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Assessing the Impact of Trade Barriers on Energy Use in Turbulent Times: Current Conditions and Future Outlook for Greece

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Abstract: This paper develops a multi-sector computable general equilibrium (CGE) model with specific features for Greece and the non-EU Rest of the World (RoW). The novelty of this work stems from the lack of energy-focused CGE models for Greece in the current literature. The study's objective is to determine how the Greek economy would react if a 30% import tariff and a quota of 67% on energy imports and 35% on remaining imports were implemented. Furthermore, if quotas and tariffs are in force, the Greek economy will initiate countermeasures by increasing investment in renewable energies through substitution and a 35% subsidy. To quantify this, the 2015 Input-Output (I-O) table for Greece and the non-EU RoW was used. To offer a better understanding, the 36 production sectors have been divided into Agriculture, Energy, Manufacturing, and Services. The quota scenario resulted in a reduction in all sectors in domestic production in terms of output and domestic uses, with some sectors experiencing around a 30% reduction. Renewable energy investments, on the other hand, have proven to be effective for domestic production, increasing output and domestic uses by (6.561%) and (7.886%), respectively. In terms of import tariffs, prices have increased, resulting in a significant decrease in household consumption that exceeds 30% in several sectors. Finally, policy recommendations for addressing these trade barriers and Greece's renewable energy opportunities are proposed.

Keywords: Greece; non-EU RoW; CGE model; Input-Output table; CES function; elasticities of substitution; estimation

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1. Introduction

Greece has a small open economy with a trade-to-GDP ratio exceeding 65% in the last years. As a member of the European Union (EU), Greece trades extensively with its EU partners as well as with countries outside the EU. In terms of exports, Greece's largest trading partners are the EU countries, which account for about 60% of its exports. The most important export sectors are food and beverages, petroleum products, pharmaceuticals, and aluminum. Outside of the EU, Greece also exports to countries such as Turkey, the United States, and China. In terms of imports, Greece relies heavily on its EU partners, which account for about 40% of its imports. The most important import sectors are petroleum products, machinery, and vehicles which are mostly related to energy. Outside of the EU, Greece imports from countries such as Russia, China, and the United States. Tourism is also a significant contributor to Greece's economy, with millions of tourists visiting the country each year. This has led to a significant trade surplus in services, which helps to offset Greece's trade deficit in goods.

Trade and energy are two significant components of the modern economy. Trade enables countries to exchange goods and services, promoting economic growth, specialization, and access to a greater range of commodities. It also promotes competitiveness,

innovation, and job opportunities while strengthening international ties between nations. Energy, alternatively, is vital to modern economies, fueling companies, transportation, and households. The availability of dependable and reasonably priced energy sources is crucial for economic activity and trade facilitation. Sustainable energy practices are becoming increasingly important in combating climate change and creating a more environmentally friendly future. For more detailed analysis, see [1–4].

Computable General Equilibrium (CGE) models are a class of economic models that simulate the behavior of an economy in response to various policy and economic shocks. CGE models are based on the principles of general equilibrium theory, which posits that all economic variables in an economy are interrelated and that a change in one variable will affect other variables. CGE models are widely used for policy analysis, as they can capture the complex interactions between different sectors of an economy and provide insights into the effects of policy changes. A CGE model combines abstract general equilibrium economic theory written as equations with real-world economic data to calculate the influence of an exogenous shock on a collection of endogenous variables. The CGE static model includes a starting scenario, typically referred to as the benchmark scenario, that depicts reality before the implementation of the policy. By changing one or more parameters, both scenarios may be compared to see how the policy affects other measures and how it interacts with them [5–9].

A CGE model of international trade includes ties with other nations, where each nation has its own set of consumers, producers, and government. The growth of an external sector involves the understanding of one critical issue, the interchangeability of imports and domestic products. Standard CGE trade models adopt the Armington assumption [10], considering that foreign and domestic products are not perfect substitutes, such that products in international trade are distinguishable by their country of origin.

The present work is motivated by the recent crisis of the Russian invasion of Ukraine and the retaliation by the EU member states on Russian imports in the form of trade restrictions. We would like to observe how the Greek economy would react in a similar situation, i.e., if trade restrictions on energy imports and imports in general were imposed on its non-EU trade with the Rest of the World. To be consistent with the EU retaliations on Russian imports, the same magnitude of trade restrictions has been used for Greece. To examine and quantify this scenario, a CGE model was constructed to mirror the effects of the imposition of trade barriers on the Greek economy, specifically the impact of the enforcement of a quota on non-EU RoW energy imports curtailing them by two-thirds and a quota of one-third on the rest of the imports, along with an ad valorem import tariff of 30%. Given that trade barriers to energy imports have come into force, the Greek economy could react with increased investment in renewable energy through the substitution effect between conventional and renewable energy; a further scenario is presented where renewable energy production is subsidized by 35%. Greece aims to increase renewable energy in its energy mix by providing incentives such as feed-in tariffs and tax advantages. These initiatives have expanded the renewable energy industry and positioned Greece as a significant participant in the global transition toward clean energy.

Another important issue is how quotas or tariffs could be introduced in the common market of the EU, taking into account that the common external tariff (CET) system is in place and the European Union works as one entity as far as trade policy is concerned. Given that this work is just a scenario to observe the Greek economy's reaction to reduced energy imports and imports in general, we will provide an outline involved in introducing quotas or tariffs on imports from non-EU countries, assuming that this policy is imposed by the EU for all EU imports from third countries. Introducing trade restrictions by the EU could be carried out for a number of reasons. First, trade impediments can be used as sanctions against countries following foreign policy, i.e., the Russian invasion of Ukraine. Second, retaliation against trade impediments can be imposed by third countries within the WTO framework. Lastly, the restrictions could act as a barrier to fossil fuel imports for increased sustainability of resources and protection of the environment.

Generally, the literature regarding energy-focused CGE modeling and energy restriction for the Greek economy is lacking. Hence, in this work, an attempt was made to fill the gap in the literature by introducing a CGE model with contemporary data, estimated elasticities of substitution, and simulation analysis for the Greek economy. This work could be used as a guide to future studies by providing a justified framework that researchers and policymakers can use to extend their work regarding Greece and CGE models in general. To the best of our knowledge, it is the first energy-focused CGE model for Greece involving trade barriers to imported goods and policy implications; thus, the originality of this work lies in a prototype in the field. Furthermore, the elasticities of substitution in the production function have been estimated for the first time in the case of Greece which contributes to the novelty and innovation of this paper.

By reviewing previous CGE models for Greece and proposing a new one for examining the effects of trade barriers and changes in prices for energy imports, this work is timely in contributing to a better understanding of the relationship between Greece and the non-EU Rest of the World. This work also provides an example for future studies to examine this relationship or other bilateral relationships for Greece in a similar manner. Moreover, researchers could use the elasticities of substitution estimated in this work to facilitate their research, instead of estimating them on their own.

The remainder of the text is structured as follows: Section 2 surveys the literature on CGE models for Greece, the CGE model and data are described in Section 3, the estimation method for the substitution elasticities is described in Section 4, the results of the estimation and those of the CGE model are presented in Section 5, along with discussion and the sensitivity analysis, and conclusions and policy implications are provided Section 6.

2. Literature Review

Greece has been the subject of extensive research, due to the country's unique economic and political context, including its recent experience with the European debt crisis. CGE models have been used to analyze the macroeconomic, distributional, and welfare effects of various policy interventions in Greece, such as fiscal restriction measures, tax policies, and labor market reforms.

The work of [11] investigates the Community Support Framework (CSF) in the case of Greece between 1989 and 1993. The authors examined the impact of CSF, which is an economic policy framework established by the EU to stimulate growth among its member states through investment in infrastructure and human resources. In their work, the authors created an economy-wide CGE model for Greece, in which direct and indirect impacts on supply and demand were analyzed using counterfactual analysis. The authors examined many components of the CSF, such as fiscal and monetary policy, structural changes, and human resources. By including these variables in the CGE model, they were able to simulate and analyze the possible effects of the CSF on the Greek economy. The study's findings reveal that the CSF had both positive and negative effects on the Greek economy throughout the period investigated. While some policies improved GDP growth, infrastructure, and human capital, others worsened inflation and budgetary issues.

Through counterfactual scenarios, a CGE model for Greece created by [12] assessed the effects on the Greek economy of current defense budget reductions comparable to the NATO average. The authors began by recognizing that defense spending is a large portion of the country's budget and that reducing it might have an impact on the whole economy. They intended to quantify the possible peace dividend, which refers to the favorable consequences of reallocating defense spending to other sectors such as infrastructure, education, or healthcare. The authors used a CGE model to simulate various defense reduction scenarios and analyze their economic impact on Greece. According to the study's conclusions, cutting defense spending in Greece might result in potential benefits in GDP, employment, and welfare as a result of resource reallocation.

The effect of the peace dividend between Greece and Turkey was investigated by [13], by developing a multi-region dynamic CGE model. The authors examined the prospect

of conflict condition that Turkey turns into a member of the European Union and the alternative use of military expenditure cuts in a CGE framework. Several scenarios are addressed in the model, implying varying amounts of decrease regarding military expenditure to GDP ratio. Alternatively, this change causes a decrease in sectoral demand for military expenditures, while on the other hand, reallocation of the reduced expenditure on education, tax decrease, and infrastructure has a significant growth impact.

A CGE model with a sub-national character was developed by [14] regarding the Euro-Mediterranean area, specifically France, Italy, Portugal, Spain, and Greece. The primary aspect of this work was to draw economic evaluations of climate change impacts with greater geographical resolution than traditional CGE models, increasing the comparability and likelihood of information sharing across economic and physical impact models. The authors' simulation results revealed that in the case of a symmetric shock to productivity, GDP results for the EU are relatively stable at the aggregate level. On the other hand, when interregional mobility is included in the factors market, diverging patterns of GDP can be detected at the sub-national level, although differing degrees of substitutability in the consumption of commodities from different subnational areas have a minimal effect.

