Systemic Economic Impacts of Variation in International Oil Prices: The Case of Colombia.

Guilherme Perobelli Salgueiro[1]; Fernando Salgueiro Perobelli[2]

Abstract

This article assesses the systemic economic impacts of oil price fluctuations on the Colombian economy through a calibrated Computable General Equilibrium (CGE) model for the year 2015. A simulation exercise was conducted, introducing a 1% positive variation in commodity prices to examine the implicit elasticity of these prices in the country's economy. The results indicate an increase in GDP due to higher investment and government spending. There is also a positive variation in real wages, driving household consumption, along with an increase in the basic prices of the economy. Domestic oil prices exhibited a greater degree of variation compared to international prices, leading to a loss of the country's external competitiveness. Consequently, economies with low diversification may become vulnerable in volatile price scenarios. The loss of competitiveness in these products can result in an expansion of the trade deficit.

Keywords: Colombia, Computable General Equilibrium, Petroleum.

[1] Master in Economics from the graduate program in Economics – UFJF and Researcher at LATES. PhD student in Economics at the Center for Development and Regional Planning – CEDEPLAR/UFMG
[2] Professor. Department of Economics, Federal University of Juiz de Fora. CNPq, LATES and NEREUS/USP researcher.

1. Introduction

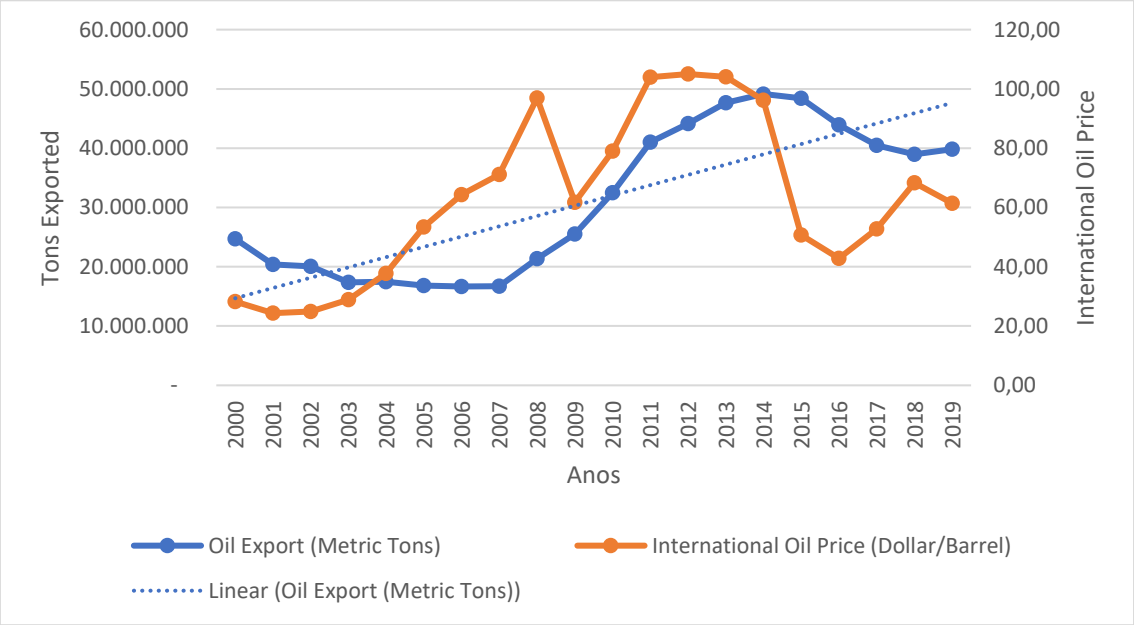
Developing countries historically have commodities and primary products as one of the driving forces of their economies. This article aims to measure the systemic economic impacts of variations in international oil prices on the Colombian economy. Through a regional computable general equilibrium model, an exercise will be conducted to simulate a positive 1% variation in global commodity prices.

According to the International Monetary Fund (IMF)[3], countries are classified into advanced and emerging economies. For such classification, the organization employs various criteria, such as per capita income level, diversification of export basket, and degree of integration into the global financial system (IMF, 2022).

Colombia falls into the group of emerging economies. Analyzing the country's international integration, a delayed trade openness is noted, becoming evident only after 2002. From the first half of the 21st century, with an increase in exports, there is also a positive shift in Colombia's Gross Domestic Product (GDP) (World Bank, 2023). In terms of economic diversification, Colombian exports are based on primary products, especially oil. During the period between 2015 and 2019, the commodity was the country's main exported product, representing 38% of total exports in that time frame. Following this, manufactured goods represent 21%, and agricultural products are responsible for 19% of Colombian exports.

Given the relevance of oil products in the country's export basket, it is noteworthy to evaluate historically the external participation of this product. The main international oil prices, such as Brent and WTI, are traded on stock exchanges and are heavily influenced by the member countries of the Organization of the Petroleum Exporting Countries (OPEC). Therefore, in the international commodity market, Colombia stands as a price taker, not exerting influence in this regard. Figure 1 depicts the variation in international oil prices and the export of the commodity by Colombia, highlighting the positive relationship between the two variables.

Figure 1 – Exports of Oil and Derivatives/International Oil Prices (US$)



Source: prepared by the author based on data from DANE

[3] They comprise those countries included in the Euro Zone, the European Union, or the G7 component countries, located outside the European community, namely: Canada, the United States, Japan, and the United Kingdom

The assessment of the behavior of the Colombian oil economy is not limited to the observation of international price variables and exports alone. According to Perry (2016), and in line with the data presented in Figure 1, the National Hydrocarbons Agency was established in 2003 as the supervisory entity for oil activities in the country. Also at that time, Ecopetrol, the largest oil company in the country, was transformed into a joint-stock company, allowing for foreign investment. With increased investment, the country saw an increase in drilling at the end of the 2010s, reaching 100 drillings in 2008, 126 in 2011, and 131 in 2012. However, in 2015, with the fall in international prices, drilling decreased to 26. Despite the reduction in drilling, crude oil production has remained, thus supplying both the domestic and international markets.

