CHAPTER 2

Greece Toward 2027: Structural Transformation, Industrial Policy, and Economic Development

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2.1 Introduction

The Greek Economy was severely affected by the 2008 economic crisis. The roots of Greece's unprecedented crisis should be sought in the country's unfavorable economic structure. The main structural problems of the Greek Economy are limited exports with low diversification; low participation of the manufacturing and technologically advanced sectors in

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production and exports; weak linkages among different economic activities; high dependency on intermediate and final imports with high-income elasticity of demand; and specialization in activities of low technological level. The above structural features lead to trade balance deficits and low international competitiveness. Furthermore, the implementation of three Economic Adjustment Programs (2010, 2012, and 2015) formed by the European Union, the International Monetary Fund, and the European Central Bank, and the imposed austerity policies failed to drive the Economy into a growth trajectory and have led to an ongoing recession.

The COVID-19 pandemic and the subsequent economic lockdown triggered a deeper recession, reduced production levels, and increased unemployment. The Greek Economy's peculiar economic structure is emerging as the main obstacle to economic growth and development, and current policies do little to the economic situation. The transformation of the Greek Economy's productive structure through appropriate industrial policies is recognized as the only way to achieve economic development.

In this chapter, the solution to the optimization problem of the economic structure of Greece, introduced in Chapter 1, is analytically discussed. The optimal economic structure is compared to the current one to define the sectors on which industrial policy should focus. Furthermore, the evolution of the backward sectoral linkages is investigated, determining the optimal structure's interconnectedness.

The structure of the chapter is the following: the methodological framework is introduced in the Sect. 2.1. Section 2.2 presents the current sectoral structure of Greece. Then, Sect. 2.3 focuses on the empirical results obtained from implementing the proposed methodology. Finally, Sect. 2.4 discusses policy implementations integrating sectoral and macroeconomic interventions.

2.2 The Sectoral Structure of Greek Economy

As was argued in Chapter 1, the elaboration of an industrial policy plan requires the in-depth knowledge of the Economy's structural features. That is, it relies in no small measure, on the ability to capture the complexity and dynamics of modern economies. Thus, before describing the goal as to how the optimal productive structure is set up, it is helpful to offer some background on the current sectoral structure of the Greek Economy and the country's position within the EU27 member countries. The remainder of this section contains a comparison between the

Greek Economy and the EU27 member countries regarding the sectoral structure of production, the technological features of production and external trade, intersectoral linkages, and the contribution of exports to the value-added generation.

The economic sectors of the Greek Economy are listed in Table 2.1. In the same table is listed the aggregation of the manufacturing sectors according to the technological intensity (Eurostat, 2010).

2.2.1 Economic structure and the Technological Level of Production

Table 2.2 shows that the tertiary sector generates a significant share of value-added in all EU27 countries, reaching 72.98% for the EU27 as a whole. The secondary sector (one-digit sectors B, C, D, and F) follows, with its contribution to value-added reaching 25.23% for the EU27, while the primary sector participates in the formation of value-added by only 1.79%. The countries with the largest share of primary sector in value-added are Romania (4.54%) and Greece (4.36%), while the countries with the smallest percentage are Belgium (0.70%) and Luxembourg (0.25%). The countries with the largest share of secondary sectors in value-added are Ireland (37.61%) and the Czech Republic (34.83%), while the countries with the smallest share are Luxembourg (12.48%) and Greece (14.86%). Finally, the countries with the largest share of the tertiary sector in value-added are Malta (85.16%) and Luxembourg (87.27%). By comparison, the countries with the smallest percentage are Ireland (61.41%) and the Czech Republic (63.03%). Although the productive structure is likely to differ among countries, Greece is one of the EU27's most diverse economies; it is at the top of the EU27 regarding the primary sector's contribution and the bottom regarding the secondary sector.

The technological level of the production is highlighted in recent literature as one of the most critical factors determining an economy's competitiveness level (Lall, 2000; Markaki & Economakis, 2020; Petralia et al., 2017). In this respect, the production structure in terms of the sectoral technological level is presented in the following (Table 2.3). Eurostat (2010) classifies the secondary sectors based on their technological features as follows:

- High Technology (HT): C21, C26
- Medium–High Technology (MHT): C20, C27, C28, C29, C30

Table 2.1 Sectoral classification and technological level

Code	*Description*	*Technological level**
A01-03	Agriculture, forestry and fishing	
B	Mining and quarrying	
C10-12	Food, beverages and tobacco products	LT
C13-15	Textiles, wearing apparel, leather and related products	LT
C16	Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials	LT
C17	Paper and paper products	LT
C18	Printing and recording services	LT
C19	Coke and refined petroleum products	MLT
C20	Chemicals and chemical products	MHT
C21	Basic pharmaceutical products and pharmaceutical preparations	HT
C22	Rubber and plastic products	MLT
C23	Other non-metallic mineral products	MLT
C24	Basic metals	MLT
C25	Fabricated metal products, except machinery and equipment	MLT
C26	Computer, electronic and optical products	HT
C27	Electrical equipment	MHT
C28	Machinery and equipment n.e.c	MHT
C29	Motor vehicles, trailers and semi-trailers	MHT
C30	Other transport equipment	MHT
C31_32	Furniture and other manufactured goods	LT
C33	Repair and installation services of machinery and equipment	MLT
35–39	Water supply, sewerage, waste management and remediation	
F	Constructions and construction works	
G45-47	Wholesale and retail trade, repair of motor vehicles and motorcycles	
H49-53	Transportation and storage	
I	Accommodation and food services	
J58-63	Publishing, audiovisual and broadcasting activities, telecommunications, IT and other information services	
K64-66	Financial and insurance activities	
L68	Real estate activities	

(continued)

Table 2.1 (continued)

Code	*Description*	*Technological level**
M69-82	Legal, accounting, management, architecture, engineering, technical testing and analysis activities, scientific research and development, other professional, scientific and technical activities, administrative and support service activities	
O	Public administration and defence services; compulsory social security services	
P	Education services	
Q86-88	Human health services	
R90-99	Arts, entertainment and recreation, other services	

Source Eurostat (2008, 2010)
Note *Technological Level of manufacturing sectors: HT: high technology; MHT: medium–high technology; MLT: medium–low technology; LT: low-technology

- Medium Technology (MT): C19, C22, C23, C24, C25, C33
- Low Technology (LT):C10-C12, C13-C15, C16, C17, C18, C31-C32

Table 2.3 shows the technological structure of the EU27 using the latest available data for the year 2019. The value-added of each technological category is calculated by adding the sectors' value as described above.