The research of [15] focuses on the macroeconomic consequences of faster decarbonization in Greece. The authors studied the effects of various decarbonization rates on key macroeconomic indices such as employment, economic growth, and government spending. The authors employed a dynamic CGE model that includes both the energy and environmental sectors to perform their investigation. The model was modified to depict the Greek economy and its interactions with energy and environmental policy. According to the study's findings, faster decarbonization rates can contribute to positive macroeconomic effects for Greece. Higher rates of decarbonization, according to the authors, can enhance economic development and employment, due to greater investment in renewable energy sources and energy efficiency improvements. The transition to a low-carbon economy has the potential to improve energy security and reduce greenhouse gas emissions, helping to meet climate obligations. Furthermore, the paper investigates the budgetary consequences of faster decarbonization. The authors concluded that, while the early costs of switching to a low-carbon economy may be significant, the long-term benefits may surpass these costs.

In their work, the authors of [16] investigated the role of agricultural cooperatives in Greece. The authors recognized the importance of agricultural cooperatives in the Greek agricultural industry, which is characterized by small-scale farming. They aimed to measure and analyze the economic value created by these cooperatives. To achieve this, the study combined Input–Output analysis using a CGE model to assess the role of various economic sectors. The authors examined the direct, indirect, and induced effects of agricultural cooperatives on the Greek economy by gathering data on agricultural sectors such as output, employment, and input usage and then incorporating them into the CGE model. The findings reveal that agricultural cooperatives make a significant economic contribution in Greece. They provide jobs, increase agricultural output, and encourage economic activity in related industries. The research emphasizes the significance of the cooperative sector in decreasing rural poverty, improving rural development, and supporting sustainable agriculture.

With Greece serving as an example of an electricity exporter, ref. [17] focused on developing a framework for evaluating a clean energy transition. The authors studied the rising relevance of clean energy transitions in addressing environmental problems, as well as the necessity to evaluate their practicality. They presented a multicriteria modeling approach for analyzing such transitions that take into account several dimensions and criteria. This framework aimed to provide a thorough examination of alternative energy transition scenarios. The authors examined the possibilities for clean energy transitions and their ramifications in the context of Greece, a country that depends largely on fossil energy imports for power generation. The approach considered several factors, including environmental consequences, economic feasibility, energy storage technology, and power grid infrastructure. The authors applied their framework to several scenarios and evaluated

each scenario's performance using the established criteria. They shed light on the possible advantages and disadvantages of each transition scenario.

With a specific focus on electrifying the Greek road transport sector, ref. [18] developed an approach for decision-making in energy planning. To evaluate and prioritize alternative electrification solutions, the paper provided a stochastic fuzzy multicriteria CGE technique. The authors aimed to develop a comprehensive methodology that incorporates numerous criteria while accounting for the unpredictable and probabilistic character of elements influencing the electrification process. The proposed technique combines fuzzy logic, which can handle imprecise data, with stochastic modeling and traditional CGE methods. To demonstrate the practicality of the methodology, the authors presented a case for Greece. They evaluated the performance and resilience of various electrification alternatives in the face of uncertainty using counterfactual scenarios and sensitivity analysis.

In this work, a multi-sector CGE model for the Greek economy was developed to capture the effects of trade impediments on energy trade and trade in general with the non-EU countries. The model aims to justify how Greece's production activities adjust if an ad valorem import tariff of 30% and a quota of 67% on energy import and 35% on the rest of the imports from RoW are imposed, and if the results are consistent with the pollution/energy haven effect, which states that strict energy regulations will lead to energy-intensive firms moving to non-abating countries or the factor endowment hypothesis, which states that capital-rich countries will become increasingly energy-intensive in the future. Another issue that this work examines is how the renewable energy industry will react to these trade barriers, i.e., if the reduction in conventional energy will initiate increased investments in renewable energy by the Greek economy through the substitution effect. Moreover, this paper addresses how a subsidy of 35% on renewable energies can offset the reduction in conventional energy resulting from the trade barriers in a separate scenario. Furthermore, this paper addresses the issue of estimating substitution elasticity parameters in the production function. The substitution elasticity parameters are estimated for each sector separately using the nonlinear least squares estimation procedure and then the elasticities of substitution are calculated. CGE model's data are drawn from the 2015 Input-Output table for Greece, where the data for the econometric estimation is available from the world Input-Output database (WIOD) [19], for the period 2000–2015.

3. Model Description for the Greek Economy

3.1. Model Overview

In this study, the trading relationship between Greece and the non-EU RoW countries has been modeled. As a counterfactual scenario, trade restrictions are suggested to observe Greece's industry reaction to reduced imports from the non-EU RoW. The model specifically estimates a 67% reduction in energy imports and a 35% reduction in the remainder of non-EU RoW's imports, along with a 30% ad valorem import tariff. The effects of these trade barriers regarding the change in prices are static and are therefore expected to be immediate. The substitution effects on production will be implemented over the middle-term period as investment incentives take some time to take effect. These measures will determine whether energy-intensive firms relocate to countries with laxer energy regulations or stay in Greece and continue to produce and pollute. If the former holds, then the Heckscher-Ohlin-Samuelson (H-O-S) model's factor endowment theory is true, and when non-EU RoW imports are high, the structure of the Greek economy should shift toward more energy-intensive industries; if the latter is true, then the pollution/energy haven theory emerges, and Greece should ultimately use less energy. Furthermore, through a subsidy of 35% on renewable energy, this study examines how Greece can maintain its production in the face of reduced energy imports from the non-EU RoW.

An overview of the CGE model is presented in Figure 1, comprising the economic flows of goods and services. The sector's i output (Y_i) and imports (M_i) are divided between uses (USS_i) and exports (EX_i). Uses are further split into two categories, intermediate inputs (II_i) and final consumption (FC_i), which are further divided into domestic and imported

final consumption and intermediate inputs. Utility depends on the final consumption of outputs from all sectors. Furthermore, consumers demand imported goods from every sector. In Figure 1, σ is the substitution elasticity in the utility function and φ is the elasticity of transformation.

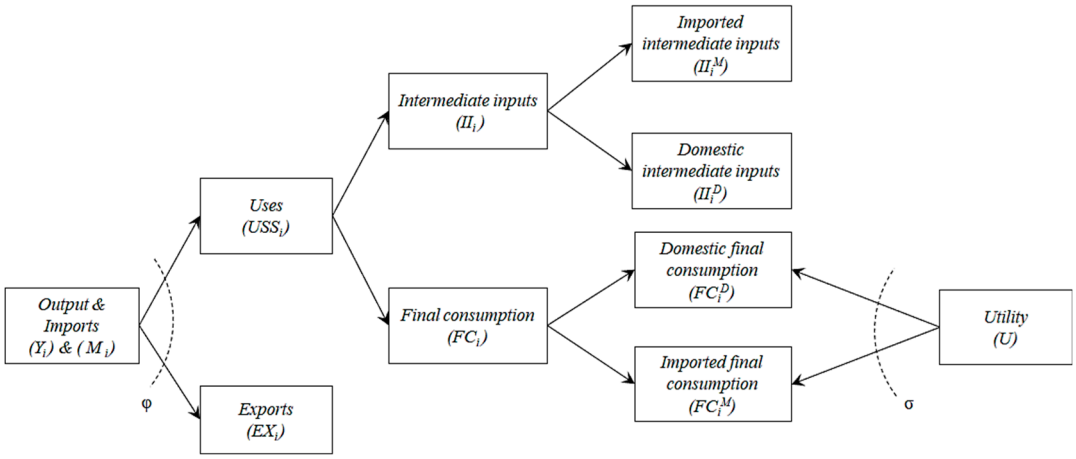


Figure 1. Overview of the Model.

Greece and the non-EU Rest of the World countries are taken into account in the model, along with 36 production sectors divided into four categories: agriculture, energy, manufacturing, and services. The production of the 36 sectors is established on perfect competition and constant returns to scale in each sector. In the economy, all goods are traded. Thus, consumers' utility is derived from the consumption of all goods available in the economy. As a counterfactual scenario, a tariff on consumption and a quota on non-EU RoW imports are introduced in the model to measure the magnitude of the endogenous variables' reaction to reduced imports.

3.2. Description of Data

In this section, an introduction of the I-O table's typical form is presented along with an analysis of Greece's economy-specific aspects, particularly those related to energy imports from non-EU RoW. For the purpose of the analysis, the 2015 I-O table for the Greek economy has been used (The 2015 I-O table has been used since 2015 is the year that the Energy Union Strategy project of the European Commission was launched, with the aim of providing secure, sustainable, competitive, and affordable energy. The EU is committed to building an Energy Union with a forward-looking climate policy on the basis of the commission's framework strategy, with five priority dimensions: (i) Energy security, solidarity, and trust; (ii) A fully integrated European energy market; (iii) Energy efficiency contributing to moderation of demand; (iv) Decarbonizing the economy; and (v) Research, innovation, and competitiveness. This strategy included a minimum of 10% electricity interconnection for all member states by 2020).

The I-O table displays the flows between various economic sectors to produce a static image for a specific year. Each row of the intermediate inputs contains transactions from a sector's output. These transactions are classified as intermediate usage and final consumption.

The I-O table employed in this work was sourced from the statistical office of the Organisation for Economic Cooperation and Development (OECD) [20]. Imported intermediate inputs for non-EU RoW countries were retrieved from [21,22]. Furthermore, the I-O table is aggregated into 36 sectors, with production inputs for all sectors differentiated between domestic and imported from non-EU RoW, resulting in two 36 $\times$ 36 I-O tables. Similarly, the final consumption for each source is also provided in the two tables (final consumption in the typical I-O table is divided into three categories: household and government consumption and investment. In this work, it is assumed that utility is derived

only from the household consumption; thus, investment and government consumption are not included). Figure 2 below depicts this aggregation.

