Analysis of the economic effect of the devaluation of the real exchange rate with a Computable General Equilibrium Model - Case study of Algeria -

تحليل التأثير الاقتصادي لتخفيض قيمة سعر الصرف الحقيقي باستخدام نموذج التوازن العام القابل للحساب – دراسة حالة الجزائر –

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Abstract:

This article aims to describe the effect of the policy of the devaluation of the real exchange rate on some variables of the Algerian economy such as domestic production and trade (importation, exportation), using the computable general equilibrium model.

The basic data of the model is the table of inputs and outputs of Algeria in 2014 which was identified using the social accounting matrix created using national accounts data.

The results of the study show that due to the devaluation of the real exchange rate by 10%, total production and imports increased while exports declined.

Keywords: Algerian Economy ; Computable General Equilibrium Model; Devaluation of Real Exchange Rate; Simulation; Trade.

Jel Classification Codes: C1, C4, C5, C6, E5, E6, E7

ملخص:

يهدف المقال إلى وصف تأثير سياسة تخفيض قيمة سعر الصرف الحقيقي على بعض متغيرات الاقتصاد الجزائري مثل الإنتاج المحلي والتجارة (الصادرات ، الواردات) باستخدام نموذج التوازن العام القابل للحساب.

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البيانات الأساسية للنموذج هي جدول المدخلات والمخرجات للجزائر لعام 2014 ، و التي تم تحديدها باستخدام مصفوفة المحاسبة الاجتماعية و التي تم إنشاؤها بواسطة بيانات محاسبية وطنية .

تظهر نتائج الدراسة أنه بسبب انخفاض قيمة سعر الصرف الحقيقي بنسبة 10 % زاد إجمالي الإنتاج والواردات بينما انخفضت الصادرات.

كلمات مفتاحية: الاقتصاد الجزائري، نموذج التوازن العام القابل للحساب، تخفيض قيمة سعر الصرف الحقيقي، المحاكاة، التجارة .

تصنيف JEL : C1, C4, C5, C6 , E5, E6, E7

1. INTRODUCTION:

When evaluating the effects of trade openness on an economy, computable general equilibrium models (CGEMs) are often used (lofgren, Harris, Robinson, 2001) because they remain the most appropriate for studying the economy. Impact on an economy of macro economic policies such as trade policies.

It seems reasonable to expect the liberalization process to have a positive impact on some sectors or actors in the economy and negative for others. Most of the Computable General Equilibrium (CGEM) model used to assess the impacts of trade liberalization policies relies on neoclassical modeling as presented in Dervis and al. (1982), Lofgren and al. (2002) modeled on international food policy. Research Institute (IFPRI), or on the EXTER model of Decaluwe (2001).The Global Trade Analysis Project (GTAP) model is also widely used to analyze the impacts of trade liberalization policies, but still relatively low in the Caribbean and Pacific countries because of its multi-regional structure and the difficulty of having recent and reliable data for the countries of this region.

The growing importance of trade openness has generated considerable controversy among countries, particularly developing countries, as to their impact on economic activity. (Kim.S.H, 2014)

THE PROBLEM:

Algeria, and like all other developing countries, is starting to feel the danger of globalization and its repercussions, which have led many countries to

economic integration to occupy competitive positions in order not to stay away from it all.

In this regard, it has been shown that a number of theoretical and applied studies determine the role of the policy of trade openness and in terms of the nature of data and methods of analysis, the positive role of openness in economic growth.

The study aims to determining the effect of the reduction of the real exchange rate on some variables of the Algerian economy to face the shocks resulting from the trade liberalization by using the computable general equilibrium model.

For this we present the problem of study as follows:

What are the consequences of the real exchange rate devaluation on the Algerian economy?

To answer the main problem of the study we put the following hypotheses:

- The devaluation of the real exchange rate affects the Algerian economy;
- The computable general equilibrium model is suitable for measuring the impact of external shocks resulting from the application of the open trade policy to the Algerian economy.