Table 2.3 shows that high-tech sectors' contribution reaches 9.33% on average among EU27 member countries, while the corresponding value ranges from 3.32% in Romania, to 34.28% in Denmark. The medium–high-tech sectors' contribution reaches 38.33% on average among EU27 countries, ranging from 4.97% in Ireland, to 52.92% in Germany. Similarly, the medium–low-tech sectors' contribution reaches 26.59%, ranging from 16.14% in Ireland, to 37.04% in Slovakia. Finally, low-tech sectors' contribution reaches 25.75% in the EU27, ranging from 14.30% in Germany, to 57.73% in Lithuania. The Greek Economy is in the 15th place in the ranking of the examined countries regarding the participation of HT sectors in manufacturing, in the 23rd position regarding the share of MHT sectors, in the 6th position regarding MLT's share, and in the 6th position for the LT tech sectors.

A measure of the technologically advanced sector's contribution to an economy is the share of HT and MHT sectors in the production.

Table 2.2 Percentage structure of value-added in EU27 (2019)

	Primary Sector (%)	*Secondary Sector (%)*	*Tertiary Sector (%)*
EU27	1.79	25.23	72.98
BE	0.70	21.42	77.88
BG	3.75	25.05	71.20
CZ	2.14	34.83	63.03
DK	1.52	24.20	74.28
DE	0.80	29.65	69.55
EE	2.87	25.33	71.81
IE	0.97	37.61	61.41
EL	4.36	14.86	80.78
ES	2.88	22.58	74.54
FR	1.80	19.27	78.94
HR	3.56	24.73	71.71
IT	2.14	23.86	74.00
CY	1.99	14.57	83.44
LV	4.28	21.32	74.39
LT	3.59	28.11	68.31
LU	0.25	12.48	87.27
HU	3.96	29.45	66.59
MT	0.80	14.03	85.16
NL	1.85	19.86	78.29
AT	1.21	28.56	70.23
PL	2.67	31.83	65.50
PT	2.38	21.85	75.78
RO	4.54	31.14	64.32
SI	2.29	33.01	64.69
SK	2.76	32.10	65.14
FI	2.67	27.97	69.36
SE	1.63	24.97	73.40

Source Eurostat

This measure is more accurate than the share of HT sectors, because there are only two HT sectors (Basic pharmaceutical products and pharmaceutical preparations and Computer, electronic and optical products). Furthermore, medium–high technology sectors include the "heavy industry", such as the automotive industry, chemical industry, mechanical engineering industry, etc.

Figure 2.1 shows the contribution of the high and medium–high tech (HT & MHT) sectors, cumulatively, to the production of the economies

Table 2.3 Technological structure of EU27* countries, 2019 (%)

	HT (%)	*MHT (%)*	*MT (%)*	*LT (%)*
EU27	9.33	38.33	26.59	25.75
BE	17.02	30.32	26.58	26.08
BG	5.98	23.15	33.25	37.62
CZ	7.79	42.38	30.06	19.76
DK	34.28	26.94	16.99	21.80
DE	10.35	52.92	22.43	14.30
EE	6.54	17.89	29.87	45.70
IE	31.13	4.97	16.14	47.76
EL	7.23	13.93	32.55	46.29
ES	6.62	28.08	29.83	35.46
FR	10.06	30.60	30.57	28.76
HR	9.75	13.05	34.80	42.41
IT	6.67	32.13	29.27	31.93
CY	14.09	5.74	32.20	47.97
LV	6.48	13.24	22.55	57.73
LT	4.66	17.07	21.20	57.07
HU	15.41	38.62	27.16	18.81
NL	8.49	37.17	23.90	30.44
AT	9.50	36.55	29.71	24.24
PL	4.89	23.90	36.99	34.22
PT	4.59	17.42	28.87	49.13
RO	3.32	28.43	26.37	41.89
SI	14.48	29.76	35.09	20.68
SK	3.69	38.34	37.04	20.93
FI	14.61	31.74	26.59	27.06
SE	4.18	44.05	26.19	25.58

Source Eurostat
Note *No data is available for Luxembourg and Malta. For Ireland, Lithuania, and Sweden, the data refers to 2018

concerned. The HT & MIT sectors account for 47.67% of the manufacturing output for the EU27. By contrast, for Germany, Denmark, Hungary, the Czech Republic, Sweden, Finland, and Belgium, the HT & MHT sectors reach or exceed 50% of the industrial production. On the other hand, Greece is in the 23rd place among the examined countries, as the share of HT & MHT sectors in manufacturing is 21.16%. Cyprus ranks in the penultimate position with 19.84% and Estonia is in the last position with 19.72%. Based on the above analysis, Greece's inferior position in the share of the technological advance sectors is mainly due to

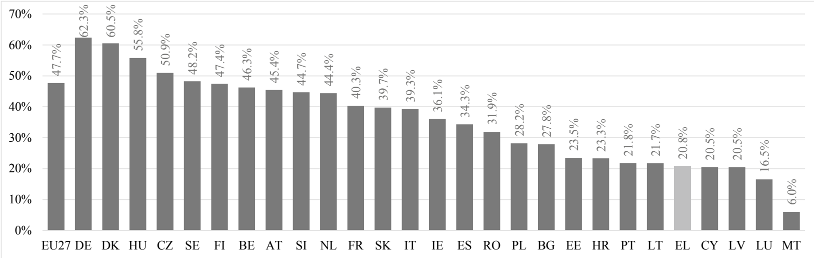

Fig. 2.1 Share of HT & MHT in value-added for EU27 countries, 2018 (%) (*Source* Eurostat and author's calculations)

the non-specialization of the Economy in the so-called "heavy industry" sectors.