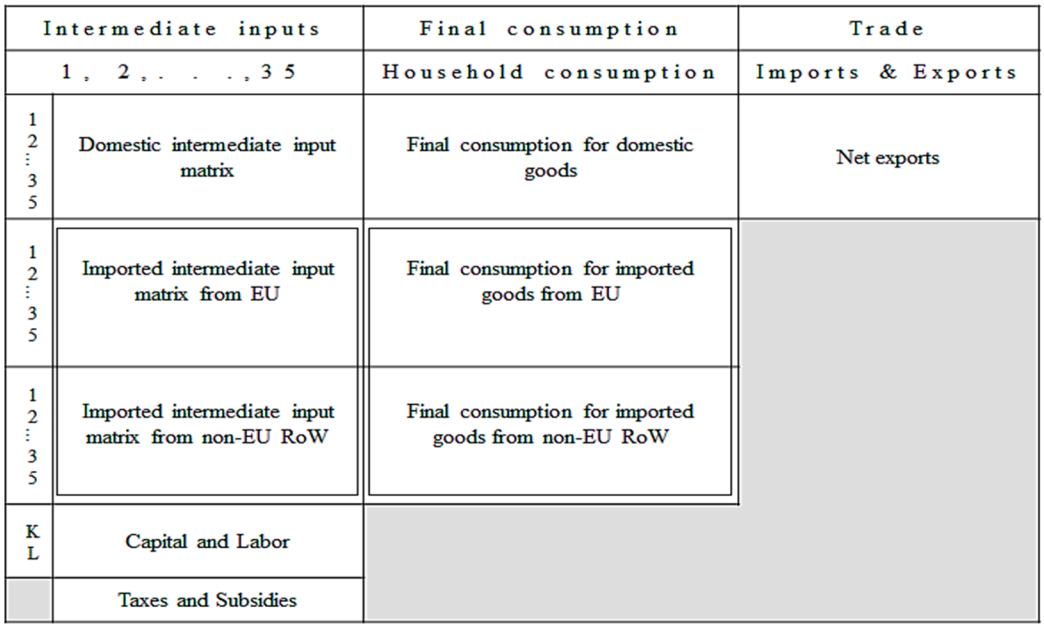


Figure 2. I-O table aggregation.

To analyze Greece's production activities response to a change in non-EU RoW imports, the intermediate inputs are divided into domestic, imported from the EU, and non-EU RoW. To develop this analysis, the bilateral trade database (BTDIxE) from OECD [22] was used. This dataset contains bilateral trade values broken down by industry and end-use. To create the renewable energy inputs in the I-O table, the Statista database [23] was employed to extract the renewable energy percentage from the 'Electricity, gas, water supply, sewerage, waste, and remediation services' energy sector.

3.3. Model Description

3.3.1. Producer's Behavior

For each sector, a single output-producing firm chooses input quantities of non-energy intermediate inputs (II_i), energy inputs (E_i), and primary factors (K_i) and (L_i). Each commodity is produced through a constant elasticity of substitution (CES) production function, with every sector having constant elasticity of substitution on its own but differing from the other; this is due to the substitution parameters being estimated separately for each sector.

The model describes Greece's production output using a two-level nesting structure first proposed by [24] and widely used in nested CES functions and CGE models [25–28]. The nesting structure is depicted in Figure 3. Energy is combined with capital and labor; in this subsection, we assume that the inputs are substitutes with constant elasticity of substitution for each other. Moving up the nest, energy, capital, and labor are aggregated once more with non-energy intermediate inputs from all sources but with different substitution elasticity than before. In each nest, we assume that inputs are substitutes but not perfect substitutes (due to region/country aggregation, imperfect substitutability is assumed).

$$Y_i = A_i \left\{ \delta_i \sum_{j=1}^{36} \sum_{k=1}^{2} \mu_{jk} II_{jk}^{\rho} + (1-\delta_i) \left[\sum_{k=1}^{2} a_k E^{\varepsilon}{}_{1_k} + \sum_{k=1}^{2} \beta_k E^{\varepsilon}{}_{2_k} + \pi_i K_i^{\varepsilon} + \left(1 - \sum_{k=1}^{2} a_k - \sum_{k=1}^{2} \beta_k - \pi_i \right) L_i^{\varepsilon} \right]^{\frac{\rho}{\varepsilon}} \right\}^{\frac{1}{\rho}} \quad (1)$$

where ρ and ε are the substitution parameters, $\frac{1}{1+\rho}$ is the substitution elasticity between the intermediate and the rest of the inputs, $\frac{1}{1+\varepsilon}$ is the substitution elasticity between energy, capital, labor, i signifies sector i; i = 1,. . .,36 and μ_{kj} is the share parameter of the sector j input into sector i (i, j = 1, . . ., 36) from source k (domestic and imported from non-EU RoW).

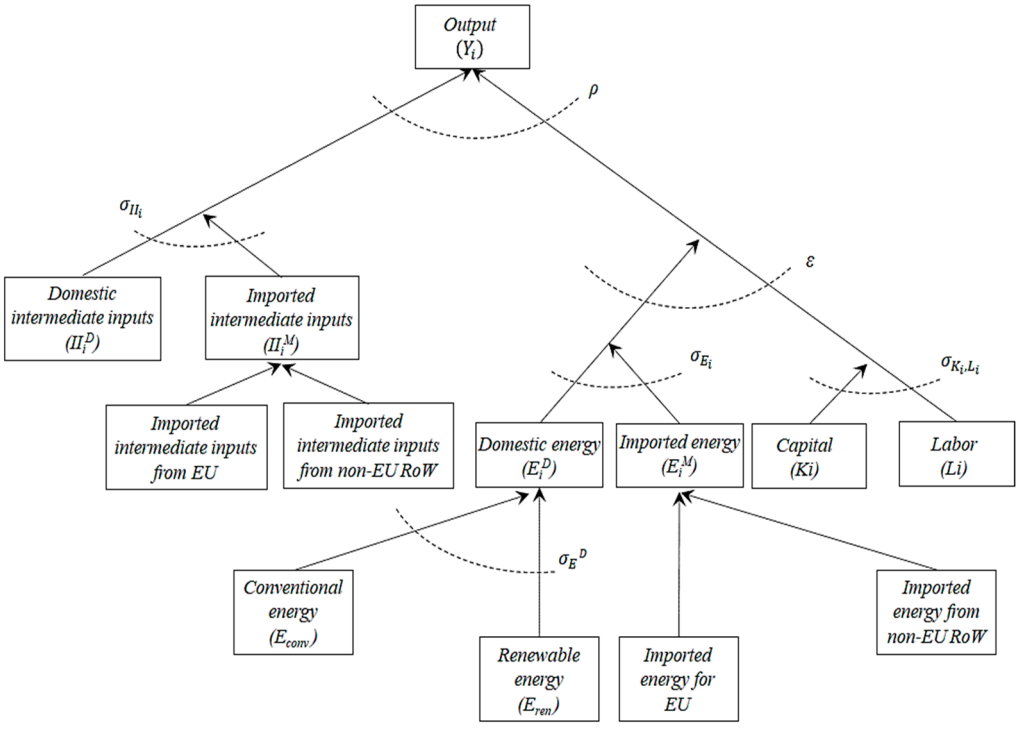


Figure 3. Production Nesting Structure.

In Figure 3, intermediate inputs, energy, capital, and labor are joined to produce the sector's i final output. There are two types of intermediate inputs and energy: domestic energy ($E_i{}^D$), domestic non-energy intermediate inputs ($II_i{}^D$), and imported energy ($E_i{}^M$), imported non-energy intermediate inputs ($II_i{}^M$). Likewise, domestic energy is aggregated into conventional energy (coil, oil, natural gas, etc.) and renewable energy (wind power, solar, geothermal), where ρ, ε are the substitution parameters for non-energy intermediate inputs and energy intermediate inputs with primary factors, respectively, σ_{II_i} is the substitution elasticity between domestic and imported non-energy intermediate inputs, and σ_{E_i} is the substitution elasticity between domestic and imported energy inputs. Further, σ_{K_i,L_i} is the substitution elasticity between the primary factors of production. Finally, the elasticity of substitution between conventional and renewable energy is equal to 1, meaning that if Greece stops producing one unit of conventional energy, it can substitute it with one unit of renewable energy. The following equation provides a better understanding of the substitutability between conventional and renewable energy:

$$E_i^D = \Lambda_i \left(\lambda_i Econv_i{}^{\sigma_E^D} + (1-\lambda_i) Eren_i{}^{\sigma_E^D} \right)^{\frac{1}{\sigma_E^D}} \quad (2)$$

Since the elasticity of substitution in Equation (2) is equal to 1, the equation collapses to:

$$E_i^D = Econv_i + Eren_i \tag{3}$$

3.3.2. Consumer's Behavior

By assumption, the representative household maximizes its utility subject to its budget constraint. A representative household's income comprises its labor and capital endowment, both of which are supplied to firms for production (in the model, unemployment is not considered). A household's utility consists of consumption, in quantity terms, of all goods available in the economy. For its utility, a CES-type function is assumed. The household's behavior can be understood by the following optimization problem:

$$max \quad U = \left(\sum_{i=1}^{36} \gamma_i^{\frac{1}{\sigma}} FC_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{4}$$

$$s.t. \quad \sum_i P_{FC_i} FC_i = \sum_v P_{FE_v} FE_v \tag{5}$$

The first equation is the objective function of utility to be maximized, household preferences are described by a CES utility function of final consumption, with FC_i representing the final consumption of good i, γ_i being its share parameter, and σ being the elasticity of substitution. A household's utility is a CES consumption composite of agriculture, energy, and non-energy manufacturing goods and services from each source. The next equation is the income constraint, which states that total expenditure on the left-hand side must equal total income on the right-hand side, where P_{FE_v} is the price of factor v, FE_v is the factor endowment of factor v, and P_{FC_i} is the price of the consumed product i.

To solve this optimization, the Lagrange method was used:

$$L = \left(\sum_{i=1}^{36} \gamma_i^{\frac{1}{\sigma}} FC_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} - \lambda \left(\sum_i P_{FC_i} FC_i - \sum_v P_{FE_v} FE_v \right) \tag{6}$$

By taking the first-order conditions of (4) and after some calculations, we obtain the demand function for each commodity i as shown below:

$$FC_i = \frac{\sum_v P_{FE_v} FE_v}{P_j - P_j^{\sigma} \sum_{i=1}^{36} \left(P_i^{1-\sigma} - 1 \right) \gamma_i} \tag{7}$$

The derived demand function of good i is affected not only by its own price (P_i) but also by the price of another good (P_j) and income ($P_v FF_v$). Furthermore, for the purpose of the analysis, the substitution elasticity is assumed to be equal to 0.3, a value proposed by [29–32].

