{inv} \in \mathbb{R}^{n \times 1}$, where $\boldsymbol{ex}$ is the vector of the exports, where $\boldsymbol{c_d}$ is the vector of the government and private consumption covered by the domestic production and where $\boldsymbol{inv}$ is the vector of the gross capital formation and change in inventories covered by the domestic production. In Eq. 1.12, the diagonal matrices $\widehat{\boldsymbol{n}_1}, \widehat{\boldsymbol{n}_2}, \widehat{\boldsymbol{n}_3} \in \mathbb{R}^{n \times n}$ are expressing the sectoral shares of $\boldsymbol{ex}$, $\boldsymbol{c_d}$ and $\boldsymbol{inv}$ final demand:

$$\boldsymbol{f_d} = \boldsymbol{ex} + \boldsymbol{c_d} + \boldsymbol{inv_d} = \widehat{\boldsymbol{n}_1} \cdot \boldsymbol{f_d} + \widehat{\boldsymbol{n}_2} \cdot \boldsymbol{f_d} + \widehat{\boldsymbol{n}_3} \cdot \boldsymbol{f_d} \tag{1.12}$$

where, $\widehat{\boldsymbol{n}_1} + \widehat{\boldsymbol{n}_2} + \widehat{\boldsymbol{n}_3} = \boldsymbol{I_n}$

Based on Eq. 1.12, we obtain that the exports of an economy can be determined as:

$$\boldsymbol{ex} = \widehat{\boldsymbol{n}_1} \cdot \boldsymbol{f_d} \tag{1.13}$$

The imports of an economy are the summation of intermediate and final imports.

The vector of intermediate imports $\boldsymbol{im_{im}} \in \mathbb{R}^{n\times 1}$ can be expressed by Eq. 1.14

$$\boldsymbol{im_{int}} = \left(1_{\boldsymbol{n}}^{\boldsymbol{T}} \cdot \boldsymbol{Z_m}\right)^{\boldsymbol{T}} = \boldsymbol{Z_m^T} \cdot 1_{\boldsymbol{n}} \tag{1.14}$$

The vector of final imports $\boldsymbol{im_f} \in \mathbb{R}^{n\times 1}$ can be expressed by Eq. 1.15.

$$\boldsymbol{im_f} = \boldsymbol{c_{im}} + \boldsymbol{inv_{im}} \tag{1.15}$$

where, $\boldsymbol{c_{im}} \in \mathbb{R}^{n\times 1}$ is the vector of consumption which is satisfied by imports and $\boldsymbol{inv_{im}} \in \mathbb{R}^{n\times 1}$ is the vector of investments satisfied by imports.

Given that the total consumption of an economy is produced by domestic industries or imported, then:

$$\boldsymbol{c_{im}} = \boldsymbol{c} - \boldsymbol{c_d} \tag{1.16}$$

where $\boldsymbol{c} \in \mathbb{R}^{n\times 1}$ is the vector of total consumption and $\boldsymbol{c_d} \in \mathbb{R}^{n\times 1}$ is the vector of consumption covered by domestic production.

Based on Eq. 1.12, we obtain that the vector of consumption covered by domestic production can be determined as:

$$\boldsymbol{c_d} = \widehat{\boldsymbol{n}_2} \cdot \boldsymbol{f_d} \tag{1.17}$$

Finally, from the combination of Eqs. 1.15, 1.16, and 1.17:

$$\boldsymbol{im_f} = \boldsymbol{c} - \widehat{\boldsymbol{n}_2} \cdot \boldsymbol{f_d} + \boldsymbol{inv_{im}} \tag{1.18}$$

Finally, the vector of total imports of an economy $\boldsymbol{im} \in \mathbb{R}^{n\times 1}$ can be defined as:

$$\begin{aligned} \boldsymbol{im} &= \boldsymbol{im_{int}} + \boldsymbol{im_f} \Rightarrow \\ \boldsymbol{im} &= \boldsymbol{Z_m^T} \cdot 1_{\boldsymbol{n}} + \boldsymbol{c} - \widehat{\boldsymbol{n}_2} \cdot \boldsymbol{f_d} + \boldsymbol{inv_{im}} \end{aligned} \tag{1.19}$$