2.2.2 *External Trade and Technological Level of Imports and Exports*

The literature on industrial policy focuses on the importance of the manufacturing sector as the driving force of economic growth. Recent studies argue that the technological structure of exports largely determines a country's position in international competition, as technologically advanced products, are characterized by higher-income elasticity of demand (Economakis & Markaki, 2014; Lall, 2000). Cohen and Zysman (1988) found a link between a country's export performance and technology's efficient use and dissemination across sectors. This view is also supported by Petralia et al. (2017), who points out the importance of technology in determining a country's level of development. Specifically, more developed countries tend to specialize in producing complex products using complex and less concentrated technologies than less developed ones.

In Greece, the share of high and medium–high technology products in exports is relatively low compared to the rest of the EU27 countries. Economakis and Markaki (2020) showed that in 2016, Greece was ranked last among EE countries in the share of HT and MHT products in total exports. The share in question was 24.3% for Greece, while in the top of the ranking was Ireland with a share of 85.5% and the median was Spain with a share of 55.5%. In the same research, the authors found a similar output when the technological level of imports is considered. The percentage of HT and MHT products in the Greek Economy's imports is 44.77% (third-lowest). By comparison, the corresponding value varies from 70.66% in Ireland to 35.1% in Cyprus, with a median of 56.5% in Austria. The technological levels of imports and exports are related. Imports include final and intermediate products and the latter are used in the production process. The technological level of intermediates reflects the technological level of output; thus, a low share of HT & MHT imports, as in Greece, indicates that domestic production tends to produce lower technology products. This is confirmed by the technological level of Greek exports of goods within the Euro Zone (Economakis et al., 2018).

Furthermore, Hausmann et al. (2014) determined that the economic complexity of a country (measured by the Economic Complexity Index—ECI) depends on the diversity of its exports and their ubiquity (the number of the countries able to produce them and those countries' complexity). Thus, countries that can maintain a diverse range of sophisticated and unique productive know-how, can produce a wide diversity of goods, including complex products that only a few other countries can produce (Markaki & Economakis., 2022; Simoes & Hidalgo, 2011).

As shown in Fig. 2.2, the Economic Complexity Index (ECI) for 2018 brings Greece in the last position within the EU27 countries. This output implies that Greece is a country that exports only a few range of products which (i) are also products of relatively high ubiquity and (ii) are exported by not very diversified countries.

In summary, the above analysis documents a divergence between Greece's production and trade structure and the rest of the EU27 countries, leading to the conclusion that Greece is facing unfavorable terms of trade within the European economies. Greece's productive structure indicates an economy with low production and export diversification, specializing in less technological advance products.

2.2.3 Economic Linkages and Sectoral Structure

The sectoral structure of an economy's production and exports is critical for identifying industrial policy objectives. However, policymakers cannot overlook that each sector's production process is based on the supply of products and services from other branches. A change in the production level of a sector will increase the demand for intermediates

Fig. 2.2 Economic Complexity Index (ECI) for the EU27* (2018) (*Source* The Growth Lab at Harvard University [2019] and *Note* *No data available for Luxembourg and Malta)

from the sector supplying industries; thus, sectoral changes are not independent. The economic interdependencies, or linkages, that develop in an economic system diffuse a change in production structure throughout the Economy. The impact of the change depends on the intensity of the linkages. A sector strongly linked with other sectors in the production network can potentially cause broader and most significant effects on the extension of production than those caused by a sector with weak links. The backward linkages of the sectors are a measure of the level of their economic interdependencies and are widely used for the investigation of the productive structure of an economic system (national, regional, local) and for the evaluation of economic and social policies as well as forecasts at macroeconomic and sectoral level (Belegri-Roboli et al., 2010, 2011; Economakis & Markaki, 2023; Economakis et al., 2015; Miller & Blair, 2009; Suh, 2009).

The inquiry into the question of the strength of backward linkages of the Greek Economy will be based on two considerations. Firstly, the literature does not provide specific values that define a strong, average, or weak level of backward linkages. Therefore, estimating the strength of backward linkages is based only on evidence from comparative studies. Thereby, the strength of the Greek Economy's backward linkages will be investigated based on comparison within the EU27 countries. Secondly, although strong backward linkages indicate that the sector significantly impacts the Economy, backward linkages measure the total change in the Economy's production when a unit change occurs in the sector's demand. Thus, the sector's size should also be taken into account; a large sector with relatively high backward linkages is more likely to have a significant output increase which will have a high multiplying effect on the whole Economy. On the contrary, in the short term, a small sector cannot extend its production to a level that will create a critical multiplying effect, even if the sector shows relatively high backward linkages.

In Fig. 2.3, the backward linkages of the Greek Economy and a comparison with EU27 countries are depicted based on the WIOD data (Timmer et al., 2015). Greece's backward linkages are lower than the median of EU27 member countries for primary and most tertiary sectors. By contrast, for the secondary sectors, the opposite picture emerges. In particular, Greece has higher sectoral links than the median of EU27 member countries for most secondary sectors (specifically sectors C13_C15, C16, C20, C21, C22, C26, C27, C29, C31_C32). However, these sectors with relatively high interconnections produce only 2.03% of the Greek Economy's product, so their impact as multipliers of the existing dynamics is limited. Thus, the findings shown, result from either the production of different output types by the same sector (as in the case of C29) or the existing ones of a small and dynamic sector (as in the case of C21).