To achieve this, it will be necessary to specify:

- Selection of the computable general equilibrium model proposed for the Algerian economy with reference to the social accounting matrix, which will serve the database to solve this model with the choice of the mathematical formula;
- Design simulation and description;
- Finally draw the results of the model and all this is done using the program called General Algebraic Modeling System (GAMS).

To understand all aspects of the subject, we have divided the research into two parts, a theoretical approach in which we have moved to different theoretical concepts, and a descriptive statistical analytical approach that focused on the collection and analysis of the practical data used.

1. LITERATURES REVIEW:

1. 1 Exchange rate and Exchange Rate systems:

Exchange rate can simply be defined as the current market price of the home currency exchanged for foreign currency. In other terms, it is is a rate at which one country‘s currency is exchanged for another (Obstfeld & Rogoff, 1995).

The nominal exchange rate between two currencies, x and y, can be expressed as E(x/y). This expression refers to the price of one unit of currency y in terms of currency x (the number of units of x per one unit of y). This exchange rate is nominal because it is not adjusted for changes in prices. It is bilateral because it is an expression of two currencies in terms of one another (Moosa, 2005).

According to (Klein & Shambaugh, 2009) there are three main types of exchange rate regimes such as free floating or flexible exchange rate regime, pegged or fixed exchange rate regime, and pegged floating or managed floating exchange rate regime. In free floating system, exchange rates are set purely by private market forces (the supply of and demand for currencies) with no government involvement. In pegged/managed floating system, currency values are allowed to change, but governments participate in currency markets in an effort to influence those values. Finally, governments may seek to fix the values of their currencies, either through participation in the market or through regulatory policy; therefore fixed/pegged exchange rate regime. Let us discuss the three regimes one by one.

1. 1. 1 Free Floating (flexible) Exchange rate Systems:

It is a type of exchange rate in which the value of a nation's currency is allowed to fluctuate based on the demand and supply of the foreign exchange market. The price is determined by market forces of the demand and supply of the foreign currency without any intervention by the government. Therefore, there is a probability of getting different prices for one currency in terms of the other currency with in specific time interval, following fluctuations in the demand and supply of foreign currency. These fluctuations will lead us to say that there is either depreciation or appreciation of domestic currency (Klein & Shambaugh, 2009).

Currency depreciation is the loss of value of a country's currency with respect to one or more foreign reference currencies, typically in a floating exchange rate system in which no official currency value is maintained. Currency appreciation in the same context is an increase in the value of the currency. In a floating exchange rate system, a currency's value goes up (or down) if the demand for it goes up more (or less) than the supply does. A longer-run trend of appreciation (or depreciation) is likely to be caused by home country inflation being lower (higher) on average than inflation in other countries, according to the principle of long-run purchasing power parity (Pettinger, 2017).

The concept of a completely free-floating exchange rate system is a theoretical one. In practice, all governments or central banks intervene in currency markets in an effort to influence exchange rates. Some countries, such as the United States, intervene to only a small degree, so that the notion of a free-floating exchange rate system comes close to what actually exists in the United States (University of Minnesota, 2016).

According to (Frankel, 2003), floating exchange rate regime has its own advantages for the practicing nation especially if both domestic and international markets for currency are well-developed. In a floating regime the exchange rate automatically adjusts to ensure continues equilibrium between the demand for and supply of the currency. The purchasing power parity theory assumes floating exchange rates adjust until a unit of currency can buy the same basket of goods and services as a unit of another currency. Second, floating exchange rates insulate the domestic economy from foreign price shocks. If there is an increase in foreign prices, provided the exchange rate moves roughly in line with purchasing power parity the domestic currency would merely appreciate so preventing the country from importing foreign inflation. Third, the system ensures monetary autonomy- It gives independence to the monetary policy. Therefore, if the nation faces some shocks from the demand side, the monetary authority will be flexible to employ any kind of monetary policies to alleviate the ongoing demand deterioration problem (Pilbeam, 2006).