With the aim of systematically analyzing the impact of variations in global oil prices on the Colombian economy, we define, through hypothetical extraction[4], the commodity's production chain in the country, identifying the sectors that could potentially be most affected. Subsequently, from the perspective of Computable General Equilibrium (CGE), a simulation exercise will be conducted through a positive 1% variation in global commodity prices. Among the wide range of available CGE models, we choose to use ORANI_G, a regional computable general equilibrium model. The model has been adapted for different countries, including customization for Colombia, developed by Haddad (2016) and calibrated based on the Colombian Input-Output Matrix for the year 2015. The regional CGE model adapted to the country allows for a more detailed analysis of the national economy, including more precise intersectoral and systemic relationships, enabling a better assessment of internal impacts following the proposed shock.

According to Palacios (2002), since the 1970s, oil has been one of the main products exported by Venezuela, Mexico, Ecuador, Colombia, Argentina, and Brazil. Colombia began exporting the product to the international market in 1986. Despite the region being a strong oil producer, it is worth noting that there is no self-sufficiency in the resource for these countries. Due to this scarce scenario, Latin American countries generally have a trade deficit when the analysis is disaggregated for petroleum-derived products. This occurs due to the difficulty in refining products by developing economies. Like other commodities, oil exhibits volatility in its price, and economies dependent on the input, as often the case with Colombia, are price takers[5]. Braginskii (2009) presents the history of international oil prices. According to the author, the formulation of oil prices throughout history has gone through four distinct phases. The first, during the 1940s, where prices were determined by a simple single base system, with production costs being the main determinant; the second stage, a dual base system adopted between 1950 and 1970, where it was determined based on a basket of oil products, still with production costs as the main factor; between 1973 and 1986, prices were determined by an official cost system, taking into account the reference prices of the Organization of the Petroleum Exporting Countries (OPEC). Finally, from 1986 onwards, international oil prices have been determined by market prices.

The theme of oil dependency and the impacts of variations in commodity prices are also addressed in the literature. Jiménez (2010) indicates that Colombia began its oil exports late, after 1986, when some mineral reserves were discovered. During the period from 2000 to 2008, oil exports represented between 3 and 5% of Colombia's Gross Domestic Product (GDP). The author emphasizes that a significant part of some of the inputs required for the country's oil production originate from imports, and investments

[4] For more details on the extraction method see Miller and Blair (2009).

[5] For more details on oil prices see Braginskii (2009).

are made through Foreign Direct Investment (FDI). Therefore, due to this dependency on the external sector, price volatility can affect production across the country.

The author indicates that commodity prices have direct and indirect impacts on the country's economic growth and other macroeconomic variables, such as exchange rates and tax variables. At the time of Jiménez's publication (2010), oil exploration and exportation were returning significant revenue volumes to the country's economy.

The dynamics of international oil prices are also discussed by some authors who aim to capture the impact of price increases in certain countries using Computable General Equilibrium (CGE) models [Fan et al. (2007) and Timilsina (2015)]. Fan et al. (2007) address this issue for the Chinese reality, and Timilsina (2015) analyzes it for a set of countries using the GTAP model[6]. The conclusion of these studies points to a reduction in GDP [Fan et al. (2007) and Timilsina (2015)] and in import and export flows [Fan et al. (2007)] as international oil prices rise.

Doumax et al. (2014) seek to identify the efficiency of adopting incentives for biodiesel consumption compared to fossil fuel prices, including oil. In this literary context, the authors aim to measure the economic impacts of energy alternatives in detriment to oil. They construct six different scenarios to measure the impacts of expanding biodiesel usage in the French economy. The scenarios differ in terms of tariffs and subsidies for fossil fuels and biodiesel, measuring issues related to energy transition. Finally, the scenarios are subdivided into two groups: in the first group, international oil prices remain unchanged, while in the second group of simulations, oil prices increase due to an exogenous shock.

The authors conclude that there is a national difficulty in achieving the goal of reducing fossil fuel usage. Therefore, incentives through tax reductions or subsidies favoring biodiesel become necessary for the wider diffusion of this energy modality. The combination of taxes on fossil fuels and the increase in international oil prices can be seen as support for biodiesel subsidies, also being efficient in driving the energy diversification process in the country. (DOUMAX et al., 2014).

This article is structured beyond this introduction with a methodology and database section describing the methods used and strategies for evaluating the topic from the perspectives of Input-Output and CGE, followed by the presentation of results and final considerations.

2. Methodology and Database

To calibrate the Computable General Equilibrium (CGE) model, among other data, it is necessary to define the Input-Output Matrix, the basis of the model. To do so, the matrix provided by the National Administrative Department of Statistics (DANE), a Colombian government agency, will be used. This matrix is originally defined in a Product X Sector format, encompassing 392 products and 60 sectors of the national economy. The model is calibrated for the year 2015 and in Colombian pesos (HADDAD, 2016). Based on this matrix, it becomes possible to conduct a descriptive analysis of trade flows in the country, with the aim of understanding the interconnection between different productive sectors of the economy.

[6] The model includes the following spatial disaggregation: Sub-Saharan Africa, Germany, Latin America and the Caribbean, Argentina, Australia and New Zealand, Brazil, Canada, China, Spain, United States, Central and Eastern Europe, Western Europe, France, India, Indonesia, Italy, Japan, Malaysia, Mexico, Middle East and North Africa, United Kingdom, Rest of Africa, Rest of Latin America and the Caribbean, Rest of East and Central Asia, Rest of Europe, Russia, Thailand.