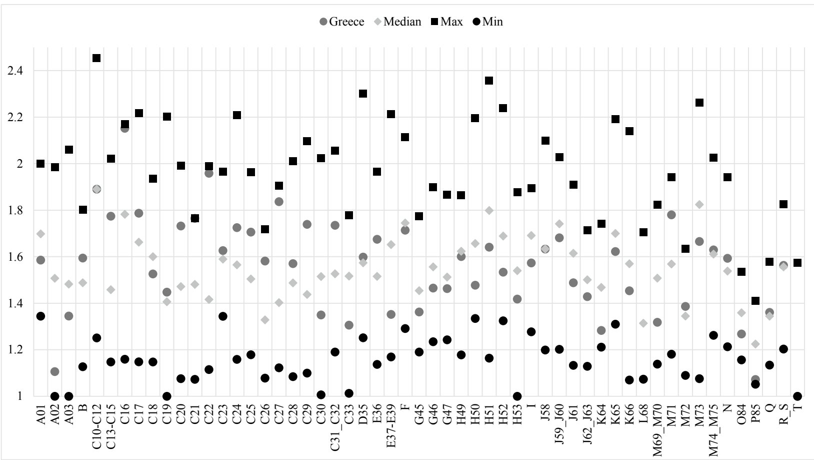

Fig. 2.3 Backward linkages for Greece and EU27 (2014) (*Source* Markaki [2019, p. 79])

For a complete assessment of the Greek Economy's level of interconnectedness, the sectors with significant contributions to value-added (2.5% of the total value-added or more) are isolated, and their backward linkages are examined. Of the 15 sectors contributing more than 2.5% to the Greek production, only two, Q (Activities related to human health and social care) and R_S (Arts, entertainment, and other service activities), have shown backward linkages greater than the median of EU27 member countries. In contrast, the rest of the sectors (i.e., A01, C10-C12, F, G46, G47, H50, I, J61, K64, L68, M69_M70, O84, P85) show lower values.

The corresponding results for the case of EU27 countries are presented in Fig. 2.4, where a significant variation is evident. Greece ranks in the penultimate position with Cyprus, Luxembourg, Malta, and the Netherlands. In other words, it appears that the dynamics of the relatively large sectors in the Greek Economy are significantly lower than those of most EU member countries.

The subordinate position of the Greek Economy's interconnectedness to the EU27 countries indicates that Greece is characterized by a different production technology to the average technology of the EU27. The non-homogenous production of a sector and diversified technology can lead to various backward linkages within the EU27 countries. This study shows that the Greek Economy's production technology creates a network of lower-intensity transactions than in most EU27 countries.

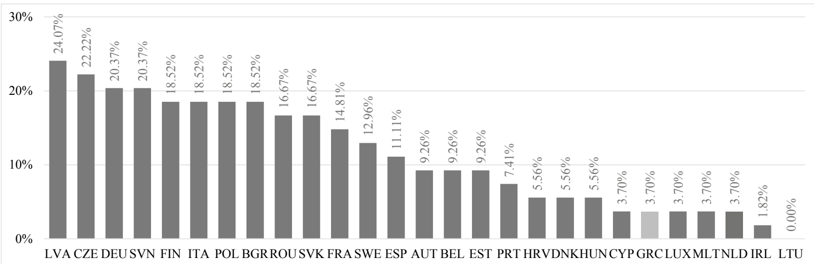

Fig. 2.4 Share of large sectors with high backward linkages (2014) (*Source* Markaki [2019, p. 79])

2.2.4 *Domestic Value-Added in Exports and Technological Level of Exports*

The Domestic Value-Added in Exports (DVX) expresses the domestic value-added, created to satisfy exports' demand. DVX depends on both the export structure and the production structure of the Economy under investigation. It is a measure that can reflect the contribution of exports to an economy or show how a country's position in international competition affects its productive potential (Hummels et al., 2001; Koopman et al., 2012).

Figure 2.5 depicts the unit DVX for all EU27 countries. The unit DVX expresses the new value-added created in each domestic Economy when exports show an increase of one unit. The estimation of the unit DVX includes all economic sectors, irrespective of whether the sector is exporting or has linkages with the exporting sectors. The unit DVX ranges between 0.714 in Germany and 0.323 in Luxembourg. Greece is found in the 9th position within the EU27 countries, with a value equal to 0.669. Greece's exporting activities generate value-added mainly in the tertiary sector, while the participation of the secondary sector is relatively low.

The results show an extensive diversification between EU27 member countries, due both to differences in the structure of exports and economic interdependencies. The EU27 countries demonstrate differentiated integration into the international competition, and therefore

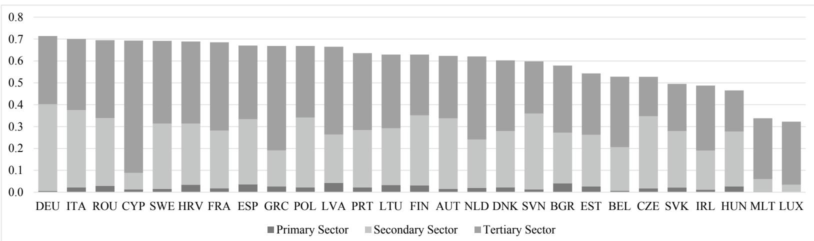

Fig. 2.5 Unit domestic value-added in exports, EU27 (2014) (*Source* WIOD and authors' calculations)

different levels of benefits from international trade. The benefit of countries in the top five of the ranking is, on average, 65% greater than that of countries in the last five positions.

Although Greece shows a relatively high unit DVX, when attention turns to the technological level of the generated value-added, the findings are not encouraging.

Figure 2.6 shows the HT & MHT sectors' contribution to the unit DVX for the EU27 countries. The contribution of technologically advanced sectors (HT and MIT sectors) ranges from 66,97% in Germany to just 17.25% in Greece, with an average value of 43.52%. This finding confirms that the integration of European countries into international competition creates conditions conducive to developing technologically advanced sectors in some countries (e.g., Germany, Hungary, Sweden) and makes it difficult for others (Latvia, Lithuania, Greece).

The technologically advanced sectors include the high-tech sectors C21 (Basic pharmaceutical products and pharmaceutical preparations) and C26 (Computer, electronic, and optical products) as well as the medium–high-tech sectors C20 (Chemicals and chemical products), C27 (Electrical equipment), C28 (Machinery and equipment n.e.c.), C29 (Motor vehicles, trailers, and semi-trailers), C30 (Other transport equipment). Conclusively, it becomes clear that the growth of those sectors and their interconnection with the rest of the economic network contribute significantly to the highly competitive position and the converse. Therefore, we conclude that strengthening the production system's coherence is an additional important aspect of industrial policy.