1. 1. 2 Fixed (pegged) exchange rate regime:

In a fixed exchange rate system, the exchange rate between two currencies is set by government policy. It is a system in which government plays a significant role in deciding the worth of its currency in terms of either a fixed weight of gold, or a fixed amount of another currency. In other words, Conventional fixed peg arrangements are exchange rate regimes where a country formally pegs its currency at a fixed rate to another currency or a basket of currencies (University of Minnesota, 2016).

The main arguments advanced in favour of the system of fixed or stable exchange rates are as follows. First, fixed exchange regime provides the best environment for the conduct of international trade and investment. This is because of the fact that if the nation uses fixed exchange rate system, it could be easy for merchants and investors to predict about the nation‘s economy and the outcome of their business as well. Secondly, fixed exchange rates eliminate the speculative

activities in the international transactions. Hence, there is no possibility of panic flight of capital from one country to another in the system of fixed exchange rates. Third, fixed exchanges rates are necessary and desirable for the developing countries for carrying out planned development efforts since fluctuating rates disturb the smooth process of economic development and restrict the inflow of foreign capital.

Fourth, uncertainty is no longer a problem in fixed exchange rate system since exchange rate is predictable and non volatile. Therefore, fixed exchange rates ensure certainty about the foreign payments and inspire confidence among the importers and exporters. This helps to promote international trade. Fixed foreign exchange rate ensures internal economic stabilization and checks unwarranted changes in the prices within the economy. Lastly, fixed exchange rate system is anti-inflationary in character. If exchange rate is allowed to decline in value, import goods tend to become dearer. High cost import goods then fuels inflation. Such a situation can be prevented by making the exchange rate fixed (Calvo & Mishkin, 2003; Pilbeam, 2006).

1. 1. 3 Managed (Dirty) floating exchange rate regime:

Managed floating exchange rate system is a system which combines (in between) both fixed and floating exchange rates. On one hand, it allows the market to adjust the exchange rate and arrives at its equilibrium level. On the other hand it allows the government to intervene in to the exchange market whenever intervention is needed so as to protect the domestic currency, trade balance and nation‘s economy from external shocks. Hence, a managed float is halfway between a fixed exchange rate and a flexible one.

The managed float is basically a flexible exchange rate system in which rates are permitted to float, but the central bank intervenes on a regular basis to keep the rate within some agreed upon limits. Government can influence exchange rates, usually through the Central Bank by buying and selling both domestic and foreign currency. In an increasingly integrated world economy, the currency rates impact any given country's economy through the trade balance. In this aspect, almost all currencies are managed since central banks or governments intervene to influence the value of their currencies. However, because most floating currencies manage their regimes with occasional central bank involvement, the term applies mainly to frequent or dramatic interventions (MacDonald, 2007). Most nations of the world currently use a managed floating

exchange rate policy. With this alternative an exchange rate is free to rise and fall, but it is subject to government control if it moves too high or too low. The Ethiopian government is also one of the countries following this system since 1990's.

Like floating exchange rate regime where fluctuations in the demand for and supply of foreign currency lead to depreciation and appreciation of domestic currency, there are official changes in the price of a currency in a fixed and managed floating exchange rate systems. When the price of the domestic currency in terms of foreign currency is officially decreased, the exchange rate is said to be devalued. Revaluation in the same context is an official increase in the value of the domestic currency within a fixed or managed floating exchange rate system (Salvatore, 2013).

As a system, managed floating has its own advantages and drawbacks. The main advantage of managed floating exchange rate system is that, it assures some sort of stability both in the financial market and in the economy as a whole since the government occasionally intervenes in to the foreign exchange market. Therefore, the regime is able to avoid a dramatic currency fluctuations and financial speculations in domestic market. (Bofinger & Wollmer shäuser, 2001).