Table 1 presents the destination of sales for each of the petroleum products. It can be observed that the destination structure varies significantly, reinforcing the characteristics of each product. In the case of gasoline blended with ethanol and liquefied petroleum gas, the main destination is households. On the other hand, crude oil's main sales destination is the external sector, and gasoline for automobiles and kerosene are widely used as intermediate consumption.

Table 1: Sales Destination of Petroleum Products

Product	Total Demand	Intermediate Consumption	Export	Household, Government, Investment
Crude Oil	100%	19,80%	**81,10%**	0,10%
Gasoline for automobile	100%	**87,90%**	11%	0,10%
Gasoline mixed with Ethanol	100%	43%	6%	**52,60%**
Kerosene	100%	**79,10%**	20%	0,90%
Petroleum Gas	100%	42,30%	5%	**49,40%**

Source: Prepared by the authors based on the Colombian I-O (DANE, 2015)

Part of the crude oil production, intended for intermediate consumption, is used as an input by the oil refining sector, which was expected, given that crude commodity is the main input for refined products. In addition to the petroleum sectors and the external market, crude oil is also used by the gas production and electricity generation sectors.

Furthermore, when analyzing the intermediate flows of refined products, especially gasoline for automobiles and kerosene, it is identified that the land transportation sector and the air transportation sector are respectively their main demanders. This reflects the importance of fuels for the operation of the national mobility network.

To consolidate the main links in the oil production chain, a hypothetical extraction exercise was conducted. This simulation aims to quantify the reduction in production of an economy due to the total or partial shutdown of one or more sectors, thus measuring the linkage of that sector in the analyzed economy (MILLER and BLAIR, 2009). By performing the hypothetical extraction of the Crude Oil Extraction and Petroleum Refining sectors, it was possible to identify the main links of the oil production chain in the Colombian economy, i.e., those sectors that are most related to petroleum. Given the systemic interconnection with oil production, these sectors tend to suffer the greatest impacts in scenarios of exogenous shocks to the country's economy. The oil production chain is described in Table 3.

Table 3: Main linkages in the Oil Production Chain

Sectors	
Land Transports	S44
Gas Production and Distribution	S35
Manufacture of basic chemical substances	S25
Electricity Generation	S34
Wholesale Trade	S42
Financial Activities	S51
Scientific and technical activities	S53

Source: prepared by the author based on the I-O Matrix for Colombia.

2.1 The Computable General Equilibrium Model

From the Computable General Equilibrium (CGE) model, the impact on the Colombian economy of increasing international oil prices will be measured. In general, CGE models use real economic data to predict the impacts of external factors on an economy, such as tariff changes, policy alterations, among other potential shocks that may affect one or more regions. Jorgenson (2012) points out that CGE models aim to demonstrate real-world policy issues and generate insights into the effects of potential shocks on areas such as trade, taxation, public spending, social security, demographics, labor markets, and other areas, allowing for the quantification of impacts on local industries and socio-economic groups.

This article will use the Orani_G[7] model calibrated for Colombia (HADDAD, 2016). The model is calibrated based on the Colombian Input-Output Matrix for the year 2015 in its original format, i.e., Product x Sector. According to Dixon (1982), Orani_G enables this formulation because in real scenarios, industries produce more than one product, making this approach feasible.

Horridge (2006) presents the production structure of the Orani_G model. As mentioned, each sector can produce one or more products using domestic or imported inputs. The primary production factors in the model are land, labor, and capital. The author indicates that in the model, the equilibrium of primary factors is obtained through a composite constant elasticity of substitution (CES) function, where the three primary factors present in the model interact. The intermediate goods of the model are also defined by CES functions, with proportions divided between imported and domestic inputs. Thus, the baskets of goods that compose the economy's inputs, in conjunction with the primary factors under a Leontief function, will result in the level of economic activity. Finally, goods are produced following a constant elasticity of transformation (CET) function, and these goods can be destined for the domestic market or for export. The household consumption structure is also developed at optimization levels. Households choose between domestic or imported goods through a CES function. The level of utility of households is determined through a Klein-Rubin function, where users allocate their resources to luxury or subsistence goods, controlled by an Armington elasticity.

For the implementation of the simulation exercise, a long-term closure was used. In this scenario, according to Horridge (2006), capital stocks become endogenous and adjust in the model, while the rates of return are fixed. Therefore, an open capital market is assumed. The employment rate is also fixed, while adjustments to real wages are permitted. Finally, GDP, from the expenditure perspective, is adjusted by household and government consumption, and the ratio of the trade balance to GDP is fixed. Aggregate investment will follow the capital stock. The closure details, including exogenous and endogenous variables, are described in the appendix.

3. Simulation Exercise

In order to simulate the impacts of increasing international oil prices on the Colombian economy, a shock will be simultaneously applied to the exogenous variable "f_{4p_c}" representing a variation in the prices of exports demand for a specific commodity, and to the variable "*pf0cif*," which pertains to a variation in the prices of imports. This

[7] Orani_G was initially formulated as a disaggregated model for the Australian economy in 1977. It has been used since then to analyze the effects on industries, the labor market, and in regional analyzes based on the simulation of variations in tariffs, world prices, rate interest rates, application of subsidies, among others. (DIXON, 1982).

approach allows for a comprehensive measurement of the impacts of increases in international oil prices.