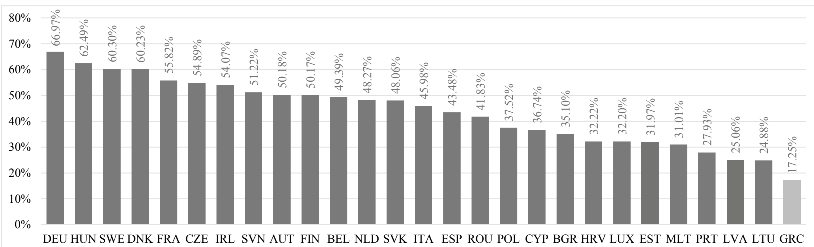

Fig. 2.6 Share of HT & MHT sectors in unit DVX, EU27 (2014) (*Source* WIOD and authors' calculations)

2.2.5 Summary

The survey findings highlight the need to implement an industrial policy that will lead to the structural transformation of the Greek Economy. In Greece's case, industrial policy should aim at (1) the reallocation of production to favor industrial and technologically advanced sectors and 2) the strengthening of sectoral linkages, leading to an increased multiplying effect of the economic system. In addition, such an industrial policy will positively impact the labor market by creating new jobs or redistributing workers to higher-productivity jobs.

2.3 Defining the Parameters of the Optimization Problem

Section 2.2 has demonstrated that, in the case of Greece, industrial policy should favor the country's development and competitiveness through an increase of the manufacturing share in production, the enhancement of the exporting orientation, the promotion of technological advances in the various sectors, and an improvement in sectoral linkages. Therefore, it is now necessary to explain the optimization model's formulation and the restructuring/transformation targets that could be empirically applied to the Greek Economy.

As was analytically discussed in Chapter 1, the Greek Economy's structural transformation aims to reduce the trade balance deficit, which is achieved by reallocating production within the economic sectors and import substitution in the intermediate demand. The parameters of the optimization problem are: the domain of the matrix of the distribution coefficients ($\boldsymbol{B}_1$ and $\boldsymbol{B}_2$) and the domain of the value-added vector ($\boldsymbol{k}_1$ and $\boldsymbol{k}_2$).

The proposed methodology is grounded on the theoretical model of input–output analysis. Thus, the application of the model requires the availability of an input–output table. The most recent one for Greece is the 2015 input–output table following the NACE Rev. 2 sectoral classification (Eurostat, 2008).

The definition of the $\boldsymbol{B}_d$ domain (i.e., the lower limit $\boldsymbol{B}_1$ and the upper limit $\boldsymbol{B}_2$) will also define the level of import substitution in intermediate demand. Presuming that the production technology remains as is, the lower limit of $\boldsymbol{B}_d$ is the current one and the upper limit is the matrix of the distribution coefficients $\boldsymbol{B}$. If the optimal matrix $\boldsymbol{B}_d^* = \boldsymbol{B}_{d,current}$

then, there is no substitution in intermediate imports and if $\boldsymbol{B}_{\boldsymbol{d}}^{*} = \boldsymbol{B}$, then, there is a full substitution of intermediate products. The second case is not valid since a modern economy does not produce all types of products domestically. In this study, the lower limit of $\boldsymbol{B}_d$ is set to $\boldsymbol{B}_{d,current}$. In this case, the structural transformation will be based on the reallocation of production within the sectors, not import substitution. The upper limit $\boldsymbol{B}_2$ is defined by the equation $\boldsymbol{B}_2 = \boldsymbol{A}_{d,current} + \boldsymbol{S}_{max} \cdot \boldsymbol{A}_{m,current}$, where $\boldsymbol{S}_{max} \in \mathbb{R}^{n \times n}$ is a diagonal matrix whose diagonal elements $s_{i,max} \in [0,1]$. $s_{i,max}$ expresses the i sector's maximum coefficient of substitution and captures the maximum possible level of sector i to produce intermediate inputs for other sectors, substituting intermediate imports from the corresponding sectors abroad. If $s_{i,max} = 0$, then, there is no possibility for intermediate import substitution for sector i, while if $s_{i,max} = 1$, then the substitution of intermediate imports is full. Thus, the optimal intersectoral structure $\boldsymbol{B}_{\boldsymbol{d}}^{*}$ is connected with the estimation of the optimal coefficient of substitution, s_i^* for each sector ($0 \leq s_i^* \leq s_i$). The coefficient of substitution, s_i applied in this research is presented in Table 2.4. For the sector not included in Table 2.4, the s_i equals zero.

Vectors $\boldsymbol{k}_1$ and $\boldsymbol{k}_2$ are defined on the basis of Oxford Economics projections (Oxford Economics, 2020). Figure 2.7 presents the percentage change in gross value-added expected from 2019 to 2027, according to the Basic and the Plus scenarios of Oxford Economics. In this research, the low level of value-added ($\boldsymbol{k}_1$) equals the projection of the Basic Scenario and the upper level of value-added ($\boldsymbol{k}_2$) is set by the authors. The determination of the maximum possible change of value-added is based on the current dynamics of the sectors.

Table 2.4 Substitution rate

Sector	*Substitution coefficient*
A01-03, C10-12, C13-15, C17, C18, C32, C33	0.6
C20, C21, C22, C23, C24, C25, C27	0.4
C26, C28, C30	0.2

Source Authors' creation

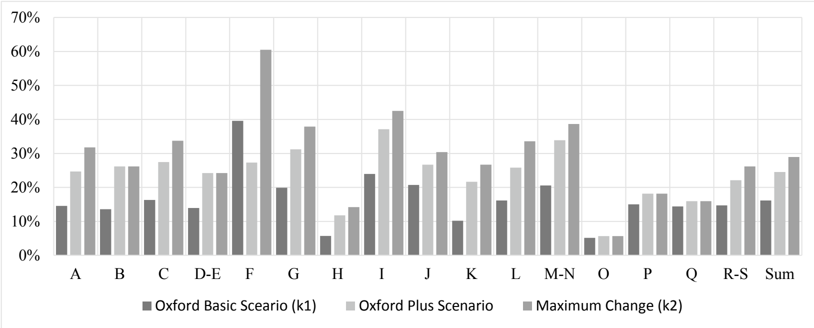

Fig. 2.7 Rate of change of value-added from 2019 to 2027 (*Source* Oxford Economics [2020] and author's own estimations)

2.4 The Optimization Algorithm

The discipline of computational intelligence includes tools and methodologies which allow solving problems that are difficult or even impossible to solve by traditional methods.