3.3.3. Transformation

In the final phase, with constant elasticity of transformation (CET), production technology firms transform their output into uses and exports:

$$Y_i = \Theta_i (\vartheta_i USS_i^{\ \varphi} + (1 - \vartheta_i) EX_i^{\ \varphi})^{\frac{1}{\varphi}} \tag{8}$$

where φ is the substitution transformation parameter and $\frac{1}{1+\varphi}$ is the elasticity of transformation among domestic and exported commodities. However, exports are thought to be perfectly transformable with uses, which means that if Greece stops producing one unit of

exports, it can still supply one unit of domestic use, implying that substitution elasticity is equal to one. Thus, Equation (8) implodes to

$$Y_i = USS_i + EX_i \tag{9}$$

3.3.4. Calibration

The model is specified using the I-O table. We need to specify parameters such as γ_i in the utility function or A_i and δ in the production function, ϑ in the transformation function, and so on in order to specify the model and run simulations. Nomenclature (Construction by authors) displays these parameters and can be found at the end of the text. The model created for this work contains many parameters that need to be specified. Therefore, it is difficult to estimate the model parameters econometrically as a system of simultaneous equations, since the number of unknown parameters is greater than the number of equations. As a result, simple functional forms with a few parameters are preferred, making the number of unknown parameters equal to the number of equations in the model, and inversely solving the unknown parameters at the benchmark equilibrium.

The reference quantity from the I-O table determines the parameters of the functions. Because benchmark data from the I-O table are given as price multiplied by quantity, separability is required. Values can thus be interpreted as quantity figures by setting all prices to one.

3.3.5. General Equilibrium

A general equilibrium model considers the competitive behavior of each economic agent. Consumers derive their income from the factor market by accumulating factor rewards from the factors they own, and they maximize their utility by purchasing final goods. Producers, in contrast, use production inputs and sell their final goods on the market. Raw materials for production are supplied by consumers or other manufacturers.

Equilibrium is not always guaranteed in all markets solely by conditions derived from demand and supply behavior, in which agents assume that prices are given and that their demand and supply are satisfied regardless of how they behave at given prices. Thus, market-clearing conditions are required for all markets to achieve a general equilibrium.

To ensure the general equilibrium, two market clearing conditions (10) and (11), along with a zero-profit condition, are assumed:

$$Y_i = \sum_{i=1}^{36} \sum_{k=1}^{2} II_{i,k} + \sum_{i=1}^{36} \sum_{k=1}^{2} FC_{i,k} \tag{10}$$

$$\sum_{i} F_{v,i} = FE_v \tag{11}$$

The first is the market clearing condition for goods which ensures that all demanded products are equal to all supplied products. Following that is the market clearing condition for factors, where the sum of the supplied factors $(F_{v,i})$ equals the market factor demand. In other words, the market clearing conditions require that the aggregate supply of each good and factor must be equal to the total intermediate and final demand in equilibrium.

$$\Pi_i = P_{Y_i} Y_i - \left(P_{L_i} L_i + P_{K_i} K_i\right),\ \Pi_i = 0 \tag{12}$$

$$P_{Y_i} Y_i = P_{L_i} L_i + P_{K_i} K_i \tag{13}$$

The zero-profit condition (12) ensures that the cost of production equals the value of output; this condition complements associated activity levels. The zero-profit condition requires that no producer earns an excess profit in equilibrium. The total value of outputs per unit activity must not exceed the total value of inputs. Under these conditions, the model is solved as a nonlinear problem.

4. Substitution Parameters Estimation

In this section, the estimation procedure, and data regarding the elasticities of substitution in the production function are examined. In the model, a nested CES production function is used with four inputs, namely, non-energy intermediate inputs (*II*), energy (*E*), capital (*K*), and labor (*L*). In the analysis, the nesting structure used is of the form (II;(E; K; (L))). This structure, proposed by [26] and van der Werf [33], consists of one of the most prevalent nested CES structures used in CGE models, while it is better suited for assessing environmental and climate policies along with economic policy.

The standard estimation procedures cannot ensure reliable results, since the CES production function in the model has non-linear characteristics. The literature suggests three methods for estimating nested CES production functions: the direct approach, which relies on non-linear estimation; the indirect approach, which relies on the cost minimization (or profit maximization) problem; and finally, the Kmenta approximation [34] to linearization. In this study, the direct approach is proposed, and the non-linear least squares estimation approach is used for the estimation. Where the substitution parameters are directly estimated for the CES production function. For the non-linear estimation, the interval 0.1–0.5 of initial values has been assumed for the iterative algorithm. For each sector, Equation (1) has the following functional form:

$$Y_i = A_i\left\{\delta II_i^{\rho} + (1-\delta)[a_i E_i^{\varepsilon} + \pi_i K_i^{\varepsilon} + (1-\alpha_i-\pi_i)L_i^{\varepsilon}]^{\frac{\rho}{\varepsilon}}\right\}^{\frac{1}{\rho}} \quad (14)$$

To provide us with the required elasticity parameters, Equation (14) was estimated for each sector separately, i.e., 36 regressions, each one indicating a specific sector in the economy. The parameters ρ and ε have been estimated and then the substitution elasticities for each sector are calculated.

The data for the estimation analysis were drawn from the World Input-Output Database (WIOD) [19] for the period 2000–2015. The WIOD data are divided into 36 sectors (the sector classifications used by the WIOD and the OECD are same because both organizations use the International Standard Industrial Classification (ISIC)) and includes information on the manufacturing, energy, and services industries. The database contains time-series data for gross output at basic prices (*Y*), non-energy intermediate inputs at purchasers' price (*II*), gross energy use in Terajoules (*E*) converted into millions of dollars, nominal capital stock (*K*), and the number of employees (*L*).

All variables are converted to millions of US dollars and presented at 2015 prices, except for labor, which is given as thousands of people. The variables used in the estimation are summarized in Table 1 below.

Table 1. Description of variables and source.

Variables	Description	Source
Output	Gross output at basic prices	WIOD SEA files
Intermediate inputs	Intermediate inputs at purchaser's price	WIOD SEA files
Energy	Gross energy use	Author's calculations and WIOD SEA files
Capital	Nominal capital stock	WIOD SEA files
Labor	Number of employees	WIOD SEA files

Source: Construction by authors.

5. Estimation and Model Results

5.1. Non-Linear Least Squares Estimation Results

The estimates of the substitution elasticity parameters are presented in this section. Table 2 shows the estimated substitution parameters for the (II;(E; K; (L))) nesting structure of the CES function, as well as the elasticities of substitution. The substitutability of a sector determines how easy or difficult it is for it to adjust its output in response to parameter

changes. By estimating the elasticity parameters ρ and ε, the elasticities of substitution are easy to calculate.

Table 2. Substitution elasticity parameters by sector.

Sector	*p*	*ε*	Elasticity of Substitution for *ρ*	Elasticity of Substitution for *ε*
Agriculture				
Agriculture, forestry, and fishing	0.293 *	0.180 *	0.774	0.848
Mining and quarrying of non-energy-producing products	0.015 *	0.056 *	0.985	0.947
Energy				
Mining and extraction of energy-producing products	0.013 *	0.180 *	0.987	0.847
Coke and refined petroleum products	0.186 *	0.187 *	0.843	0.843
Electricity, gas, water supply, sewerage, waste, and remediation services	0.128 *	0.031 *	0.887	0.970
Wind power, solar, geothermal	0.096 *	0.012 *	0.912	0.988
Manufacturing				
Food products, beverages, and tobacco	0.005 *	0.001 *	0.995	0.999
Textiles, wearing apparel, leather, and related products	0.049 *	0.157 *	0.953	0.864
Wood and products of wood and cork	0.067 *	0.187 *	0.937	0.843
Paper products and printing chemicals and pharmaceutical products	0.024 *	0.001 *	0.977	0.999
Chemicals and pharmaceutical products	0.043 *	0.207 *	0.959	0.829
Rubber and plastic products	0.052 *	0.167 *	0.951	0.857
Other non-metallic mineral products	0.037 *	0.170 *	0.965	0.855
Basic metals	0.029 *	0.094 *	0.972	0.914
Fabricated metal products	0.023 *	0.097 *	0.978	0.912
Computer, electronic, and optical products	0.098 *	0.160 *	0.911	0.862
Electrical equipment	0.081 *	0.029 *	0.925	0.972
Machinery and equipment, NEC	0.258 *	0.047 *	0.795	0.955
Motor vehicles, trailers, and semi-trailers	0.003 *	0.023 *	0.997	0.978
Other transport equipment	0.242 *	0.074 *	0.805	0.931
Other manufacturing; repair and installation of machinery and equipment	0.281 *	0.012 *	0.781	0.988
Construction	0.016 *	0.001 *	0.984	0.999
Publishing, audiovisual, and broadcasting activities	0.006 *	0.097 *	0.994	0.912
Services				
Mining support service activities	0.068 *	0.049 *	0.936	0.953
Wholesale and retail trade; repair of motor vehicles	0.148 *	0.191 *	0.871	0.840
Transportation and storage	0.003 *	0.093 *	0.997	0.915
Accommodation and food services	0.624 *	0.279 *	0.616	0.782
Telecommunications	0.016 *	0.049 *	0.984	0.953
IT and other information services	0.186 *	0.261 *	0.843	0.793
Financial and insurance activities	0.099 *	0.166 *	0.910	0.857
Real estate activities	0.284 *	0.844 *	0.779	0.542
Other business sector services	0.162 *	0.170 *	0.861	0.855
Public admin. and defense; compulsory social security	0.223 *	0.207 *	0.818	0.829
Education	0.057 *	0.084 *	0.947	0.922
Human health and social work	0.117 *	0.198 *	0.895	0.835
Arts, entertainment, recreation, and other service activities	0.044 *	0.002 *	0.957	0.998

Source: Estimated by authors/Note: The asterisk denotes statistical significance at least at the 5% level.

In the analysis, two substitution parameters were estimated: one for the (II;(E; K; (L))) nest, denoted by (*ρ*), and one for the (E; K; (L)) nest, denoted by (*ε*). All the substitution parameters are less than one-half (except for the 'Accommodation and food services' and 'Real Estate activities' sectors, which have a value of 0.624 and 0.844, respectively), indicating that substitution elasticity values are high.

To substitute one unit of *K* or *E* while keeping the contribution to production constant, a large amount of L is required, if the elasticity of substitution is rather small. Furthermore,

the likelihood of goods being economic complements increases with higher substitution elasticity values. This means that when substitution elasticities are close to unity, it is either easier to substitute energy, capital, or labor with intermediate inputs and vice versa in the (II;(E; K; (L))) nest or to substitute energy and capital with labor and vice versa in the (E; K; (L)) nest, depending on which part of the nest this occurs in.