In general terms, modifying world oil prices changes the behavior of export demand, which, given the closure of the model, is guided by the ratio between domestic prices and world prices. External demand for Colombian product, c, x_{4c}, is a function of the average price in foreign currency ($p_{4c} - \varphi$) and displacement variables (f_{4x_c} ,f_{4p_c}).

$$x_{4c-}f_{4x_c} = \sigma_{Ex,c}\left(p_{4c} - \varphi - f_{4p_c}\right)$$

Where φ is the percentage change in the exchange rate (exogenous model currency), and $\sigma_{Ex,c}$ is a constant price elasticity parameter of demand. Therefore, those products that experience a change in the average prices in foreign currency ($p_{4c} - \varphi$), greater than the variation in world prices (f_{4p_c} = 1%), will experience a reduction in their export demand, and vice versa. It is worth noting that export demands are decreasing functions of ($p_{4c} - \varphi$). Domestic prices are endogenous and adjust according to the simulations.

In summary, the immediate consequences of a variation in world prices (f_{4p_c}) can be described as follows:

i) Impact on the export demand curve – (x_{4c}). It should be emphasized that the magnitude of the variation in export volume also directly depends on the prices of the exported products ($p_{4c} - \varphi$) and the elasticity of export demand ($\sigma_{Ex,c}$); the price of exported products is affected by internal production costs, which depend on the relative price of factors and production inputs.

ii) The variation in export volume (x_{4c}) has a direct impact on the balance between supply and demand in the non-margin goods market.

iii) Adjustment in the non-margin goods market from the supply side, meaning the shift of the export demand curve can be understood as an increase in the "preference" to offer goods outside the country rather than domestically. However, this shift in sales allocation may be limited by supply constraints, i.e., production capacity, and the increase in production costs (in the short-term closure of the model, investment and capital stock are fixed). Therefore, adjustments may occur in consumption, investment (only in the long term), and government spending (domestic absorption).

From the perspective of imports, an effect on the volume imported by the country is expected, which consequently will affect the domestic supply and demand for these external goods. Under such circumstances, the impact occurs directly on the basic prices of imports, as presented by the equation below.

$$p_0 = pf0cif + \varphi + t_{0imp}$$

Given the adopted closure, the exchange rate (φ) and import tariffs are defined as exogenous, therefore, the shock directly affects the basic prices of imported goods. The shock will be applied to all petroleum-derived products present in the Colombian economy. These include: Crude oil; gasoline for automobiles; gasoline blended with ethanol; aviation kerosene; and liquefied petroleum gas. Thus, the objective of simulating the increase in prices in related products stems from their connection with crude oil, assuming that an increase in international prices is also reflected in their petroleum-intensive derivatives.

For the proposed simulation, the aim is to apply an ad-hoc shock of 1% to the world prices of the commodity, thus capturing the implicit elasticity of prices in the Colombian economy. The main objective is to identify the movement and signs of variables, rather than making predictions regarding future oil prices.

Due to the computable general equilibrium model using various elasticities in its equations, it is valid to present the values of the Armington and Export elasticities for petroleum products, as these values will impact the results obtained.

The Armington elasticity is included in the equations for household consumption, investment, and intermediate consumption. This elasticity affects the choice of economic agents between domestically produced and imported commodities, depending on the price. On the other hand, the export elasticity is included in the export demand equation. Products with higher absolute values tend to be more demanded externally. The elasticities used in the model are shown in Table 4.

Table 4: Elasticity Parameters

Products		Armington Elast.	Exportation Elast.
Crude Oil	P57	2,6	-0,420
Gasoline for automobile	P157	1,05	-0,648
Gasoline mixed with Ethanol	P158	0	-0,648
Kerosene	P159	1,05	-0,648
Petroleum Gas	P162	1,05	-0,648

Source: prepared by the author based on the model calibrated for Colombia (Haddad, 2016)

3.1 Results

In macroeconomic terms, an increase in international oil prices can result in a positive percentage change in GDP, driven by a positive percentage change in household consumption, investment levels, and government spending. Table 5 presents the macroeconomic results after the simulation.

Table 5: Macroeconomic Indicators

Macroeconomic Indicators	Var %
GDP	2,27
Trade Balance	-2,27
Exported Volume	-0,45
Imported Volume	1,10
Household Consumption	1,27
Investment	0,97
Government Spending	2,03
Real Salary	1,50
Consumer Price Index	1,47
Terms of Trade	0,97

Source: prepared by the author based on the results.

The positive variation in GDP is driven by the increase in government spending, which shifts positively. Investment and household consumption also show positive variations. The positive variation in investments is partly a reflection of the need to increase production to meet the new demand in the national economy. Despite the increase in petroleum-derived product prices and consequently the higher cost of goods such as gasoline, there was an increase in household consumption. This movement can be explained because the most affected goods do not correspond to a significant portion of the household consumption basket in the model. Due to the increase in investments and productive demand, there was an increase in workers' wages, at a level higher than identified in the price index, resulting in a real increase in wages and consumption.

The percentage variation in imports exceeds exports, indicating a potential trade deficit in the country in the long term, especially due to the reduction in the volume exported by the country. The terms of trade of the Colombian economy also showed a positive variation, indicating that domestic prices are relatively higher than international prices. This may reflect a loss of international competitiveness in terms of exports. On the other hand, due to external products being relatively cheaper, an increase in imports is expected. The decline in exports is a direct result of the increase in the price of crude oil, which represents the country's main export product. Therefore, the loss of external competitiveness in this product directly impacts the Colombian trade balance. When an exogenous shock is established in oil prices, it becomes necessary to assess the pass-through of this increase to Colombian products. Such analysis will be described through the percentage variations in basic prices.

Table 6: Basic Prices

Products	p0	Var %
Gasoline mixed with Ethanol	P158	1,69
Petroleum Gas	P162	1,63
Crude Oil	P57	1,12
Gasoline for automobile	P157	0,95
Kerosene	P159	0,69

Source: prepared by the author based on the results.

