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A financial approach to the sustainability of public debt: the case of Colombia

Fernando Arenas

Professor – Faculty of Economic and Administrative Sciences
Pontificia Universidad Javeriana
Calle 18 No. 118-250 Avenida Cañasgordas - Pance
Cali – Valle
Colombia
Pone No.: 57 2 321 8243
Fax No.: 57 2 555 3547
E-mail: farenas@puj.edu.co

ABSTRACT

The public debt in developing countries, its management and sustainability, is a topic that, especially in the recent years, has been a main concern and a source of controversy among economists, academics and government policy makers. This article shows a system dynamics model that approaches the topic from a financial point of view, in order to contribute to the analysis of which are the policies and variables that present the higher degree of leverage for getting a sustainable level of the debt. The model has been developed considering the case of Colombia, as representative of the performance of public debt in several developing countries, where variables such as debt composition (foreign and local), inflation, devaluation, exchange rate, government expenditure structure and specifically military expenditure, are of major importance. The paper presents a preliminary univariate analysis whose results serve as a basis for a multivariate analysis where some high leverage policies and variables are suggested.

Introduction

The performance, trend and sustainability of the public debt in developing countries has been a controversial topic during recent years among academics, analysts, politicians and government representatives. The political and economic collapse of Argentina in December of 2001 has brought to our attention the importance of designing adequate economic policies in order to avoid the catastrophic risk that an inappropriate management of the debt may imply. Some of them (Cabrera, Gonzalez, 2000a, 2000b) argue that the current situation of Colombian debt has its origin mainly in an erroneous monetary policy of the Central Bank (Banco de la República), while others (Sánchez, Barrera, 2002; Hernández et al., 2000; Posada, Arango, (2001) state the continuous primary deficit of the Central Government as the main driving force. Cuddington (1996), highlights the importance of considering factors that have been frequently neglected, such as the simultaneous presence of foreign and domestic debt, in the analysis of sustainability of fiscal deficits in developing countries. Bevilaqua and Garcia (2000), study the importance of debt maturity in the management of public debt in Brazil. Caballero (2003) shows the importance of military expense in achieving GDP growth rate in countries with warfare, being GDP growth a “sine

qua non" condition for debt sustainability. In general, the different approaches to the topic of debt sustainability, ignore the main role that feedback relationships and dynamics performance of the variables play in the results obtained by the application of a fiscal policy. This document presents a system dynamics model, taking as starting point the paper by Posada and Arango (2001), from a financial standpoint. System dynamics and the financial approach, allow us to develop a model that includes some feedback relationships considered highly relevant by the author as well as several of the variables mentioned above, permitting a wider look at the complexity of the topic.

Starting point: a system dynamics point of view of an economic model

The starting point of this document is the first part of the paper by Posada and Arango (2001), whose variables and relationships have been translated to the system dynamics model shown in Figure 1. The Gross Domestic Product (GDP) is increased by its real growth which depends on the GDP real growth rate. The debt is increased by the primary deficit, expressed as a fraction of the GDP, and by the debt service which depends on the real interest rate, and is depleted by primary surplus (negative primary deficit). *Primary Deficit* refers to the deficit calculated without taking into account the capital revenue produced by credit granting, and the financial expenditure (debt service).

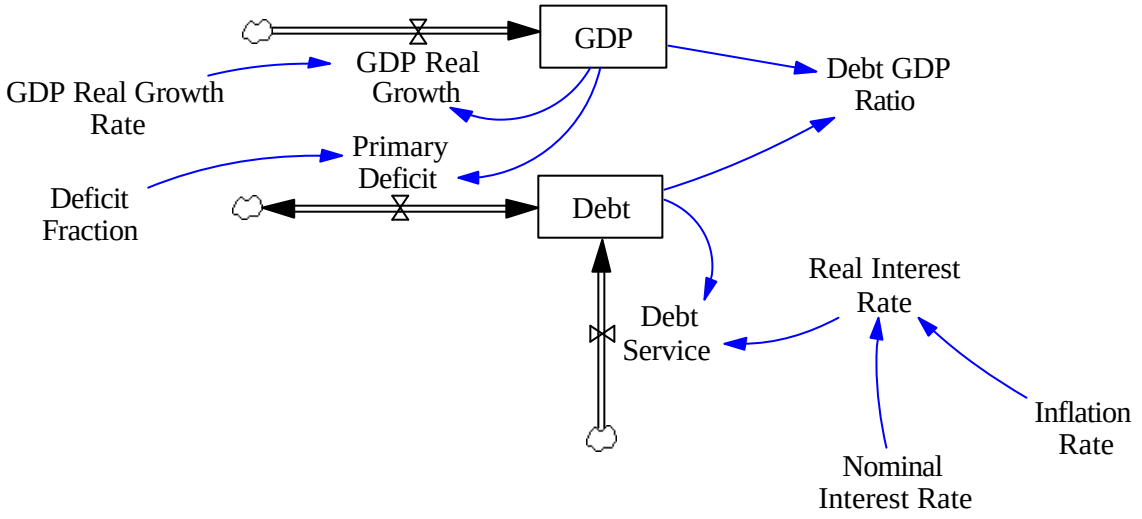

Figure 1 *An economic model of the debt performance, based on Posada and Arango (2001)*