5.2. Results of the CGE Model

The purpose of the analysis is to estimate and isolate the impact of reduced non-EU RoW imports on the Greek economy by means of counterfactual scenarios. By imposing a quota of 67% on non-EU RoW energy imports and 35% on the other non-EU RoW imports, as well as a 30% ad valorem import tariff, we assess Greece's reliance on non-EU RoW imports, particularly energy imports. Since trade restrictions have been enforced and the Greek economy is suffering from reduced energy imports, the prospect of a counter-measure attempt to increase investment in renewable energy through the substitution effect between conventional and renewable energy and a subsidy of 35%, as a separate scenario, have been investigated. Tables 3–5 present the results for the quota, tariff, subsidy, and substitution scenarios.

Table 3. Greece's Output Changes.

Sector	Benchmark	Substitution Effect with Quota	Effect of Quota/Subsidy	Percentage Change of Quota/Subsidy
Agriculture				
Agriculture, forestry, and fishing	46,394.80	40,861.76	41,446.33	(−10.666)
Mining and quarrying of non-energy-producing products	3539.40	3209.103	3250.939	(−8.150)
Energy				
Mining and extraction of energy-producing products	3264.57	3016.463	3070.034	(−5.959)
Coke and refined petroleum products	49,806.70	41,464.58	40,880.84	(−17.921)
Electricity, gas, water supply, sewerage, waste, and remediation services	125,443.5	86,029.15	90,008.189	(−28.248)
Wind power, solar, geothermal	772.400	818.682	823.081	(6.561)
Manufacturing				
Food products, beverages, and tobacco	137,713.40	11,5819.7	117,957	(−14.346)
Textiles, wearing apparel, leather, and related products	15,604.70	11,928.08	12,268.73	(−21.378)
Wood and products of wood and cork	20,143.70	16,160.89	16,539.79	(−17.891)
Paper products and printing chemicals and pharmaceutical products	40,876.30	29,800.87	30,819.91	(−24.602)
Chemicals and pharmaceutical products	118,207.60	91,224.35	93,921.85	(−20.545)
Rubber and plastic products	52,755.90	38,447.44	39,760.01	(−24.634)
Other non-metallic mineral products	29,829.10	22,844.32	23,520.54	(−21.149)
Basic metals	83,121.90	71,257.91	72,674.31	(−12.569)
Fabricated metal products	77,734.10	54,740.35	56,829.85	(−26.892)
Computer, electronic, and optical products	46,516.60	36,887.66	37,788.69	(−18.763)
Electrical equipment	63,755.70	49,486.54	50,812.02	(−20.302)
Machinery and equipment, NEC	158,896.50	121,336.5	124,843.4	(−21.431)
Motor vehicles, trailers, and semi-trailers	248,510.80	176,703.6	183,234.5	(−26.267)
Other transport equipment	30,852.70	24,498.59	251,00.52	(−18.644)
Other manufacturing; repair and installation of machinery and equipment	55,118.80	38,811.9	40,296.25	(−26.892)
Construction	152,475.80	102,384.4	106,893.2	(−29.895)
Publishing, audiovisual, and broadcasting activities	40,278.00	27,146.97	28,328.725	(−29.667)

Table 3. *Cont.*

Sector	Benchmark	Substitution Effect with Quota	Effect of Quota/Subsidy	Percentage Change of Quota/Subsidy
Services				
Mining support service activities	60,524.13	56,953.21	60,450.9	(−0.121)
Wholesale and retail trade; repair of motor vehicles	219,266.20	142,053.8	148,954.1	(−32.067)
Transportation and storage	232,156.87	154,646.4	161,650.8	(−30.370)
Accommodation and food services	47,733.60	31,849.76	33,277.48	(−30.285)
Telecommunications	47,441.29	31,695.05	33,108.8	(−30.211)
IT and other information services	60,111.27	39,867.1	41,684.76	(−30.654)
Financial and insurance activities	178,716.70	117,046.9	122,571.1	(−31.416)
Real estate activities	134,570.58	87,264.98	91,494.54	(−32.010)
Other business sector services	252,403.69	165,367.3	173,166.6	(−31.393)
Public admin. and defense; compulsory social security	105,912.12	69,287.71	72,568.87	(−31.482)
Education	49,348.76	32,157.62	33,697.3	(−31.716)
Human health and social work	102,087.54	67,090.91	70,230.1	(−31.206)
Arts, entertainment, recreation, and other service activities	57,517.25	37,872.81	39,633.987	(−31.092)

Source: Estimated by authors.

Table 4. Changes in Greece's domestic uses.

Sector	Benchmark	Substitution Effect with Quota	Effect of Quota/Subsidy	Percentage Change of Quota/Subsidy
Agriculture				
Agriculture, forestry, and fishing	44,295.18	38,766.7	39,350.07	(−11.164)
Mining and quarrying of non-energy-producing products	3299.13	2969.415	3011.116	(−8.730)
Energy				
Mining and extraction of energy-producing products	3261.07	3012.97	3066.549	(−5.965)
Coke and refined petroleum products	43,545.33	35,258.22	36,869.83	(−15.330)
Electricity, gas, water supply, sewerage, waste, and remediation services	125,364.29	85,969.82	89,914.86	(−28.277)
Wind power, solar, geothermal	831.002	891.091	896.54	(7.886)
Manufacturing				
Food products, beverages, and tobacco	135,042.17	113,166.7	115,300.4	(−14.619)
Textiles, wearing apparel, leather, and related products	14,955.69	11,288.85	11,627.43	(−22.249)
Wood and products of wood and cork	20,090.38	16,108.07	16,486.97	(−17.936)
Paper products and printing chemicals and pharmaceutical products	40,703.60	29,631.09	30,649.06	(−24.700)
Chemicals and pharmaceutical products	116,433.33	89,476.69	92,168.62	(−20.840)
Rubber and plastic products	52,170.72	37,873.66	39,184.16	(−24.891)
Other non-metallic mineral products	29,344.46	22,367.53	23,042.16	(−21.477)
Basic metals	80,774.32	68,923.92	70,337.47	(−12.921)
Fabricated metal products	77,122.16	54,144.39	56,230.54	(−27.089)
Computer, electronic, and optical products	46,263.88	36,636.96	37,537.24	(−18.861)
Electrical equipment	63,364.36	49,100.41	50,425.36	(−20.420)
Machinery and equipment, NEC	158,251.71	120,701	124,206.2	(−21.513)
Motor vehicles, trailers, and semi-trailers	248,463.67	176,657	183,186.6	(−26.272)
Other transport equipment	30,660.68	24,307.92	24,909.46	(−18.755)

Table 4. *Cont.*

Sector	Benchmark	Substitution Effect with Quota	Effect of Quota/Subsidy	Percentage Change of Quota/Subsidy
Other manufacturing; repair and installation of machinery and equipment	54,719.65	38,422.35	39,904.67	(−27.073)
Construction	152,482.37	102,385.8	106,896.2	(−29.796)
Publishing, audiovisual, and broadcasting activities	40,183.30	27,055.01	28,236.4	(−29.731)
Services				
Mining support service activities	60,515.36	56,641.77	60,442.14	(−0.119)
Wholesale and retail trade; repair of motor vehicles	215,056.16	137,965	144,838.2	(−32.651)
Transportation and storage	220,233.50	143,184.2	150,070.8	(−31.858)
Accommodation and food services	47,720.08	31,836.93	33,264.24	(−30.293)
Telecommunications	47,133.41	31,397.45	32,809.57	(−30.390)
IT and other information services	59,729.22	39,497.74	41,313.51	(−30.832)
Financial and insurance activities	177,983.27	116,335.2	121,854.5	(−31.536)
Real estate activities	134,551.95	87,245.53	91,475.81	(−32.714)
Other business sector services	251,435.55	164,435.7	172,227.6	(−31.502)
Public admin. and defense; compulsory social security	105,894.05	69,270.6	72,551.19	(−31.487)
Education	49,289.77	32,099.8	33,639.09	(−31.751)
Human health and social work	102,086.14	67,089.99	70,229.14	(−31.206)
Arts, entertainment, recreation, and other service activities	57,485.85	37,841.7	39,602.464	(−31.108)

Source: Estimated by authors.

Table 5. Household consumption and price changes.

Sector	Benchmark	Price Percentage Change	Quantity Percentage Change	Effect of Tariff and Subsidy on Renewable Energy	Substitution Effect with Tariff
Agriculture					
Agriculture, forestry, and fishing	3801.9	(0.618)	(−30.002)	2661.253	2647.338
Mining and quarrying of non-energy-producing products	7.8	(1.035)	(−15.132)	6.619	6.605
Energy					
Mining and extraction of energy-producing products	4.7	(0.298)	(−12.485)	4.113	4.106
Coke and refined petroleum products	2746.1	(0.375)	(−22.208)	2136.246	2128.806
Electricity, gas, water supply, sewerage, waste, and remediation services	3001.4	(1.626)	(−34.552)	1964.356	1520.384
Wind power, solar, geothermal	663.301	(−0.239)	(7.411)	712.462	709.1673
Manufacturing					
Food products, beverages, and tobacco	10,569.9	(1.054)	(−31.640)	7225.584	7184.783
Textiles, wearing apparel, leather, and related products	643.0	(1.308)	(−11.113)	571.543	570.671
Wood and products of wood and cork	16.6	(0.836)	(−17.732)	13.656	13.620
Paper products and printing chemicals and pharmaceutical products	311.3	(1.078)	(−16.014)	261.448	260.840
Chemicals and pharmaceutical products	565.1	(1.752)	(−17.306)	467.306	466.113
Rubber and plastic products	105.4	(0.353)	(−19.589)	84.753	84.501
Other non-metallic mineral products	172.6	(0.801)	(−10.872)	153.835	153.605
Basic metals	96.4	(0.57)	(−15.156)	81.790	81.611