Using Eqs. 1.13 and 1.19, Eq. 1.11 is transformed as follows:

$$\begin{aligned} \text{balance} &= 1_{\boldsymbol{n}}^{\boldsymbol{T}} \cdot (\boldsymbol{ex} - \boldsymbol{im}) \Rightarrow \\ &= 1_{\boldsymbol{n}}^{\boldsymbol{T}} \cdot \left(\widehat{\boldsymbol{n}_1} \cdot \boldsymbol{f_d} - \left(\boldsymbol{Z_m^T} \cdot 1_{\boldsymbol{n}} + \boldsymbol{c} - \widehat{\boldsymbol{n}_2} \cdot \boldsymbol{f_d} + \boldsymbol{inv_{im}}\right)\right) \end{aligned} \tag{1.20}$$

The deficit of the balance of goods and services by sector of economic activity is expressed as

$$\text{deficit} = -\text{balance} \tag{1.21}$$

The first constraint involves the GDP growth rate that the economy should achieveÛy equals the sum of all sectors value-added:

$$gdp = 1_{\boldsymbol{n}}{}' \cdot \boldsymbol{v_a} \tag{1.22}$$

The second constraint involves the economic complexity, which will be approached using the Krugman Specialization Index. The Krugman Specialization Index (KSI) is a widely used measure of a country's specialization (Krugman, 1991). The index measures the distance between the economic structure of the examined country and a reference group.

$$KSI = \sum \left| S_{i,gr} - S_{i,EU28} \right| \tag{1.23}$$

where, $S_{i,gr}i$ is the exports share of sector i of Greece and $S_{i,EU28}$ is the exports share of sector i of EU28. KSI measures the absolute distance between a sector's relative share between a country and the EU28, and then sums all sectors to create an index. If KSI is equal to zero, then examined country has an industrial structure identical to the EU28 (the country is not specialized). A high value of the index indicates a country with strong sectoral specialization. We should note that the indicator can only be evaluated as a relative one, compared with a group of countries.

In matrix formation, consider a vector $\boldsymbol{s_{gr}} \in \mathbb{R}^{n\times 1}$ is expressed as $\boldsymbol{s_{gr}} = \frac{1}{\boldsymbol{ex}\cdot 1_{\boldsymbol{n}}{}'} \cdot \boldsymbol{ex}$, while the vector $\boldsymbol{s_{EU}}_{28} \in \mathbb{R}^{n\times 1}$ is defined based on the data of 2015 for EU28 ($\boldsymbol{S_{EU}}_{28}$ is a vector with constant elements). Then $KSI \in \mathbb{R}^{1\times 1}$ is defined as:

$$KSI = \left\| \boldsymbol{s_{gr}} - \boldsymbol{s_{eu28}} \right\|_1 \tag{1.24}$$

1.5.4 *The Optimization Problem*

The aim of the restructuring problem is to minimize the deficit of the goods and services' balances under specific restriction. The decision variables of the analysis are the matrix of the distribution coefficients $\boldsymbol{B_d}$ and the vector $\boldsymbol{v_a}$ of the sectors' value-added.

$$\text{deficit} = -\text{balance} \tag{1.25}$$

The optimization problem is to define the optimal $\boldsymbol{B_d}$ and $\boldsymbol{v_a}$ in order to minimize $deficit(\boldsymbol{B_d}, \boldsymbol{v_a})$.

The domain of $\boldsymbol{B}_d$ is defined by a lower and an upper matrix $\boldsymbol{B}_1, \boldsymbol{B}_2 \in \mathbb{R}^{n \times n}$, respectively.

$$\boldsymbol{B}_1 \preccurlyeq \boldsymbol{B}_d \preccurlyeq \boldsymbol{B}_2 \tag{1.26}$$

In addition, the domain of $\boldsymbol{v_\alpha}$ is defined by a lower and an upper vector $\boldsymbol{k}_1, \boldsymbol{k}_2 \in \mathbb{R}^{n \times 1}$, respectively, according to Eq. 1.27.

$$\boldsymbol{k}_1 \preccurlyeq \boldsymbol{v_a} \preccurlyeq \boldsymbol{k}_2 \tag{1.27}$$

The symbol $\preccurlyeq$ denotes element-wise inequality.