2. Social Accounting Matrix:

The social accounting matrix is a complete accounting system to represent a particular economy in a given period. (mourad, 1987)

It is an analytical tool in national accounting to measure, present, analyze and interpret the benefits and costs in the economy of a given society, in order to: evaluate its performance and determine its contribution to the well-being of society. The Social Accounting Matrix was first designed in the 1960s, a research team from Cambridge University completed an English economic matrix whose data was used to solve the early growth models and used for purposes academic.

The first practical applications of the social accounting matrix date back to the mid-1970s, when a research team from the International Labor Office created a matrix for the Sri Lankan economy under the supervision of economists Richard Stone and Geery Pyatt. (Ismael, 2007)

3. The theoretical structure of the social accounting matrix:

The social accounting matrix is a square table with two entries for a given year, the different accounting flows are recorded from the income and expenditure

of the economy studied. Revenues are given in lines indicated by i, expenses in columns are indicated by j.

The internal compatibility of the accounting nature of the social accounting matrix is guaranteed for each account. General revenues are identical to overheads.

$$\sum_j t_{ij} = \sum_i t_{ki}$$

Total Revenue = Total Expenses

4. Close the social accounting matrix:

Different statistical approaches used in the creation of branch accounts, the institutional sectors result in a difference between the balances of the different accounts. The preparation of the various accounts is accompanied by a systematic review of the overall coherence of the system. (mourad, Cours de comptabilité nationale , 1979)

It is a question of balancing supply and use of accounts by balancing the product accounts to reach the final overall balance of the social accounting matrix.

5. Equilibrium of the social accounting matrix:

The next step in developing or building a social accounting matrix is to balance all the matrix entries generated by the expenditure and revenue calculations, that is, to balance all the total values of the columns and lines.

However, before constructing the exact social accounting matrix that can be considered as the appropriate data set for the computable general equilibrium model, some adjustments need to be made.

In order to align the matrix with the computable general equilibrium model, the aggregated social accounting matrix of an economy is considered an important element before preparing the ground for the discussion of the equations of the basic computable general equilibrium model. (Bernard, 2001)

6. The importance of the social accounting matrix in defining activity multiples:

6. 1 The Leontief multiplier:

Multipliers measure the impact of additional demand tests and Leontief multiples that take into account tribal and distant productive links, which are required exclusively for intermediate consumption, it is recognized that each sectoral production requires fixed-rate intermediate consumption noted a_{ij}. If we have:

$$X_{ij} = a_{ij} + X_j$$

Or Xij represents the production in sector i sold in sector j as intermediate consumption and Xj the total production in sector j.

In this case, we assume that the economy is closed and that the final and intermediate demand is satisfied by their local production needs. The balance between supply and demand in each sector is written as follows:

$$X_i = \sum_{j=1}^{n} a_{ij} X_j F_i$$

Where F is the beam of demand

$$X = AX + F$$
$$(I - A) X = F$$
$$X = (I - A)^{-1}F$$

Or: $(I - A)^{-1}$ is a multiplier matrix of Leontief

7. The social accounting matrix of the Algerian economy for 2014 :

In this section, we will present the social accounting matrix for the Algerian economy in 2014, this year's selection as a reference year is explained on the basis of the available data of input and output tables published by the national statistics office for the year 2014.

7. 1 Data sources used:

The sources used to construct the social accounting matrix are first an input-output table for 2014 which is originally a table representing a balance of resources for the use of goods and services and various data on consumption. Intermediary and value-added analysis to compensate for wages .

This table includes 19 activity sectors according to the functional classification established by the system of Algerian economic accounts as well as a table for the production account and the accounts (operation of the insurance companies - operation of the banks - real estate - public administration) .

The second data source used is the 2014 General Economic Table. This table includes four accounts: the production account, the operating account, the income and expenditure account and the investment account according to the Algerian economic calculation system.

7. 2 Accounts of the social accounting matrix for the year 2014:

The matrix we constructed includes fourteen sectoral activities from the 19 activity groups of the 2014 Input-Output Table: agriculture, forestry, fishing (01),

oil sector (03), as well as the Petroleum Services and Public Works Department (04).