Table 5. *Cont.*

Sector	Benchmark	Price Percentage Change	Quantity Percentage Change	Effect of Tariff and Subsidy on Renewable Energy	Substitution Effect with Tariff
Fabricated metal products	372.5	(0.580)	(−14.439)	318.715	318.059
Computer, electronic, and optical products	140.8	(1.530)	(−13.722)	121.479	121.243
Electrical equipment	281.9	(0.848)	(−13.006)	245.237	244.790
Machinery and equipment, NEC	46.1	(1.580)	(−12.289)	40.435	40.365
Motor vehicles, trailers, and semi-trailers	126.2	(1.918)	(−11.572)	111.596	111.417
Other transport equipment	106.1	(0.344)	(−10.856)	94.582	94.441
Other manufacturing; repair and installation of machinery and equipment	411.7	(1.308)	(−10.139)	369.958	369.448
Construction	166.1	(2.164)	(−37.422)	103.942	103.183
Publishing, audiovisual, and broadcasting activities	443.8	(1.153)	(−36.706)	280.901	278.913
Services					
Mining support service activities	102.5	(0.161)	(−7.989)	94.311	94.211
Wholesale and retail trade; repair of motor vehicles	13,712.8	(1.787)	(−29.272)	9698.759	9649.787
Transportation and storage	5260.7	(2.063)	(−6.556)	4915.832	4911.624
Accommodation and food services	14,471.7	(1.681)	(−5.839)	13,626.714	13,616.4
Telecommunications	3951.5	(0.471)	(−5.122)	3749.095	3746.626
IT and other information services	5.9	(1.271)	(−4.406)	5.640	5.636
Financial and insurance activities	2399.7	(1.896)	(−3.689)	2311.178	2310.098
Real estate activities	22,012.7	(2.582)	(−28.972)	15,635.132	15,557.33
Other business sector services	1967.9	(2.100)	(−7.256)	1825.118	1823.376
Public admin. and defense; compulsory social security	518.3	(2.525)	(−9.539)	468.860	468.256
Education	1453.7	(1.930)	(−11.822)	1281.840	1279.744
Human health and social work	9626.7	(2.057)	(−5.106)	9135.203	9129.207
Arts, entertainment, recreation, and other service activities	4095.6	(1.925)	(−13.611)	3538.143	3531.342

Source: Estimated by authors.

Imports respond to parameter changes since they are endogenous in the model. Imposing a quota of 67% on energy imports and 35% on all other imports reduces output and uses in the Greek economy. Each sector's output and domestic uses are reduced proportionally. With the imposition of quotas, the energy sectors as well as the manufacturing and services sectors are harmed the most. Greece's own energy production is primarily based on solar power (7.55%) and the combustion of fossil fuels (71.01%). However, Greece's energy imports exceed its exports, making the country energy dependent. Imposing a quota on its energy supply drastically reduces energy usage, forcing it to rely on its own energy production. As a result, output and consequently domestic uses in energy sectors are significantly decreased. Services and manufacturing also play a major role in Greece's comparative advantage, with reductions in output and consumption exceeding 20% and 30% in each sector, respectively. Reduced imports from non-EU RoW, on the other hand, have a much smaller impact in labor-intensive sectors, such as agriculture, than in capital and/or capital-intensive sectors.

The introduction of quotas resulted in a decline in all sectors, according to the calibration specification. Reduced non-EU RoW imports have an impact on both consumption (through tariffs) and output (via quotas), as imported energy, is a driving force in the Greek economy. On the other hand, the subsidy on renewable energy and the substitution effect on the 'Wind power, solar, and geothermal' sector have the opposite effect. More specifically, if the conventional energy is reduced, the Greek economy could react with increased investment in renewable energy and maintain its energy demand in the short term. We derive the following results by fitting the results of Table 2 into the CGE model:

The results of the imposition of quotas on non-EU RoW imports regarding output and domestic uses are presented in Tables 3 and 4. Greece's overall energy use decreases along with the continued decrease in imports from non-EU RoW. As far as the output level is considered, the most significant reduction in energy sectors (−28.248%) is found in the 'Electricity, gas, water supply, sewerage, waste, and remediation services' sector. In this sector, the decline was the most significant since electricity and gas in particular are the dominant power sources of Greece's production activities which are mostly supplied from non-EU RoW imports. Thus, this reduction could push Greece to use its renewable energy sources to compensate for the reduced conventional energy. The investment in renewable energy in the face of reduced energy imports can be seen in the 'Wind power, solar, and geothermal' energy sector. This sector is the only one that displays an increase (6.561%) in comparison to the rest of the energy sectors since the subsidy scenario has been implemented. This occurs because firms can more easily buy and sell it and, thus, its demand increases. The manufacturing sector has witnessed the biggest drop (−29.895%) in the 'Construction' sector. This is due to a large growth in the Greek construction index in recent years, which is predicted to expand by 4.8% to EUR 14,020,000,000 by the end of 2023. This rise is due to the increased demand for housing from both locals and visitors. The construction of dwellings necessitates the use of high-energy machinery; thus, the imposition of energy and raw-material restrictions has a negative impact on this industry. The services sectors comprise Greece's source of comparative advantage supplied by both domestic inputs and imported from non-EU RoW. The most significant reduction in the services sector is seen in 'Wholesale and retail trade; repair of motor vehicles' (−32.067%) and 'Real estate activities' (−32.010%). These sectors have experienced significant declines because they rely the most on the non-EU RoW. On the one hand, 'Wholesale and retail trade; repair of motor vehicles' and 'Real estate activities' are highly energy-intensive sectors; on the other hand, the 'Real estate activities' sector in Greece has experienced a surge in recent years, largely due to tourism arrivals; thus, the restriction on non-EU RoW imports has the greatest impact on it. Regarding the agricultural sectors, the most significant reduction can be observed in the 'Agriculture, forestry, and fishing' sector (−10.666%). This sector is the most energy-demanding since the current agricultural, forestry, and fishing production is based on machinery usage. Thus, the reduction of energy imports from non-EU RoW puts this sector in a position to rely on the country's own energy production. However, the reduction in this sector is less significant compared to the others due to the lack of Greece's specialization in agricultural production.

In a similar manner, domestic uses decrease as a result of the decreased output since the quantity available in the economy for both exports and domestic uses is reduced. In terms of Greece's uses, the most substantial decline (−28.277%) in the energy sectors may be found in the 'Electricity, gas, water supply, sewerage, waste, and remediation services' sector, which involves domestic power consumption. Since imports from the non-EU RoW are reduced, this sector cannot compensate for the high energy demand in Greece. However, the renewable energy sector exhibits an increase (7.886%) because the domestic consumption of renewable energy is cheaper in comparison to the imported energy. The most significant drop (−29.796%) in the manufacturing sector can likewise be found in the 'Construction' sector. Because the Greek economy has to reduce its construction activities due to reduced non-EU RoW imports, this reduction affects the construction of households which is displayed in the negative sign of the coefficient. In the services sector, a considerable decrease (−32.714%) is noted in the 'Real estate activities' sector, as previously. The real estate sector plays a crucial role in providing housing for the domestic and international population. Changes in this sector due to the quotas can impact affordability and living standards. Ultimately, the agricultural sector displayed the smallest reduction (−11.164%) compared to the other sectors. Since the quotas have been imposed, the domestic use in this sector has decreased resulting from the reduced energy supply in the domestic market.

Tables 3 and 4 show that the results of the substitution effect are slightly different from those of the subsidy scenario. In particular, the results of the subsidy scenario in column 3 of each table are closer to the benchmark results, indicating that this scenario is more favorable to the Greek economy in terms of output and domestic uses. Looking at the renewable energy results in the 'Wind power, Solar, and Geothermal' sector in both tables, we can observe that the Greek economy's initiative to subsidize the renewable energy industry proved to be more effective than the substitution effect, as indicated in Equation (3). Subsidies directly target the renewable energy sector, reducing production costs while increasing output and domestic uses. This diverges from the substitution effect, which focuses on changing consumption patterns and limited production capacity. Subsidies directly stimulate the market's supply side, promoting economic growth and development in the renewable energy sector.

The results of a 30% ad valorem import tariff on non-EU RoW imports are shown in Table 5. Imports tariffs raise the price of the consumed goods in the economy. According to Table 5, all sectors' prices have risen, resulting in a fall in consumption due to the law of demand. In particular, the most significant price increase in the energy sector is evident in the 'Electricity, gas, water supply, sewerage, waste, and remediation services' sector, which comprises the most dominant power source for households' energy consumption in Greece. The price of electricity and gas is raised by (1.626%), resulting in a decrease in the quantity available (−34.552%). Regarding the renewable energy, its price has decreased (−0.239) since its demand has increased (7.411%). This increase in demand sets off a chain reaction in which demand continues to rise since households can afford it for less money, which drives up demand even more, and so on. This shows that a small increase in the price of electricity causes a rather large effect on the consumed quantity from households. This in turn indicates that households are not willing to pay for conventional energy but, on the other hand, are willing to pay for renewable energy that is domestically produced, and its price is cheaper, due to the subsidies, in terms of the conventional energy. The most substantial price increase in the manufacturing sector is evident in the 'Construction' sector (2.164%), which corresponds to a major fall in its quantity (−37.422%). Import tariffs on construction inputs can increase production costs for domestic manufacturers. This leads to higher prices for consumer goods that are domestically produced, affecting household spending. This is because households are unable to invest in new dwellings due to the higher prices of imported raw materials and rent rates, hence the lower quantity. After that, the most significant price increase (2.582%) is reported in the 'Real estate activities' sector, which also has the most substantial fall in quantity (−28.972%). Import tariffs in this sector increase the cost associated with property management services affecting service prices for households. This price increase leads to limited availability of imported real estate services; thus, the quantity of imported services is reduced. Finally, in the agricultural sector, the most significant increase is noted in 'Agriculture, forestry, and fishing', whose price increased by (0.618%) and whose quantity decreased by (−30.002). This vividly shows the dependence of households on certain imported agricultural products and their unwillingness to pay the new higher price. As a result, the sector's quantity falls, which limits consumer's choices and leads to a decrease in consumption.

These trade impediments allow the energy haven hypothesis to be included in the Heckscher-Ohlin-Samuelson (H-O-S) theory by showing preferences for lower energy consumption and causing energy use to diverge from the original H-O-S prediction, which predicted that energy consumption would increase in the face of trade liberalization. Greece traditionally holds a comparative advantage in service activities, especially those related to tourism, and continues to increase energy use as imports from non-EU RoW increase to maintain it. Nevertheless, the trade barriers cause Greece to consume less energy for both household and industrial activities since the substitution between energy-intensive firms and energy use across sectors is no longer present. Given that energy consumption decreases, so does the output of Greece's production activities. As a result, because the economy must rely on its own power generation and distribution capacities, manufacturing

costs will rise. Consequently, earnings will fall, generating a snowball effect. This situation allows the energy-haven hypothesis to arise because firms may opt to reallocate to nations with laxer energy regulations and continue to produce in the same way as before. In the case that the Greek economy increases investment in renewable energies, through subsidies, the country can sustain its energy demand for a short period of time. Given the renewable energy opportunities in Greece, this scenario gives the country a comparative advantage in contrast to other countries.