The point made by Posada and Arango is illustrated in Figure 2. Starting with a debt/GDP ratio of 0.5, and even with a low real interest rate (2%) the debt/GDP ratio continues to grow as long as a primary deficit as low as 2% of GDP persists (curve 2), following an ever increasing pattern, while the debt/GDP ratio diminishes constantly with time when primary surpluses of 1.5% of GDP are generated, even with a real interest rate of 5% curve 1). This demonstrates that primary deficit is the main driver of debt performance and that the real interest rate, although important, is not as relevant.

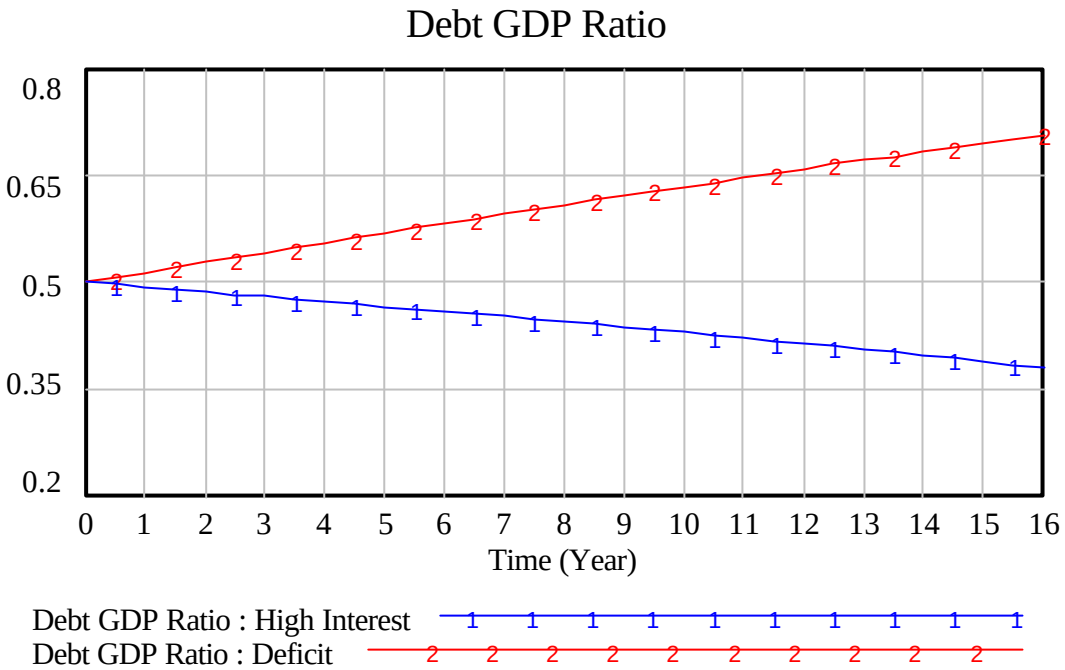

Figure 2. *Debt/GDP Ratio performance with primary deficit of 2% and real interest rate of 2% (curve 2), and primary surplus of 1.5% and real interest rate of 5% (curve 1).*

As can be seen in the model of Figure 1, some assumptions have been made by Posada and Arango in order to simplify the analysis: the deficit fraction is considered as exogenous and, therefore, is not affected by the debt service (interest and principal repayment) ; the nominal interest rate is a type of implicit rate not affected by the external/internal debt composition; the deficit fraction remains constant in spite of the GDP growth.
A financial approach to the problem through a system dynamics model allows us to overcome these assumptions, describing more closely the complexity of the situation. This implies the use of "nominal" variables instead of "real" variables, and the inclusion of new variables and some highly relevant feedback relationships between them.