The industrial sector is composed of a group of industrial branches for the input-output table for the year 2014 designates the industries of the steel, mechanical, metallurgical and electrical industries (06), building materials industry (07), Industrial Chemistry, Plastics and Rubber (09), Food Industry (10), Textile industry, clothing and socks (11), Leather and footwear industry (12), Manufacture of wood, paper and cork (13), Miscellaneous Industries (14), Mines and quarries (05).

The service sector includes transportation and communications (15), trade (16), hotels, cafes, restaurants (17) , institutional services (18), family services (19), the last section the Directorate of Hydropower (02), Buildings, Public Works (08).

We explain the selection of this group to the nature of the problem studied and the nature of the model used, which requires at least ten sectors as well as the nature of the characteristics of the national economy. The other accounts in the social accounting matrix are the 14 composite products approved for the 14 sectors mentioned above.

8. Computable General Equilibrium Models Applied to International Trade:

The general equilibrium model is a complex system of mathematical equations illustrating and visualizing the nature and functioning of an economy based on neoclassical economic theory of general equilibrium, a detailed description of production techniques, behavior and consumer preferences.

The computable general equilibrium model is therefore applied to the theory of general equilibrium on the data of the social accounting matrix. (Kehoe.T.J, 1996)

Among these models, the Johansen Leif model in 1960 for the study of economic growth in Norway and the Harberger model in 1962 to study the impact of tax policy on corporate profits in the United States, this approach is used as an analytical tool to study the effects of the implementation of long-term economic policies such as the liberalization of foreign trade, the introduction of a new type of taxation in the tax system and other policies economic. (B.Ravikumar, 2016)

Since the early 1980s, much work has been done using this modeling technique using advanced computer programs such as the Comprehensive Modeling System and the General Algebraic Modeling System (GAMS). (Mcdonald.S, 2015)

The construction of a multi-state model in which each member of the integration structure is modeled in detail and interconnected by commercial flows, for

example the Bayat and Raownd models in 1984 for Malaysia and the construction of the famous model by Hicks 1988 in Australia. Kimble and Harrison in 1984 and Morgan in 1989 used multiregional models to analyze tax effects.

Jonas and Halley (1989) also presented a computable general equilibrium model for Canadian provinces that focuses on assessing the impact of government policies. (Lofgren.H, 2001)

Derradov and Starn (1981) also developed a business valuation model, the best-known model for analyzing trade liberalization problems in 34 industrialized countries and other developing countries, it has been used to assess the effects of reducing tariff barriers and non-tariff barriers. Finally, we mention the Mirage model, built in 2002 to evaluate the European Union's trade policy with its environment. (Abdelhak.T, 1998)

9. The computable general equilibrium model proposed for the Algerian economy:

We have proposed a computable general equilibrium model of the Algerian economy, which is a set of nonlinear real-time equations submitted by Lofgren and All 2002 which, like most other computable general equilibrium models, belong to classical general equilibrium models centered on trade liberalization. or commercial openness in developing countries, described by Dervis de Melo and Robinson in 1982.

It is a modular static model, which allows the implementation of a set of policy simulations to modify policies and other external conditions, and measure the impact of these changes.

The computable general equilibrium model was used to analyze the state of the Algerian economy in the direction of further liberalization of the trading system and its interaction with various external shocks. The basic data for the model was the table of inputs and outputs for the year 2014.

10. The execution of the model and the consistency test:

This model is solved in the General Program of the Linear Modeling System (GAMS). The consistency of the model is tested simultaneously. By solving this model, the program (GAMS) is used to find a range of prices, wages and exchange rates that respond to the complex set of non-linear equations (Lofgren et al 2002).

11. Simulation design and description:

In this section, we will present the different policy simulations that we would like to implement using a computable general equilibrium model developed for this purpose. The simulations that will be conducted primarily based on the realistic state of the economy have been tested to match the direction of the economy.