After the shock, in the long term, there was a positive variation in the basic prices of almost all products traded in the country. It is noteworthy the variation for those products that directly received the shock in prices. For blended gasoline, liquefied petroleum gas, and crude oil, the variation exceeded the value of the shock, 1%. For such products, it is evaluated that domestically produced goods experienced an even greater increase than world prices. As a result, these products tend to lose international competitiveness in the long term, as they are relatively more expensive compared to external prices. In this way, especially regarding crude oil, there is a reduction in the international participation of this Colombian product, which can directly reflect on the country's export decline, as this product is the main item in Colombia's export basket.

In addition to the price variation, it is possible to assess the change in intermediate costs of productive sectors in the country. This occurs because sectors acquire their inputs and trade their productions with other productive sectors besides the elements of final demand. The multi-production nature of the Input-Output Matrix used in this simulation is emphasized; therefore, each productive sector can produce one or more goods. Table 7 presents the variation in intermediate costs incurred by productive sectors after the shock in the long term.

Table 7: Intermediate Input Price Index – Long Term

Setor	p1mat	Var %
Gas products and Distribution	S35	1,55
Petroleum Refining Products	S24	1,21
Land Transports	S44	1,18
Crude Oil Extraction	S6	1,06
Air Transport	S46	1,02

Source: prepared by the author based on the results (2023).

Due to the overall price variation in the economy, there is a rise in intermediate costs for all sectors belonging to the input-output matrix. The sector of Gas Production and Distribution stands out due to its direct productive interconnection with the petroleum

sector. This connection arises because its main input, coal, is predominantly produced by the crude oil extraction sector. Therefore, a variation in the prices of the crude commodity indirectly affects the prices of the coal input, thereby increasing the costs of the gas production and distribution sector.

For the land transport and air transport sectors, the use of refined petroleum products, such as gasoline and kerosene, stands out as their main inputs in their production processes. Therefore, the shock in these commodities directly impacts the costs of these transport sectors.

Finally, both petroleum sectors also experienced an increase in their intermediate costs, which is explained by the use of their products as productive inputs. Moreover, the main input of the refined petroleum products sector is crude oil, which incurred a price increase after the shock.

In addition to the price and intermediate cost variations, the country's production is also impacted both at the national level and by imports, which also supply the domestic market. The results of the percentage variation in supply are described in Table 8.

Table 8: Supply and Import of goods

Products	**Production**	**Var%**	**Products**	**Importation**	**Var%**
Gasoline mixed with ethanol	P158	0,872	Gasoline mixed with ethanol	P158	0,169
Petroleum Gas	P162	0,849	Petroleum Gas	P162	1,494
Gasoline for automobiles	P157	0,509	Gasoline for automobiles	P157	0,621
Kerosene	P159	0,381	Kerosene	P159	0,238
Crude Oil	P57	0,077	Crude Oil	P57	0,931

Source: prepared by the author based on the results (2023).

When assessing the impacts of the shock on production, it is observed that all petroleum products had their production boosted despite the price variation, thus increasing the national supply of these goods. From the perspective of imports, positive values are highlighted for all goods, indicating that the domestic supply is also supplemented by imported products after the shock. The increase in imports may be the result, in part, of the superior variation in domestic prices compared to imported ones. The decomposition of supply, aimed at identifying the reasons for the production variation, is presented in Table 9.

Table 9: The Decomposition of Supply

Sectors	**Decomposition**	**Local Market**	**Domestic Participation**	**Exportation**	**Total**
Gasoline mixed with ethanol	P158	0,904	0,000	-0,032	0,872
Petroleum Gas	P162	0,900	-0,029	-0,022	0,849
Gasoline for automobiles	P157	0,483	0,018	0,007	0,509
Kerosene	P159	0,173	0,116	0,091	0,381
Crude Oil	P57	0,118	-0,001	-0,003	0,077

Source: prepared by the author based on the results (2023).

Analysis of the Destination of the Positive Variation in the Production of Petroleum Products reveals that the primary boost for these products is the domestic market. Upon examining domestic participation, it's evident that only kerosene shows a significant positive variation. This is because its domestic prices are lower than the imported ones, inducing a process of import substitution for this product.

The same trend is observed in exports, where only kerosene and gasoline for automobiles show a positive export effect, also explained by relative prices. Crude oil, despite being Colombia's main export product, exhibits a negative export effect,

indicating that an increase in its prices relative to world prices reduces its competitiveness. Given the importance of crude oil in Colombia's trade balance, this movement could be one of the catalysts for the increase in the country's trade deficit in the long-term simulation.

To capture the systemic effects of the shock, Table 10 presents the percentage variation in intersectoral intermediate flows. For this, sectoral aggregation was performed.

Table 10: Intersectoral Intermediate Flows

Sectors	Var %
Agriculture	1,705
Extractive Sector	1,048
Light Manufacturing	0,896
Heavy Manufacturing	1,224
Utilities and Construction	1,405
Transportation, Trade and Communications	1,896
Other Services	1,981

Source: prepared by the author based on the results (2023).

It is evident that the effects spread more heterogeneously across the productive sectors in Colombia. For example, the sectors encompassing petroleum products (extractive and heavy manufacturing) are not among the sectors that have experienced the most variation in their intermediate flows.

Due to the overall increase in prices throughout the economy, including to a greater extent for other products compared to petroleum products, inputs for all sectors have become more expensive. Consequently, there has been an increase in intermediate flows in monetary terms. In agriculture, the livestock and fishing sectors stood out with increases in their flows, which can be explained by increased household consumption. The aggregation of extractive sectors, on the other hand, includes the only sector that individually experienced a reduction in its intermediate flows, the disaggregated sector of activities supporting extraction.