The GDP of the economy should equal with the GDP projection, as shown in Eq. 1.28:

$$gdp\left(\boldsymbol{B}_d^*, \boldsymbol{v_a}\right) = gdp_{\text{optimum}} \tag{1.28}$$

And the complexity of the economy should increase to

$$ksi\left(\boldsymbol{B}_d^*, \boldsymbol{v_a}\right) = ksi_{\text{target}} \tag{1.29}$$

In summary, the productive restructuring model can be formulated as a constraint optimization problem in Eq. 1.30:

$$\begin{array}{ll} \underset{\substack{\boldsymbol{B}_1 \preccurlyeq \boldsymbol{B}_d \preccurlyeq \boldsymbol{B}_2 \\ \boldsymbol{k}_1 \preccurlyeq \boldsymbol{v_a} \preccurlyeq \boldsymbol{k}_2}}{\text{Minimize}} & \text{deficit}\left(\text{B}_\text{d}, \text{v}_\text{a}\right) \\ \text{subject to:} & \\ gdp(\boldsymbol{v_a}) = gdp_{\text{optimum}} & \\ \boldsymbol{k}_{\text{si,min}} \leq \boldsymbol{k}_{\text{si}}(\boldsymbol{B}_d, \boldsymbol{v_a}) \leq \boldsymbol{k}_{\text{si,max}} & \end{array} \tag{1.30}$$

1.6 Future Directions

In this chapter, a theoretical and methodological framework for the formulation of an industrial policy strategy to promote the productive transformation of an economy is introduced.

Firstly, the issues surrounding the definition and the contribution of industrial policy are discussed. In particular, in the first section of the chapter, industrial policy is defined as sector-specific interventions in an economic system toward the productive transformation and the achievement of economic development. This definition emphasizes the vertical nature of industrial policy, given that the process of productive transformation involves targeted interventions.

In addition, productive transformation is analyzed in the theoretical framework of input–output analysis, providing a background to the methodological approach elaborated later in the chapter. In particular, input–output analysis is selected as a methodology capable of reflecting the complexity and complementarity of an economic system and suitable for the formulation of productive transformation as an optimization problem. The literature review highlights the lack of a methodological framework for exploring different aspects (economic, social, and environmental) of productive transformation.

Next, the broad outlines of an industrial policy toward productive transformation is examined. Three complementary aspects are analyzed: The role of industrial sectors, the importance of diversification and sophistication of production, and the contribution of production linkages. The main conclusion of the section is that a successful productive transformation strategy relies on both diversification and sophistication of production and that the improvement of productive linkages is essential to sustain macroeconomic gains.

Finally, a methodological approach is introduced to address the question: which sectors should a productive transformation strategy target to optimize the productive structure, satisfying specific macroeconomic targets in parallel? Furthermore, the mathematical model for the productive transformation of an economy is introduced. The optimization model's objectives and constraints are designed for the Greek economy, a country with structural weaknesses and deep macroeconomic problems. In this case, the objective is minimization of the trade balance deficit. The constraints are achieving a specific growth level with increased economic complexity. The optimal productive structure involves the distribution of final demand between the sectors and the improvement of productive linkages due to import substitution policies.

The novelty of the proposed methodology is that it captures the full economic potential of productive transformation. Furthermore, the intermediate transactions are not considered stable but depend on the growth rates of the sectors they refer to. Thus, the sector's potential role as a consumer of inputs and the producer of intermediate and final products or services is fully documented. In sum, this chapter introduces an in-depth productive transformation that estimates the optimal reallocation of production among the sectors and the optimal level of import substitution.

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