11.1 Reduction in the value of the real exchange rate:

It is a simulation that aims to test the effect on the local economy, so that the exchange rate is one of the main tools of trade policy is often used to correct the current account deficit and also to maintain the international reserve.

The exchange rate can be manipulated as a promotional tool (interchangeable), and more diversified in the production and structure of exports.

Algeria often applies a devaluation policy, but it is gradually reduced because it is often linked to sovereignty and national significance.

In practice, the devaluation of the exchange rate is applied to support and encourage exports and reduce imports. Therefore, in this scenario, we assume that the exchange rate is fixed and that foreign savings is a budget variable.

To provide effective and neutral economic incentives, the reform of trade policy still requires a devaluation of the real exchange rate (Bautista 1996).

The devaluation of the real exchange rate makes expensive tradable goods in the domestic market, encouraging the transfer of resources to market output and helping to prevent the deterioration of the current account balance.

Currency devaluation mainly acts by influencing the terms-of-trade devaluation, often arguing that devaluation leads to a deterioration of the terms of trade, and that a country that reduces value has to issue more to pay foreign exchange current level of imports.

The results obtained from the simulation do not correspond to the theory underlying the devaluation, since it is assumed that imports are expensive in the domestic market, which will modify local exchange rates (PEc / PDc) for exports. and imports decline, leading to an improvement in the real trade balance, but the results show that the real trade balance has decreased by 5.544%,

In terms of GDP and private consumption, they rose respectively by 0.127937% and 0.142373% from the base level.

11. 1. 1 The effect of the reduction in the value of the real exchange rate on domestic production:

At the sectoral level, production has increased in most sectors, produced only for domestic consumption because their export value is very low compared to the hydrocarbon sector, which accounts for more than 97% of the country's exports.

Decrease in production from base level, in addition to the food, tobacco, sulfur and textile sectors, clothing and socks, respectively -0.76876%, -0.10068% and -0. 90867%.

While production has increased considerably in the sectors of water, energy, construction, public works and steel, mechanics, metallurgy, electricity, chemistry, plastics and rubber. Price changes were in line with changes in production at the industry level, so prices rose in all sectors where there was an increase in production.

Table N° 01: The effect of the reduction in the value of the real exchange rate on domestic production - Unit (%) -

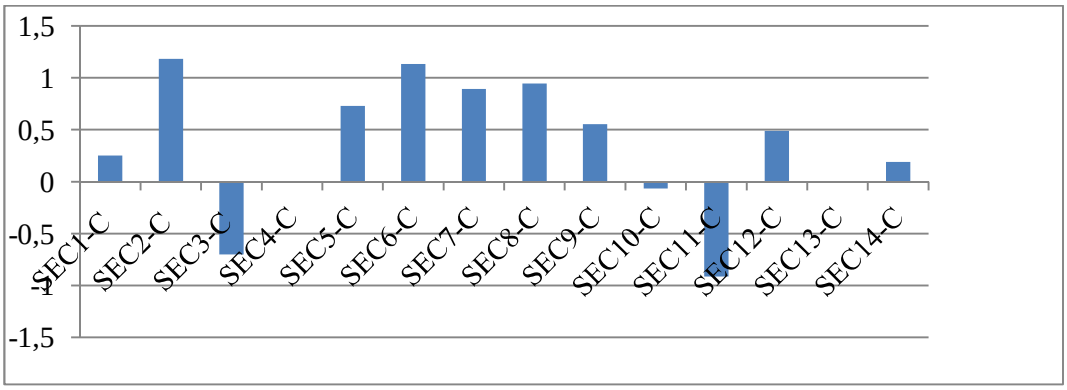
National Production	Scen 2	Price
TOT	0.134039	
SEC1-C	0.256326	0.096794
SEC2-C	1.19174	1.050026
SEC3-C	-0.76876	-0.25208
SEC4-C	0.880672	0.33256
SEC5-C	0.734905	0.377515
SEC6-C	1.137903	1.429696
SEC7-C	0.894199	0.537668
SEC8-C	0.949377	0.358504
SEC9-C	0.562577	0.21244
SEC10-C	-0.10068	-0.04798
SEC11-C	-0.90867	-0.44358
SEC12-C	0.506669	0.191329
SEC13-C	0.207375	0.278309
SEC14-C	0.198948	0.175127