The transportation, trade, and communications sector, on the other hand, showed a positive variation in sectors interconnected with the petroleum production chain, such as trade and wholesale, land transportation, and air transportation, demonstrating that the variation in petroleum commodity prices also impacts those sectors linked to petroleum production.

3.2 Decomposition of Shocks

When employing a computable general equilibrium model and defining more than one simultaneous shock, each modification in the endogenous variables will depend on each of the shocks applied. According to Harrison et al. (1999), these distinct shocks can be decomposed in order to measure the contribution of each shock to the variations after the simulation. The decomposition of the macroeconomic indicators is presented in Table 11.

Table 11: Decomposition of the Macroeconomic Indicators

Macroeconomic Indicatoors	Var %	F4p	Pf0Cif
GDP	1,69	2,28	-0,59
Exported Volume	-0,45	-0,62	0,17
Import Volume	1,04	1,44	-0,39
Employment Variation	0	0	0
Consumer Price Index	1,48	1,99	-0,51

Household Consumption	1,27	1,75	-0,48
Investment	0,97	1,30	-0,33
Government Spending	2,03	2,73	-0,69
Terms of Trade	0,97	1,32	-0,35

Source: prepared by the author based on the results (2023).

The positive percentage variation in Colombian GDP (1.69%) in the long term is mostly linked to the variation in prices of exports demand (2.28%). Regarding export volume, a reduction is observed due to the combined shocks. However, once again, crude oil is responsible for most of this reduction. This is because after the simulation shock, in the long term, Colombian crude oil became relatively more expensive compared to international oil, leading to a loss of competitiveness and a consequent reduction in exports of this commodity. Since it is the country's main export product, this decrease in volume directly impacts Colombian total exports.

From the perspective of import volume, it is noticeable that the variation in the price of exported goods (f4p) had a greater contribution. This movement aligns with the variation in export volume, indicating a loss of competitiveness of the product in relative terms, leading to an increase in imports of this commodity, which traditionally has a trade surplus. On the other hand, the variation in the price of imports reflects a reduction effect on import volume due to the increased cost of these goods.

Regarding both investment and government spending variations, it is noted that the shock in world prices positively drives both variables. This occurs, in part, due to the need for greater investment due to price increases. The variation in import prices has a negative effect on these variables due to the reduction in prices of some imported goods, which hinders investment.

Table 12 indicates the results of the decomposition of shocks on basic prices.

Table 12: Decomposition of Basic Prices

p0	Var %	F4p	Pf0Cif
Crude Oil	1,12	1,41	-0,28
Gasoline for automobile	0,955	0,504	0,411
Gasoline mixed with ethanol	1,685	1,989	-0,303
Kerosene	0,698	0,213	0,485
Petroleum Gas	1,639	1,881	-0,241

Source: prepared by the author based on the results (2023).

When analyzing the variation in the basic prices of petroleum products in the long term, it is observed that those in which the variation exceeded the value of the shock (1%) are the ones that were most impacted by the variation in world prices of the commodity. This occurs because, for these products, the transmission of the shock in f4p made such goods more expensive compared to the external market. Therefore, the importation of these goods becomes viable and reduces the variation in basic prices.

The impacts are closely linked to the variation in relative prices; thus, products that experience a transmission greater than the value of the shock become less attractive domestically and may be substituted by imported products. The same logic applies to products whose main destination is exports, such as crude oil.

3.3 Sensitivity Analysis

In a computable general equilibrium model, several elasticities are used, constituting the parameters of the model. These parameters can be established through econometric estimates or assumptions based on the behavior of each evaluated economy. Therefore, with the aim of testing the model's robustness, the use of sensitivity analysis is proposed.

In the systematic sensitivity analysis of this work, the Gaussian quadrature methodology proposed by DeYust and Preckel (1997) was used, as contained in some works such as Domingues et al. (2003) and Perobelli (2004). The computable general equilibrium model is treated as a numerical integration problem where the solution of the model can be obtained simultaneously with the results of the endogenous variables and their first two moments (mean and standard deviation) given a variation in the parameters.

The robustness test of the parameters consisted of a variation of ±10% in the export elasticities and the Armington elasticity. This variation seeks to identify the movement of the variables given a modification in the elasticities used to calibrate the model. Thus, it is expected that there is no variation in the signs, demonstrating that the parameters are robust.

Table 13: Sensitivity Test – Export Elasticity

Macroeconomic Indicators	Long Term		
	Simulation %	Mean	Standard Deviation
GDP	2,2711	2,3682	0,4183
Export Volume	-0,4578	-0,4780	0,8666
Import Volume	1,0963	1,1406	0,1913
Employment Variation	0	0	0
Real Household Consumption	1,2708	1,3248	0,2346
Consumer Price Index	1,4858	1,5487	0,2172
Terms of Trade	0,9763	1,0181	0,1801

Source: prepared by the author based on the results (2023).

Table 14: Sensitivity Test – Armington Elasticity

Macroeconomic Indicators	Long Term		
	Simulation %	Mean	Standard Deviation
GDP	2,2711	2,2903	0,2020
Export Volume	-0,4578	-0,4626	0,5015
Import Volume	1,0963	1,1044	0,0855
Employment Variation	0	0	0
Real Household Consumption	1,2708	1,2814	0,1129
Consumer Price Index	1,4858	1,4983	0,1311
Terms of Trade	0,9763	0,9845	0,0855

Source: prepared by the author based on the results (2023).

4. Final Considerations

In general terms, after simulating the change in global oil prices, it was possible to assess the recurring impacts of this shock on the Colombian economy. In macroeconomic terms, there is an increase in GDP, mainly driven by higher investment and government spending. Overall, there is a positive variation in real wages after the shock, which can also be reflected in increased household consumption. However, the systemic results for the Colombian economy in the long run also point to a generalized positive variation in basic prices of the economy.