By comparing the results in Table 5 for the 'Effect of tariff and subsidy on renewable energy' with those of 'Substitution effect with tariff', we can see that the subsidy scenario is slightly better for the Greek economy. More specifically, a subsidy of 35% in the renewable energy sector 'Wind power, solar, and geothermal' is closer to the benchmark than the substitution effect shown in Equation (3). Subsidies in renewable energy reduce the cost of adopting renewable energy sources, making them economically more attractive. This makes it easier for households to switch to cleaner energy without significant financial burden. Households, on the other hand, have limited capacity for large-scale measures, making the substitution effect less impactful on their overall energy options.

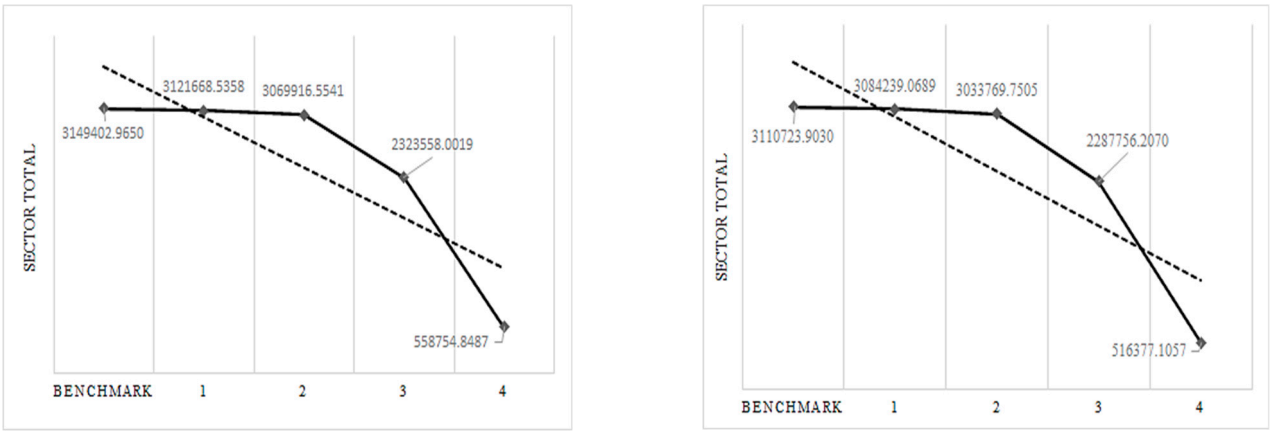
5.3. Sensitivity Analysis

Sensitivity analysis is used to examine how separate parameter values affect the model's output under a certain set of assumptions. The sensitivity analysis is important in determining which parameters affect the model and how much they change it. Moreover, it simplifies the model results and provides a thorough view of the scenario under consideration.

Sensitivity analysis is employed in this study to assess the impact of lower non-EU RoW imports on the Greek economy. We can observe how the trade barriers affect Greece's output, uses, pricing, and household consumption by adjusting the values of the factors relating to non-EU RoW imports.

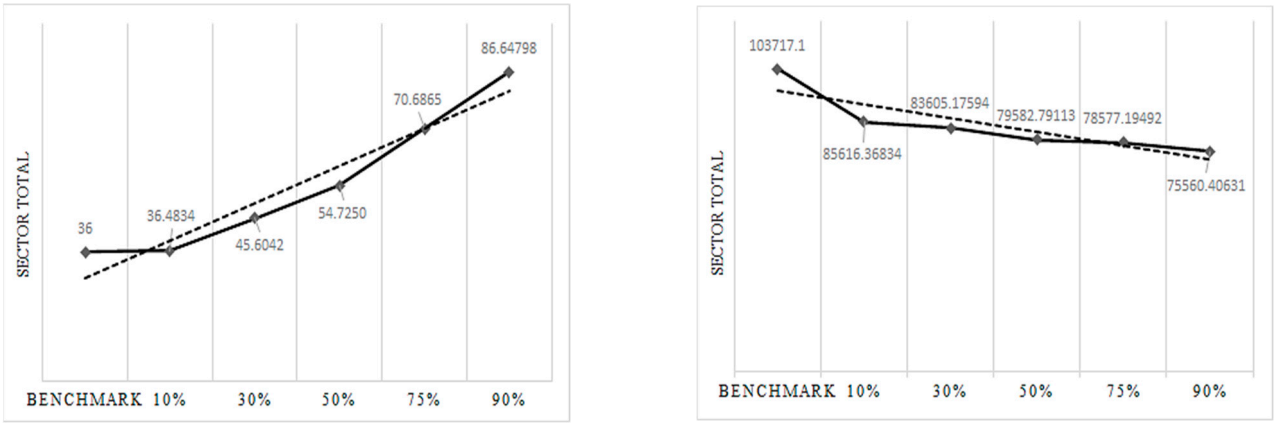
Figure 4 shows that the levels of both output and domestic uses are ultimately lower than their benchmark due to the imposition of quotas. This is plausible since Greece is a highly energy-dependent country, and the Rest of the World countries have always been the foundation of its energy consumption (63.55% increase in energy imports compared to 2021, reaching 20.10 TWh in 2022). In the worst-case scenario, where the non-EU RoW supply is cut off, Greece loses nearly one-third of its energy supply. Greece's trigger response is determined by the current situation, such as consumption levels when the supply is cut off, the amount of filling in gas storage, and the re-establishment of the coal-burning facilities to sustain its domestic consumption. Domestic uses in Figure 4b fall in proportion to the declining trend of output as quotas grow because the quantity accessible in the economy between domestic uses and exports is considerably decreased.

Figure 5 depicts changes in final consumption as a result of increased imported energy prices due to global crises or for any other reasons such as the imposition of tariffs, which raise the price of the economy's consumed commodities. Starting with the baseline of no tariffs and raising the tariff rate from 10% to 90%, we perceive that as the energy import prices grow, so does the price, resulting in a commensurate fall in household consumption, as shown in Figure 5b. Because of the higher cost, households are being forced to rely on domestic power sources to power their activities. Nonetheless, Greece could rise to the occasion through investment in renewable energies both through the substitution effect or through subsidies in the renewable energy sector.



(**a**) (**b**)

Figure 4. Changes in Greece's output and uses. Panel (**a**) shows the effect of quotas on Greece's output, while panel (**b**) shows the effect of quotas on Greece's uses. Note: 1, 2, 3, and 4 indicate quotas of 10% on energy imports and 1% on all other imports, 35% on energy imports and 10% on all other imports, 67% on energy imports and 35% on all other imports, and 100% on energy imports and 100% on all other imports, respectively. The dot line represents the trend line.

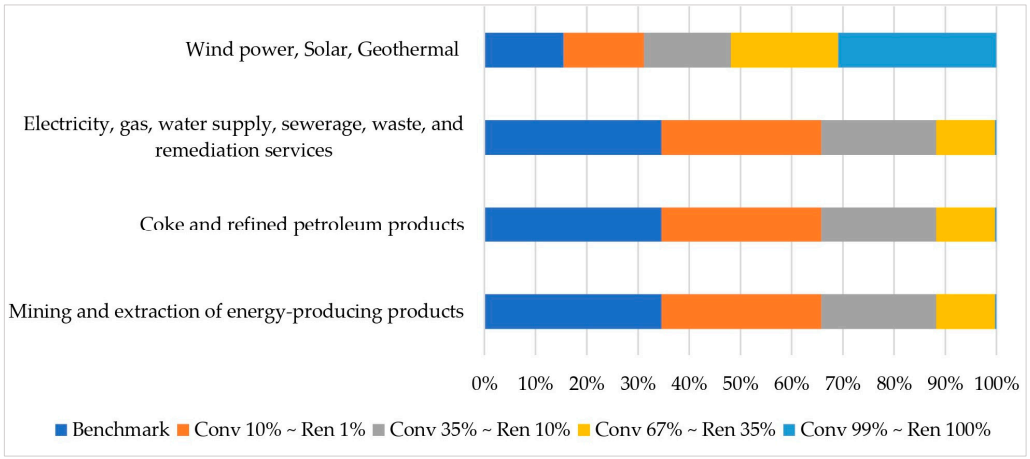


(**a**) (**b**)

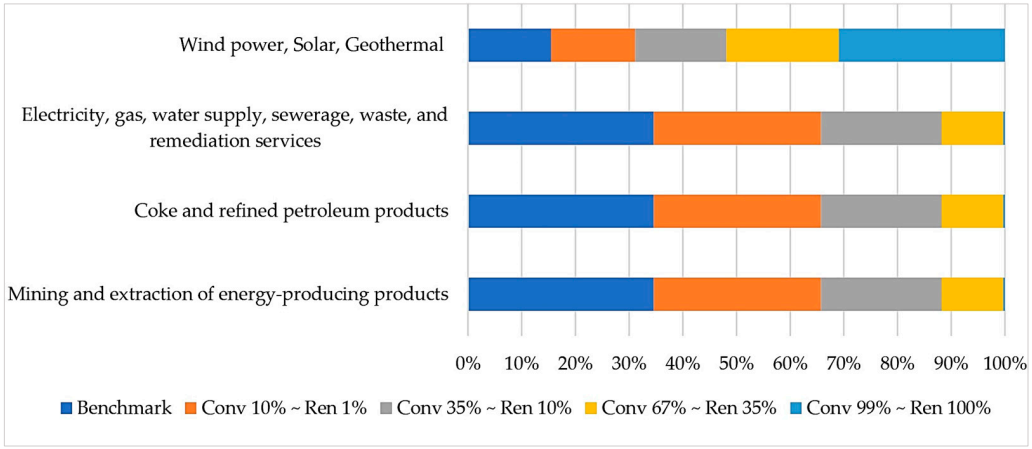
Figure 5. Changes in Greece's prices and household consumption. Panel (**a**) shows the effect of increased imported energy prices, while panel (**b**) shows the effect of the ad valorem import tariff on Greece's household consumption. Note: the dotted line represents the trendline.