Source : According to the author's calculations using GAMS software simulation results

11. 1. 2 The effects of a devaluation of the real exchange rate of 10% on exports:

In the Algerian general equilibrium model, the devaluation of the real exchange rate has led to an increase in exports in most sectors, but these increases are very small in absolute value and their share in total exports is less than 3%. While the hydrocarbon sector, which alone represents the remaining percentage of the total value of exports, has seen a decline in the value of its exports, therefore, the small change in exports did not change the exchange rate ratio, on the contrary, due to the devaluation of the currency, the trade balance set a deficit of -15.544% and this is illustrated in Graph N° 01 as follows:

Graph N ° 01: The effects of a devaluation of the real exchange rate of 10% on exports

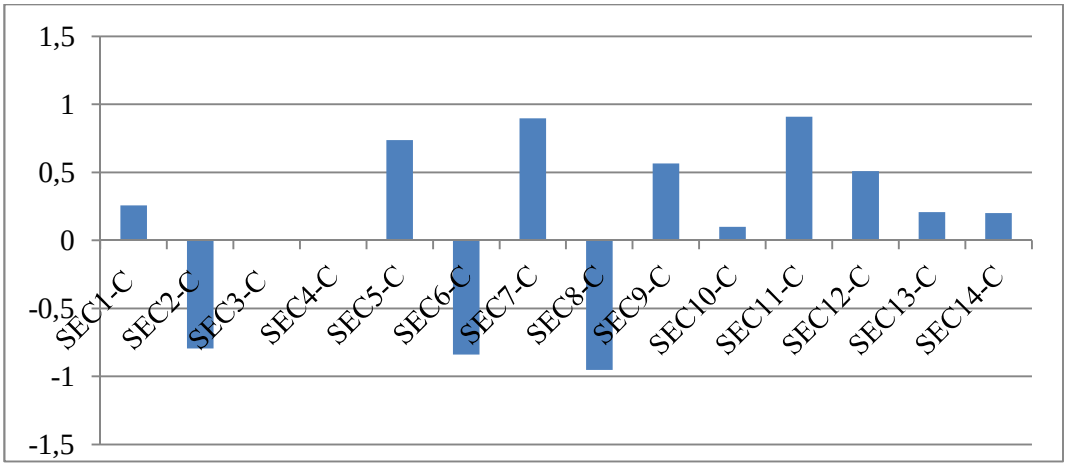


Source: Based on author's calculations using GAMS software simulation results

11. 1. 3 The effects of a 10% real exchange rate devaluation on imports:

In the area of imports, the latter saw an increase in most sectors of the national economy following the devaluation, with the exception of the water, energy, construction and public works sectors. and steel, mechanical, metallurgical, electrical, industrial, chemical, plastic, this may be due to the improvement of production in these sectors, so that the increase in demand for imported inputs in most sectors pushes imports to increase.

Graph N ° 02: The effects of a 10% real exchange rate depreciation on imports



Source: Based on author's calculations using GAMS software simulation results

12. CONCLUSION:

According to the Real Exchange Rate Simulation Total production and total imports increased, but total exports were insufficient, which led to a deficit in the trade balance, this reduction also led to an increase in private consumption.

The results obtained from the simulation can support political conclusions and can help shape the future policy of the country.