One of the key pillars of computational intelligence is algorithms able to optimize the parameters of a system toward achieving a clearly defined goal. This optimization is achieved with evolutionary optimization algorithms inspired by nature. The concept of optimization is a general concept, which may include either the evolution of a system's structure to meet specific objectives or the determination of the values of the parameters of a system's predefined architecture by formulating its behavior as a parameterized function with respect to its parameters (function optimization).

In this work, the concept of optimization focuses on defining the parameters of a system's clearly defined architecture. That is, we deal with function optimization.

Although most evolutionary algorithms can be appropriately designed for structure and function optimization problems, two subfields of computational intelligence are more appropriate, more efficient, and more easily applicable for facing function optimization problems. (a) Genetic Algorithms (GA), which are inspired by the evolution of species through natural selection and (b) particle swarm optimization (PSO), which is inspired by the social behavior and cooperation of flocks while seeking food. Especially in the field of function optimization, it has been empirically shown that PSO is more efficient than Genetic Algorithms, as it provides a clearer ability to adjust for exploration and exploitation power. The balance between exploration and exploitation capacity is a key concept for every optimization process. This balance is regulated through the emphasis that each particle gives to its individual and social behavior and addresses one of the inherent problems of Genetic Algorithms, which effectively attains the optimal region but has difficulties in accurately locating it (for an analytical presentation of nature-inspired evolutionary optimization algorithms, see: Papadakis & Markaki, 2019; Markaki & Papadakis, 2021).

The problem we treat in this work falls into the category of function optimization. The objective function, which is to be optimized, is non-linear and the computation of its derivatives is quite difficult. Moreover, the objective function is non-continuous due to some min., max. operators involved in the constraints, which an accepted solution must satisfy. Thus, a PSO algorithm is employed for the solution of the optimization problem.

2.5 The Structural Transformation of the Greek Economy

The optimal economic structure for the Greek Economy is obtained with the solution of the optimization problem. After presenting the basic macroeconomic results, a comparative analysis of the optimal structure against the current one will focus on (1) the industrial structure, (2) the economic linkages, and (3) the domestic value-added in exports. The descriptive evidence presented in the previous section has shown that the subordinate position of the Greek Economy among EU27 countries is due to technological and structural weaknesses. Thus, potential improvements in the Economy's technological and structural features resulting from the optimal structural transformation are also investigated.

The Greek Economy's structural transformation will lead to a trade balance of goods equal to -8.6% of GDP, a significant improvement compared to the respective value of 2019, which reaches −12.45% of GDP. Furthermore, the trade balance of goods and services is estimated at −1.32% of GDP. However, this value does not include the travel balance, as the input–output table only exports goods and services. Therefore, the balance of goods and services could rise to as much as 5% of GDP in 2027, assuming a travel balance equal to the level of 2019.

2.5.1 The Structural Change of Production

Table 2.5 compares the Greek Economy's current structure for 2019 with the optimization problem's output for 2027. The Economy's structural transformation will potentially increase the share of secondary sectors (sectors with codes B, C, D, and E at the NACE Rev. 2 classification) in value-added production from 14.86% in 2019 to 18.16% in 2027. Notably, the share of secondary sectors in the optimal structure is more significant than in the Basic and the Plus Scenarios of Oxford Economics estimation (15.92% and 16.39%, respectively). Furthermore, a part of the increase in secondary sectors is identified in the manufacturing sector (C), whereas the rest mainly concerns construction sector (F).

Moreover, the findings show a considerable reduction of the tertiary sector and a slight increase in the primary sectors. As a result, the primary sector (A) share in the optimal structure reached 4.52% of the total value-added, showing a slight increase compared to 2019, where the respective share was 4.36%. By contrast, the percentage of tertiary sectors is 77.32% in the optimal structure, lower than in 2019, when the respective share was 80.78%.

As shown in Table 2.6, the technological structure of manufacturing sectors exhibits significant improvement. The percentage of high-tech and medium–high-tech sectors is significantly increased, while the share of medium–low and low-tech sectors is decreased. As a result, the cumulative share of HT and MHT sectors will reach 29.43%, improving the Greek Economy's position in the EU27 countries compared to 2019 (see Fig. 2.1).

Table 2.5 Current Structure (2019) and Optimal Structure (2027)

	2019 (%)	*2027 (%)*
Primary Sectors (A)	4.36	*4.52*
Secondary Sectors (B, C, D, F)	14.86	*18.16*
Of which Manufacturing (C)	*9.85*	*10.86*
Tertiary Sectors	80.78	*77.32*

Source Authors' calculations

The analytical structure of manufacturing at the sectoral level is depicted in Fig. 2.8. The economic sectors are listed in the vertical axis based on their technological level. Furthermore, Fig. 2.9 presents the manufacturing sectors' share change from 2019 to 2027. The five larger sectors for Greece in the optimal structure are C10-C12, C20, C21, C24, and C25. These sectors produce 66.23% of the total manufacturing value-added. All these sectors indicate an increase in their participation in production. Notably, sector C19 was included in the larger five sectors in 2019, but the participation, as shown in the optimal structure decreased its importance.

The evidence presented in Fig. 2.9 suggests that the Greek Economy's optimal productive structure will potentially increase the participation of HT and MHT sectors, except sectors C29 (Motor vehicles, trailers, and semi-trailers) and C30 (Other transport equipment). This finding is expected, as the expansion of the aforementioned sectors implies significant scale capital investments. Moreover, the majority of MLT and LT sectors show a decrease in their participation in value-added generation, with the exceptions of sectors C24 (Basic metals), C25 (Fabricated metal products), and C10-C12 (Food, beverages, and tobacco products). These findings regarding sectors C24 and C25 agree with the concept of import substitution, as both sectors play an essential role in the Greek Economy as producers of intermediates. Moreover, sector C10-C12 is the larger manufacturing sector and a significant exporter and contributes to the productive network of tourism activities.