The positive variation in prices does not negatively affect production; there is an increase in the supply of goods in the country, driven in part by increased real household consumption and intermediate flows. The higher demand for products is reflected in increased intermediate flows of sectors in the country due to a greater need for intermediate inputs.

Analyzing Colombia's behavior in the international market, historically, it can be observed that in times of high oil prices, the Colombian economy tends to perform positively. According to the Colombian Input-Output Matrix, in the model's calibration year, crude oil accounts for 32% of the country's total exports. However, in the adopted closure, the increase in the price of the Colombian product had a negative impact on its exports.

From the simulation shock, the main impact on the Colombian economy is the transmission of this shock to the basic prices of the economy. From the perspective of the trade balance, imports increased by a volume greater than exports, widening the country's trade deficit. When analyzing the effects on crude oil, a decrease in external demand for this product was observed due to the high price relative to the global variation. Therefore, there is a loss of international competitiveness for this product, which may indicate a need for diversification of the export basket in the long term in scenarios of high commodity prices.

In the long term, in systemic terms, when evaluating the variation in total intermediate and production flows, the greatest variations are concentrated in sectors that are part of the oil production chain, such as gas production and distribution; land transport and wholesale trade. This analysis corroborates the conclusion that the country's oil production does not have a high level of interconnection, resulting in a low spread of results to other sectors. This fragmentation of the oil production process can impact the country's growth due to the sector's low connection with the economy as a whole. In addition, there is the high participation of the commodity in national exports, which demonstrates the need for diversification of the export basket due to the existing dependence on crude oil. In the long-term scenario, where commodity prices varied to a greater extent compared to international prices, there is a loss of external competitiveness for the country. It is therefore suggested that economies with a low degree of diversification tend to become more vulnerable in situations of commodity price volatility, as the loss of competitiveness in these products can lead to an increase in the trade deficit. This was also observed regarding imported products, which increased their entry into the country after the shock in the long term, indicating a potential external dependence on other products as well.

References

BRAGINSKII, O. B. **Crude oil prices**: History, forecast, and impact on economy. Russian Journal of General Chemistry, v. 79, n. 11, p. 2486-2498, 2009. Disponível em: https://link.springer.com/article/10.1134/S1070363209110371

DANE, **Exportaciones de café, carbón, petróleo y sus derivados. 1992-2022,** Bogotá, 2022. Disponível em: https://www.dane.gov.co/index.php/estadisticas-por-tema/comercio-internacional/exportaciones

DANE, **Exportaciones Totales segundo agregación CUCI,** Bogotá, 2022. Disponível em: https://www.dane.gov.co/index.php/estadisticas-por-tema/comercio-internacional/exportaciones

DANE, **Importaciones Totales segundo agregación CUCI,** Bogotá, 2022. Disponível em: https://www.dane.gov.co/index.php/estadisticas-por-tema/comercio-internacional/importaciones#:~:text=De%20acuerdo%20con%20las%20declaraciones,en%20el%20grupo%20de%20Manufacturas

DANE, **Matriz Insumo Producto Base – 2015**, Bogotá, 2015. Disponível em: https://www.dane.gov.co/files/investigaciones/pib/especiales/Boletin-matriz-insumo-producto-2015.pdf

DEYUST, E. A; PRECKEL, P. V. **Sensitivity analysis revisited**: A quadrature-based approach. Journal of Policy Modeling, 19(2), 175-185, 1997. Disponível em: https://ideas.repec.org/a/eee/jpolmo/v19y1997i2p175-185.html

DIXON, Peter B.; JORGENSON, Dale (Ed.). **Handbook of computable general equilibrium modeling**. Newnes, 2012.

DOMINGUES, E. P; HADDAD, E. A; HEWINGS, G. J. D. **Análise de Sensibilidade em Modelos de Equilíbrio Geral Computável:** Uma Aplicação para a Integração Brasileira na ALCA. Nereus, Universidade de São Paulo, São Paulo, 2003. Disponível em: http://www.usp.br/nereus/wp-content/uploads/TDNereus_19_03.pdf

DOUMAX, Virginie; PHILIP, Jean-Marc; SARASA, Cristina. Biofuels, **tax policies and oil prices in France: Insights from a dynamic CGE model**. **Energy Policy**, v. 66, p. 603-614, 2014. Disponível em: https://econpapers.repec.org/article/eeeenepol/v_3a66_3ay_3a2014_3ai_3ac_3ap_3a603-614.htm

FAN, Ying et al. **The impact of rising international crude oil price on China's economy**: an empirical analysis with CGE model. International Journal of Global Energy Issues, v. 27, n. 4, p. 404-424, 2007. Disponível em: https://econpapers.repec.org/article/idsijgeni/v_3a27_3ay_3a2007_3ai_3a4_3ap_3a404-424.html

FMI. PIB Colombiano. International Monetarty Fund, 2022. Disponível em: https://www.imf.org/en/Countries/COL#countrydata

HADDAD, E; AROCA, P. **Especificação e Implementação de Modelo de Insumo Produto e Modelo de Equilíbrio Geral Computável para a Economia Colombiana.** São Paulo, 2016.