A system dynamics model based on a financial point of view

Figure 3 shows a causal diagram of the model, modified to include the feedback relationship between Debt and *Total Deficit* (the deficit calculated including capital revenue and debt service). *Total Debt* has been divided into *External* and *Internal*, and the *Exchange Rate* included in order to allow currency conversion between US Dollars (USD) and Colombian Pesos (COP). A new variable, *Internal Debt Ratio*, determines which fraction of the *Total Deficit* is covered by *Internal Debt*, while the remaining deficit is covered by *External Debt*, this ratio could be determined by the availability of local and foreign credit and/or by a fiscal policy. The presence of external (foreign) and internal (domestic) debt and, therefore, the necessity of taking into account the management of

foreign and local currency in the debt, have been mentioned as important factors that must be considered in the analysis of public debt in developing countries (Cuddington, 1996).
Total Deficit is calculated as the difference between *Total Expenditure* (Financial and Non-Financial) and *Total Income* (Current Income as a Fraction of GDP, and Capital Revenue). *Current Income* corresponds to tax income mainly while Capital Revenue corresponds to credit revenue.
Now, through the causal diagram of Figure 3, the positive feedback (reinforcing) cycle that promotes the debt growth, can be clearly seen. An increase in the debt generates an increase in the debt service (external and internal debt principal repayment and interest), expressed as *Financial Expenditure*, increasing *Total Expenditure*; if, as has happened in recent years, *Total Expenditure* is higher than *Total Income*, a Total Deficit is generated that has to be covered with Internal and External Capital Revenue, in a proportion determined by the Internal Debt Ratio, increasing the total debt and closing the positive feedback loop, generating in this way an upward spiral: a "snowball effect".

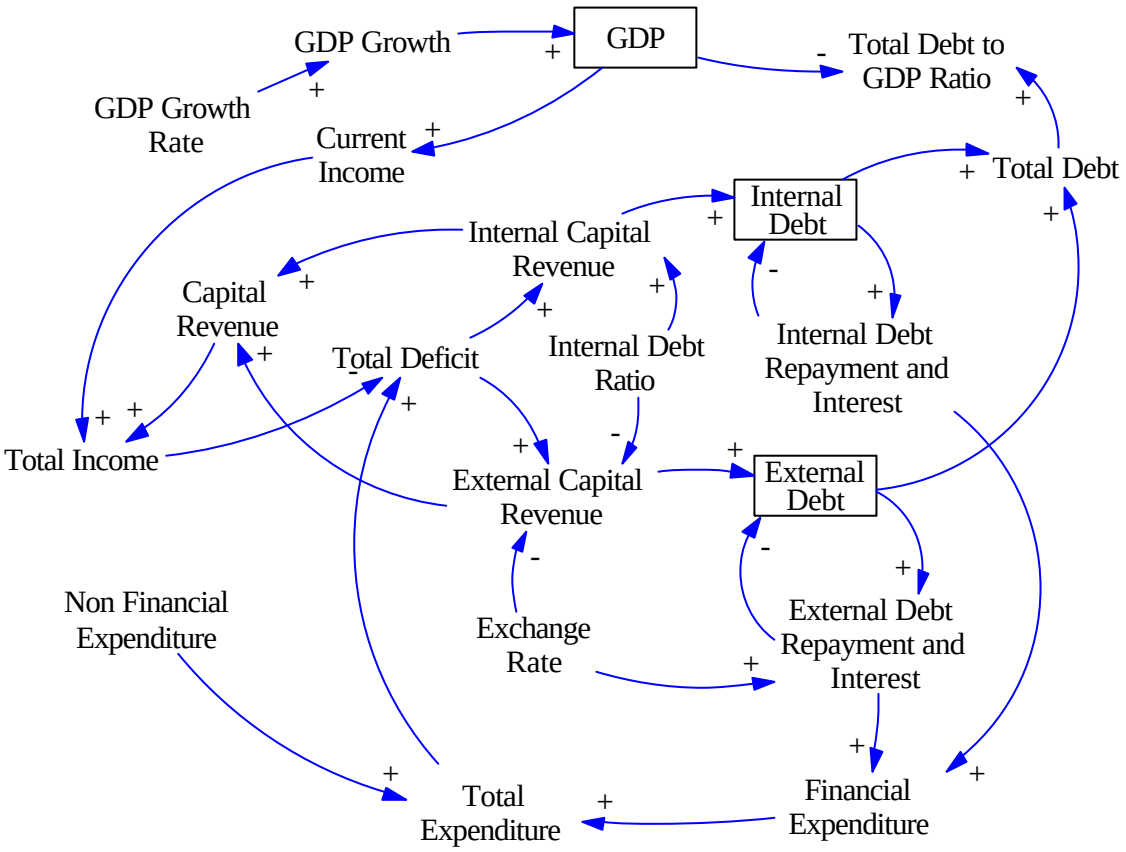

Figure 3. *Causal Diagram of the financial model including some relevant feedback relationships.*

Figure 4 shows some important details of the model:

• *Average Internal Interest Rate* is nominal and endogenous and calculated for uncovered interest parity in an open economy as:
Average Internal Interest Rate = Average External Interest Rate + Devaluation
where *Average External Interest Rate* is nominal and, therefore includes the country risk premium.