2.5.2 The Structural Change of Economic Linkages

Figures 2.10 and 2.11 illustrate the backward linkages of the optimal structure and the percentage change between the optimal structure and the last available input–output table, respectively. As Fig. 2.10 shows, the backward linkages of the manufacturing sectors are, in most cases, higher than those of the services sectors. Furthermore, the process of structural transformation, as Fig. 2.11 indicates, leads to a strong positive impact on backward linkages in all the economic sectors.

The more significant increase of backward linkages (more than 15%) is located in sectors C22 (Rubber and plastic products), C13-C15 (Textiles, wearing apparel, leather, and related products), C17 (Paper and paper products), and C26 (Computer, electronic, and optical products). Following that, sectors C24 (Printing and recording services),

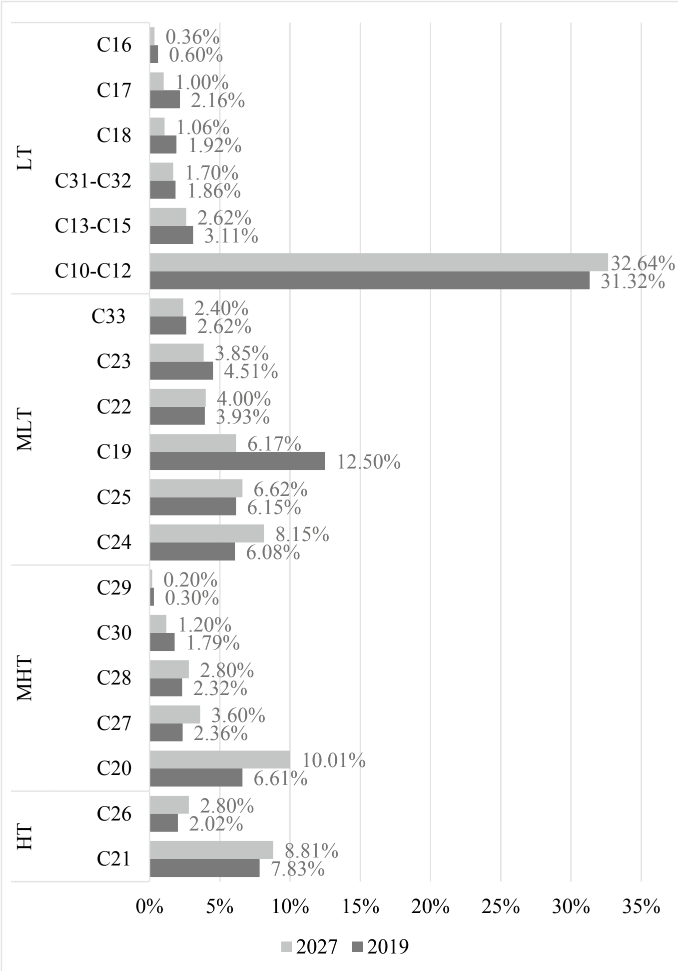

Fig. 2.8 Structure of manufacturing (2019 and Optimal Structure 2027) (*Source* Authors' calculations)

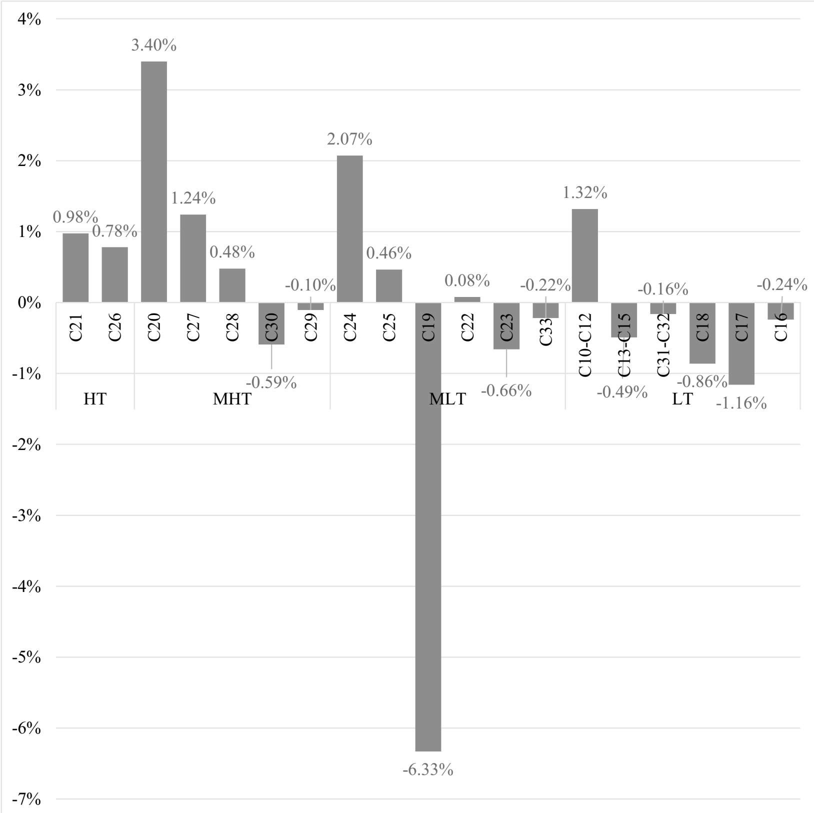

Fig. 2.9 Change of the manufacturing sectors' share from 2019 to 2027 (*Source* Authors' calculations)

Table 2.6 Technological structure of manufacturing sector (2019 and optimal structure 2027)