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4.Appendices:

Appendix N ° 01: Equations and variables of the model

Equation of the model:

Price block:

$$PM_c = pwm_c(1 + tm_c) \cdot EXR \quad (1)$$

$$PE_c = pwe_c(1 - te_c) \cdot EXR \quad (2)$$

$$PQ_c QQ_c = [PD_c QD_c + PM_c QM_c](1 + tq_c) \quad (3)$$

$$PX_c \cdot QX_c = PD_c QD_c + PE_c QE_c \quad (4)$$

$$PA_a = \sum_{c \in C} PX_{ac}\, \theta_{ac} \quad (5)$$

$$PVA_a = PA_a - \sum_{c \in C} PQ_c\, ica_{ca} \quad (6)$$

Block of production and trade:

$$QA_c = ad_a \prod_{f \in F} QF_{fa}^{\alpha_{fa}} \quad (7)$$

$$WF_f WFDIST_{fa} = \frac{a_{fa} PVA_a QA_a}{QF_{fa}} \quad (8)$$

$$QINT_{ca} = ica_a QA_a \quad (9)$$

$$QX_c = \sum_{a \epsilon A} \theta_{ac}\, QA_a \quad (10)$$

$$QQ_c = aq_c \left(\delta_c^q QM_c^{-p_c^q} + (1 - \delta_c^q) QD_c^{-p_c^q}\right)^{\frac{-1}{p_c^q}} \quad (11)$$

$$\frac{QM_c}{QD_c} = \left(\frac{PD_c}{PM_c} \frac{\delta_c^q}{(1-\delta_c^q)}\right)^{\frac{1}{1+p_c^q}} - 1 < p_c^q < \infty \quad (12)$$

$$QQ_c = QD_c \quad (13)$$

$$QX_c = at_c \left(\delta_c^t QE_c^{p_c^t} + (1 - \delta_c^t) QD_c^{p_c^t}\right)^{\frac{1}{p_c^t}} \quad (14)$$

$$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PD_c}\frac{(1-\delta_c^t)}{\delta_c^t}\right)^{\frac{1}{p_c^t-1}} - 1 < p_c^t < \infty \quad (15)$$

$$QX_c = QD_c \quad (16)$$

Foundation block:

$$YF_{hf} = shry_{hf}\sum_{a\in A} WF_f WFDIST_{fa} QF_{fa} \quad (17)$$

$$YH_h = \sum_{f\in F} YF_{hf} + tr_{h,gov} + EXR \cdot tr_{h,row} \quad (18)$$

$$QH_{ch} = \frac{\beta_{ch}(1-mps_h)(1-ty_h)YH_h}{PQ_c} \quad (19)$$

$$QINV_c = qinv_c \cdot IADJ \quad (20)$$

$$YG = \sum_{h\in H} ty_h \cdot YH_h + EXR \cdot tr_{gov,row} + \sum_{c\in C} tq_c\,(PD_c QD_c + PM_c QM_c) + \sum_{c\in CM} tm_c EXR \cdot pwmc_c \cdot QM_c + \sum_{c\in CE} te_c\, EXR \cdot pwe_c \cdot QE_c + ygi \quad (21)$$

$$EG = \sum_{h\in H} tr_{h,gov} + \sum_{c\in CE} PQ_c \cdot qg_c \quad (22)$$

Block of the limitation system:

$$\sum_{\propto\in A} QF_{fa} = QFS_f \quad (23)$$

$$QQ_c = \sum_{\propto\in A} QINT_{ca} + \sum_{h\in H} QH_{ch} + qg_c + QINV_c \quad (24)$$

$$\sum_{c\in CE} pwe_c \cdot QE_c + \sum_{i\in I} tr_{i.row} + TASV = \sum_{c\in CM} pwm_c \cdot QM_c + irepat + yfrepat_f \quad (25)$$

$$\sum_{h\in H} mps_h \cdot (1-ty_h)YH_h + (YG - EG) + EXR \cdot FSAV = ygi + EXR \cdot irepat + \sum_{c\in C} PQ_c \cdot QINV_c + WALRAS \quad (26)$$

$$\sum_{c\in C} PQ_c \cdot cwts_c = cpi \quad (27)$$