HARRISON, J; HORRIDGE, M; JERIE, M. **Gempack Manual.** Gempack Software, 2014. Disponível em: https://www.copsmodels.com/gpmanual.htm

HARRISON, W.J; HORRIDGE, J.M. **Decomposing Simulation Results with Respect to Exogenous Shocks.** Centre of Policy Studies and the Impact Project. Monash University, Australia. 1999, Disponível em: https://www.copsmodels.com/ftp/workpapr/ip-73.pdf

HORRIDGE, M; FILHO FERREIRA, J. **Linking GTAP to National Models:** Some Highlights and a Pratical Approach. GTAP, Purdue. 2003. Disponível em: https://www.semanticscholar.org/paper/LINKING-GTAP-TO-NATIONAL-MODELS-%3A-SOME-HIGLIGHTS-A-Horridge-Filho/29c01c32b03da26812d4cd91189f073c533df22c

HORRIDGE, Mark. ORANI-G: **A generic single-country computable general equilibrium model**. Clayton: Centre of Policy Studies and Impact Project, Monash University, 2006. Disponível em: http://www.usp.br/nereus/wp-content/uploads/oranig06.pdf

JIMÉNEZ, Juan Ricardo Perilla. **El impacto de los precios del petróleo sobre el crecimiento económico de Colombia**. Revista de economía del Rosario, v. 13, n. 1, p. 75-116, 2010. Disponível em: https://www.banrep.gov.co/sites/default/files/eventos/archivos/Seminario35_0.pdf

MILLER, Ronald E.; BLAIR, Peter D. **Input-output analysis: foundations and extensions**. Cambridge university press, Cambridge, 2009.

PALACIOS, Luisa et al. **The petroleum sector in latin america: reforming the crown jewels**. Fondations nationale des sciences politiques-CERI, 2002. Disponível em: https://www.sciencespo.fr/ceri/en/content/petroleum-sector-latin-america-reforming-crown-jewels

TIMILSINA, Govinda R. **Oil prices and the global economy**: A general equilibrium analysis. **Energy Economics**, v. 49, p. 669-675, 2015. Disponível em: https://ideas.repec.org/a/eee/eneeco/v49y2015icp669-675.html

WORLDBANK. **GDP (Current US$) – Colômbia.** Banco Mundial, Washington, 2022. Disponível em: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=CO

Appendix 1: Long Term Closure

Exogenous	a0com ; ! COM Commodity CET technology shifter (negative=good)
Exogenous	a1 ; ! COM*SRC*IND Intermediate basic tech change
Exogenous	a1cap ; ! IND Capital-augmenting technical change
Exogenous	a1lab_o ; ! IND Labor-augmenting technical change
Exogenous	a1lnd ; ! IND Land-augmenting technical change
Exogenous	a1mar ; ! COM*SRC*IND*MAR Intermediate margin tech change
Exogenous	a1oct ; ! IND "Other cost" ticket augmenting techncal change
Exogenous	a1prim ; ! IND All factor augmenting technical change
Exogenous	a1tot ; ! IND All input augmenting technical change
Exogenous	a1_s ; ! COM*IND Tech change, intmdiate imp/dom composite
Exogenous	a2 ; ! COM*SRC*IND Investment basic tech change
Exogenous	a2mar ; ! COM*SRC*IND*MAR Investment margin tech change
Exogenous	a2tot ; ! IND Neutral technical change - investment
Exogenous	a2_s ; ! COM*IND Tech change, investment imp/dom composite
Exogenous	a3 ; ! COM*SRC Household basic taste change
Exogenous	a3mar ; ! COM*SRC*MAR Household margin tech change
Exogenous	a3_s ; ! COM Taste change, household imp/dom composite
Exogenous	a4mar ; ! COM*SRC*MAR Export margin tech change
Exogenous	a5mar ; ! COM*SRC*MAR Governmnt margin tech change
Exogenous	capslack ; ! 1 Slack variable to allow fixing aggregate capital
Exogenous	delPTXRATE ; ! IND*DTAX Change in rate of production tax
Exogenous	f0tax_s ; ! COM*TAXS General sales tax shifter
Exogenous	f1lab ; ! IND*OCC Wage shift variable
Exogenous	f1lab_i ; ! OCC Occupation-specific wage shifter
Exogenous	employ_i; ! total employment - wage weights
Exogenous	f1lab_o ; ! IND Industry-specific wage shifter
Exogenous	f1oct ; ! IND Shift in price of "other cost" tickets
Exogenous	f1tax_csi ; ! 1 Uniform % change in powers of taxes on intermediate usage
Exogenous	f2tax_csi ; ! 1 Uniform % change in powers of taxes on investment
Exogenous	f3tax_cs ; ! 1 Uniform % change in powers of taxes on household usage
Exogenous	f4p ; ! COM*SRC Price (upward) shift in export demand schedule
Exogenous	f4p_ntrad ; ! 1 Uniform upward (price) demand shift for collective exports
Exogenous	f4q ; ! COM*SRC Quantity (right) shift in export demands
Exogenous	f4q_ntrad ; ! 1 Uniform right (quantity) demand shift for collective exports
Exogenous	f4tax_ntrad ; ! 1 Uniform % change in powers of taxes on nontradtnl exports

```
Exogenous       f4tax_trad ; ! TRADEXP*SRC*TAXS   % change in powers of taxes on tradtnl exports
Exogenous            f5 ; ! COM*SRC   Government demand shift
Exogenous        f5tax_cs ; ! 1   Uniform % change in powers of taxes on government usage
Exogenous           delx6 ; ! COM*SRC   Shifter on rule for stocks
Exogenous        delB ; !  balance of trade/GDP
Exogenous        invslack ; !  aggregate investment determined by industry specific rules
Exogenous        f5tot2 ; !  link government demands to total household
Exogenous         pf0cif ; ! COM   C.I.F. foreign currency import prices
Exogenous           phi ; ! 1   Exchange rate, local currency/$world
Exogenous             q ; ! 1   Number of households
Exogenous          t0imp ; ! COM   Power of tariff
Exogenous          gret; ! IND   gross sectoral rates of return
Exogenous          x1lnd ; ! IND   Use of land
Exogenous          finv2 ; ! IND   Investment by using industry
Rest endogenous;
```