The energy loss mentioned above in both output and domestic uses can be offset if the renewable energies are considered, since the Greek economy can sustain its energy demand when the supply from the non-EU RoW countries is reduced or even cut off. Figure 6 shows how all types of energies behave if quotas in conventional types of energies and subsidies in renewable energies are implemented, at various quota and subsidy levels.

Figure 6 shows how conventional and renewable energy behave if various levels of import quotas and subsidies are implemented. Starting with a small level of quota in conventional energy and a small level of subsidy in renewable energy, the scenario progresses to the extreme case where conventional energy is almost non-existent and only renewable energy reigns. We note that if the supply of energy from non-EU RoW countries is cut off, the Greek economy can sustain about one-third of this energy demand. This extreme scenario is particularly interesting since Greece can balance one-third of its energy consumption with renewable energy in both output and home usage.



(**a**)



(**b**)

Figure 6. Changes in Greece's energy use for output and domestic uses. Panel (**a**) shows the effect of quotas on Greece's conventional energy and subsidies on renewable energy regarding output. Panel (**b**) shows the effect of quotas on Greece's conventional energy and subsidies on renewable energy regarding domestic uses.

The case where Greece operates with only its domestic renewable energy supply is rather promising for the future of the country. Greece has the potential to establish a sustainable economy by embracing its renewable energy sources. By shifting its focus toward a clean and green energy sector, in accordance with the European Green Deal, Greece can reduce its dependence on fossil fuels, mitigate climate change impacts, and create long-term economic opportunities.

6. Conclusions and Policy Implications

Computable general equilibrium models are a frequently used tool for examining policy implications through counterfactual experiments and their impact on various economic agents. They form a consistent framework for analyzing links between certain sectors and the rest of the economy.

This study developed a multi-sector CGE model with specific characteristics for the Greek—non-EU RoW trade relationship, utilizing Greece's I-O table for 2015 as the base year. The model integrates trade impediments (such as tariffs and quotas) on non-EU RoW imports through counterfactual scenarios to examine the Greek economy's response to lower energy and other imports. Additionally, a scenario related to increased investments in renewable energies through subsidies along with the substitution effect between renewable

and conventional energy has been included. The intermediate inputs in the I-O table have been divided into domestic and imported from the Rest of the World countries to assess how Greece's energy use responds to a decline in non-EU RoW imports. Since Greece is an energy-dependent country, restrictions placed on its energy supply have a substantial effect on its consumption and production activities. Simulating a 67% quota on energy imports and 35% on the remainder of non-EU RoW imports, along with a 30% ad valorem import tariff, results in a decrease in output and domestic uses from the quota, as well as an increase in prices from the import tariff, which leads to a decrease in consumed quantities. By contrast, the investment in renewable energies through the substitution between conventional and renewable energy and a subsidy of 35% to counterbalance the reduced energy imports from non-EU RoW has a positive effect. The implementation of trade barriers allows for the emergence of the pollution/energy haven effect. Firms under pressure from rising energy prices and reduced output, as well as the fact that Greece must rely on its own energy capacity, may decide to reallocate to countries with laxer energy regulations and continue to produce as before.

Our conclusion on trade barriers in Greece's trade with the non-EU RoW countries suggests some beneficial policy implications. Policymakers in Greece can evaluate the impact of trade barriers and the potential counter-balance of renewable energies, i.e., by investing more in renewable energies, the country could become less reliant on non-EU RoW imports and the impact of trade barriers would be reduced.

As we can see from the study's results regarding the changes in output and domestic uses, a decrease of 67% in energy imports and 35% in the rest of the imports had a rather larger effect on Greece's production behavior. This situation shows how dependent the Greek economy is not only on energy imports, as most countries are, but also on all kinds of imports including manufacturing, agriculture, and services. Policymakers in Greece may avoid this situation and reduce the country's reliance on non-EU RoW imports by investing in more sustainable industries in domestic production. More specifically, in the 'Agriculture, forestry, and fishing' sector, a quota of 30% decreases the output and domestic uses of the sector by (10.666%) and (11.164%), respectively, indicating the large penetration of non-EU RoW imports into the Greek agricultural sector. Policymakers could compensate for this decrease by providing a framework that could make Greece more resilient on non-EU RoW imports by investing in agricultural infrastructure (storage facilities, and transportation networks to support agricultural productivity and reduce post-harvest losses), by providing financial incentives (offer subsidies, grants, and low-interest loans to farmers for modernizing equipment, adopting advanced technologies, and implementing sustainable farming practices), and by promoting research and development in the agricultural sector (collaborate with universities and agriculturally oriented firms to develop innovative farming techniques, crop varieties, and value-added products. Regarding the energy sector, a quota of 67% induced a reduction of (28.248%) in output and (28.277%) in domestic uses in the 'Electricity, gas, water supply, sewerage, waste, and remediation services' sector. These numbers show the Greek industry's reliance on imported energy. In this situation, policymakers could encourage renewable energy production, as the article shows. A subsidy of 35% resulted in an increase in renewable energy by (6.561%) in output and (7.886%) in domestic uses. On the other hand, the substitution effect resulted in an increase in renewable energy by (5.992%) in output and (7.231%) in domestic uses. These indicate that Greece, in the short term, can substitute about one-third of its energy demand produced from fossil fuels for both output and domestic uses, while in the medium or long term, renewable energy could substitute fossil fuel energy to a larger extent. In the manufacturing sector, the most substantial decrease is observed in the 'Construction' sector, where a quota of 35% reduced output and domestic uses by (29.895%) and (29.796%), respectively. This demonstrates that the construction index is highly affected by fluctuations in non-EU RoW imports due to the lack of high prices of raw materials in Greece. Policymakers may provide financial support to construction firms by establishing funding mechanisms such as loans and tax incentives so that they can encourage investment in the sector. On

the other hand, by promoting industrial clusters, not only the construction but also the entire manufacturing sector can create specialized industrial clusters that bring together manufacturers in order to foster collaboration, innovation, and knowledge spillovers. The services sector 'Real estate activities' exhibited the most significant decrease, with (32.010%) in output and (32.714%) in domestic uses. This sector is of particular interest due to tourism-related activities in Greece; thus, a quota of 35% in this sector demonstrated that Greece's output and domestic uses are exposed to external selling or buying or renting real estate. Therefore, policymakers can enhance tourism infrastructure that can sustain both domestic and external tourism. By investing in tourism infrastructure including transportation, and accommodation to attract more visitors and extend the tourism season, the Greek economy could create a barrier to external shocks in this sector.

In terms of the tariff effect on prices and consumed quantities, this study's results showed that households in Greece are unwilling to pay the increased price of the imported goods offered by each sector; thus, the quantities are decreased. More specifically, in the agricultural sectors, due to the 30% import tariff, the 'Agriculture, forestry, and fishing' sector indicated that a small increase in its price (0.619%) resulted in a larger decrease in its quantity (30.002%), implying that households prefer not to pay more for the imported goods. In this manner, policymakers could improve agricultural productivity through research and development support, i.e., via investment in agricultural research to develop and promote advanced farming techniques or more efficient production practices, which can increase incomes and reduce production costs. Furthermore, the Greek economy, by enhancing market efficiency, i.e., investments in agricultural infrastructure, and improvement of transportation networks and marketplaces to reduce post-harvest losses, may reduce prices and increase the availability of products in the domestic market. As far as the energy sector is concerned, the increase in the price of conventional electricity by (1.626%) resulted in a decrease in quantity of (34.552%); on the other hand, the decrease in the price of renewable energy (0.239%) resulted in an increase of (7.411%) in the consumed quantity. This implies that policymakers could react with an increase in investment in renewable energies in order to protect households from the increased prices of imported conventional energy. Related to the manufacturing sector, prices of the 'Construction' sector have increased by (2.164%), resulting in a consumed quantity decrease of (37.422%) which constitutes the most affected sector. Policy intervention in this sector could be focused on promoting the production of sustainable domestic inputs, resulting in reduced transportation costs of materials from abroad and decreased reliance on imported inputs. Moreover, policymakers can facilitate an environment that encourages fair competition between construction firms, promoting efficiency and driving down prices. Lastly, the sector that was affected the most in services was 'Real estate activities', whose price increased by (2.582%) and whose consumed quantity was reduced by (28.972%). Policymakers could reduce prices in this sector by promoting housing supply through investments in infrastructure. By simplifying the process of obtaining permits for housing construction, they could encourage more housing development. Moreover, by enhancing housing affordability, they could provide financial support to assist low-income households in affordable housing, such as rental subsidies, down payment assistance, or low-interest mortgage loans.

The framework used in this work can also be applied to various mechanisms and policy-related research. The nature of the traditional CGE analysis allows the user to customize the model with different data inputs, different sets of equations, and different scenarios to be examined. Thus, this work composes a versatile framework that can be extended to include more sectors based on the combination of more I-O tables, various types of equations regarding the production and consumption behavior of the model's agents, more scenarios to be analyzed including the scenario where the Greek economy operates using only renewable energy, and the transition of the model into a dynamic CGE model that can encompass the dynamic course of Greece to energy independence. In terms of limitations, the study cannot capture the whole spectrum of diversification that the real world offers, and it is the case that traditional CGE models are static, focusing specifically

on a single year. Additionally, CGE models are rather sensitive to parameter changes and which values are chosen for the counterfactual analysis. The reader may learn from the results of this study that the Greek economy heavily relies on imports from non-EU Rest of the World countries for both energy and general imports. As a result of reducing its imports, the country suffers from lower output, lower domestic usage, higher costs, and lower household consumption. This predicament could be mitigated in certain ways if we examine Greece's renewable energy prospects. According to the research results, Greece can meet one-third of its energy demand using just renewable energies if the supply from non-EU RoW is cut off. This extreme scenario is particularly hopeful for the country's energy future since it indicates the possibility of the country being energy independent only through renewable energy in the foreseeable future.

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Nomenclature

Parameter	Explanation
γ_i	Share parameter in the utility function
A_i	Scale parameter in the production function
δ_i	Share parameter in the production function
a_k, β_k	Share parameter for energy (source)
$\mu_{j,k}$	Share parameter for intermediate inputs (source, sector)
Π_i	Share parameter for capital input
Θ_i	Scale parameter in the transformation function
ϑ_i	Share parameter in the transformation function
Λ_i	Share parameter in the energy transformation function

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