	2019 (%)	*2027 (%)*
HT	9.85	11.61
MHT	13.39	17.82
MLT	35.79	31.20
LT	40.96	39.37

Source Authors' calculations

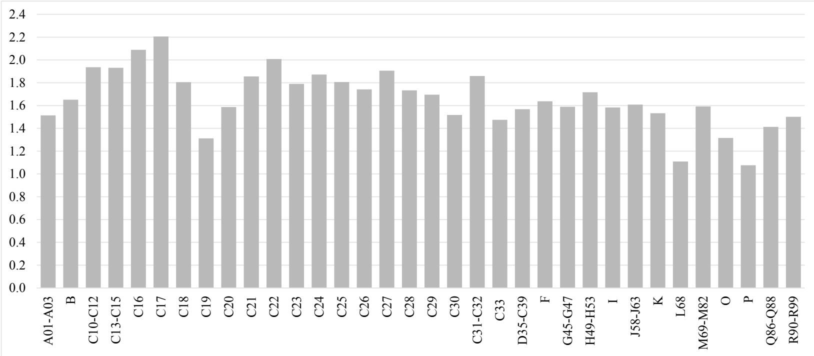

Fig. 2.10 Backward Linkages with the optimal structure, 2027 (*Source* Authors' calculations)

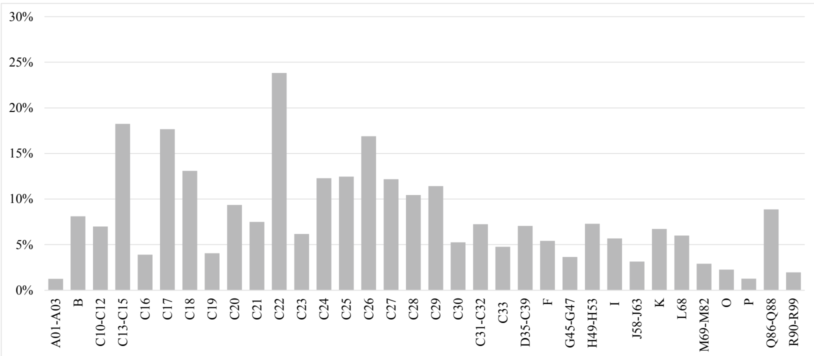

Fig. 2.11 Percentage change of backward linkages, 2015–2027 (*Source* Authors' calculations)

C25 (Fabricated metal products, except machinery and equipment), C27 (Electrical equipment), and C28 (Machinery and equipment n.e.c) show an increase in backward linkages of 10% to 15%. The increase is lower in the rest of the sectors.

The improvement of the backward linkages results from (i) the import distribution in intermediates and (ii) the reallocation of production within sectors. On the one hand, import substitution develops a more robust network of linkages, as domestic sectors satisfy a much larger part of the

Table 2.7 The domestic value-added in exports before and after the restructuring process

	2014	*2027*
DVX (Total Economy)	0.669	0.741
Manufacturing DVX	0.165	0.227
Share of Manufacturing DVX	24.73%	30.71%

Source Authors' calculations

intermediate demand for products and services. On the other hand, the reallocation of production diversifies the economic system's internal structure, as the distribution of intermediate demand (and supply) within the sectors also changes. Therefore, the effect of structural transformation is diffused throughout the Economy.

2.5.3 *The Improvement of the Domestic Value-Added in Exports*

The domestic value-added per unit of exports (Table 2.7) increased by 10.74%, from 0.069 in 2014 to 0.741 in 2019. For the same period, the contribution of the secondary sectors increased from 24.7 to 30.71%

The technological change of the DVX is presented in Fig. 2.12. As shown in Fig. 2.12, the contribution of HT and MHT sectors increases and MLT and LT's contribution decreases. As a result, the cumulative percentage of HT and MHT sectors rises from 17.25 to 21.45%, improving the country's competitive position among the EU27.

The empirical findings discussed in Sect. 2.4 show that the Greek Economy's structural transformation can improve the country's productive structure, increase manufacturing contribution in the value-added generation, and increase the share of technologically advanced products. As a result, the value-added generated by imports is significantly increased, improving the Greek Economy's terms of trade.

2.6 Policy Interventions

In this research, an optimization methodology based on input–output analysis is introduced. The proposed methodology aims to define the Greek Economy's optimal structure to maximize the impact of structural transformation policies. Furthermore, this approach traces a growth trajectory based on a robust economic and mathematical model that

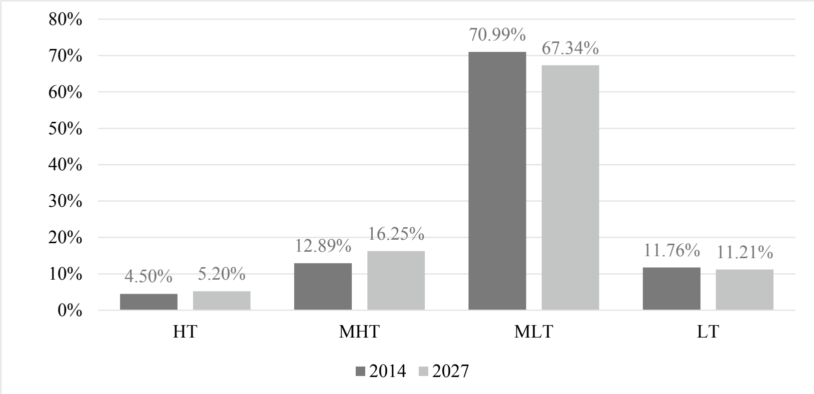

Fig. 2.12 Percentage change of backward linkages, 2015–2027 (*Source* Authors' calculation)

goes beyond the descriptive information usually found in industrial policy studies.

Taken together, the research findings suggest that the Greek Economy's structural transformation can lead to an increased GDP growth rate and, simultaneously, achieve a relatively low deficit in the balance of goods and services along with increased interconnectedness of the economic activities. Moreover, based on the optimal productive structure, policymakers can pursue a mix of structural policies, integrating sectoral and macroeconomic interventions.

Besides the fact that sectoral-specific policy interventions are necessary for achieving the reallocation of production within the sectors, this research highlights the dependency of the country's total economic performance on the diffusion of structural change throughout the economic network. Thus, sectoral interventions should be planned as a coherent whole rather than as individual sectoral policies. In this context, different policy interventions, such as export promotion, import substitution, public procurement policies, encouraging foreign direct investment, R&D development, and promotion of technologically advanced sectors, can be crucial for economic development. Finally, the importance of horizontal policies cannot be overlooked, especially concerning labor market policies (skills and education policies, training subsidies).

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