• *Debt Repayment* (Internal and External) is calculated as:
Debt Repayment = Debt/Average Debt Maturity

• As *GDP* and *GDP Growth* are nominal, but projections are made for *Real GDP Growth Rate*, then:
GDP Growth = GDP(Real GDP Growth Rate + Inflation Rate + Real GDP Growth Rate*Inflation Rate)*

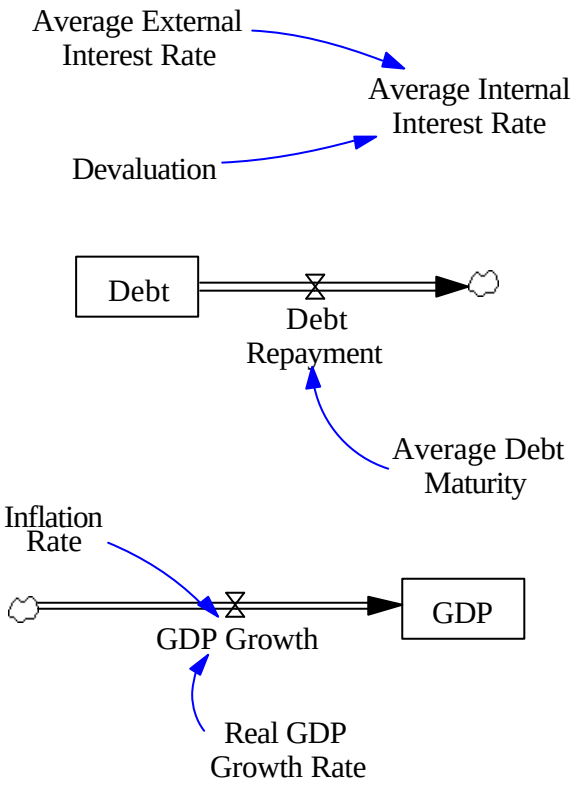

Figure 4. *Some important details of the model*

The "stock and flow" structures used in the model are shown in Figure 5. As can be seen there, *GDP* is increased by the *GDP Growth*, *Debt* (*External and Internal*) is increased by *Capital Revenue* and depleted by *Debt Repayment*, and *Exchange Rate* is increased by *Exchange Rate Variation*.

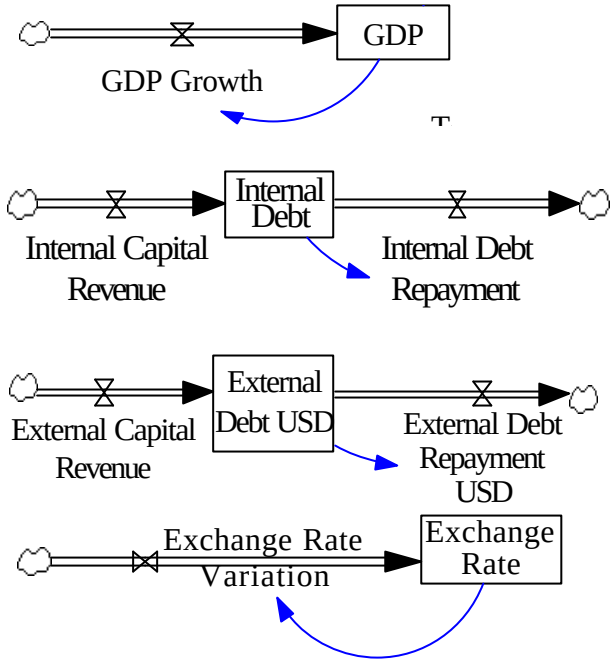

Figure 5. *Stock and flow structures of the model*

The detail of the income and expenditures that give *Total Deficit* is described in a model View named "Deficit Dynamics" (the main View is named "Debt Dynamics"). Figure 6 shows a causal diagram of this "Deficit Dynamics".
Total Income is composed of *External Capital Revenue*, *Internal Capital Revenue* and *Current Income*, while *Total Expenditures* are classified as *Financial and Non-Financial*. A convenient classification of *Non-Financial Expenditures* as *Obligatory* (those established as obligatory by the Constitutional Reform of 1991) and *Discretionary* (those whose use can be decided by the government) has been made.

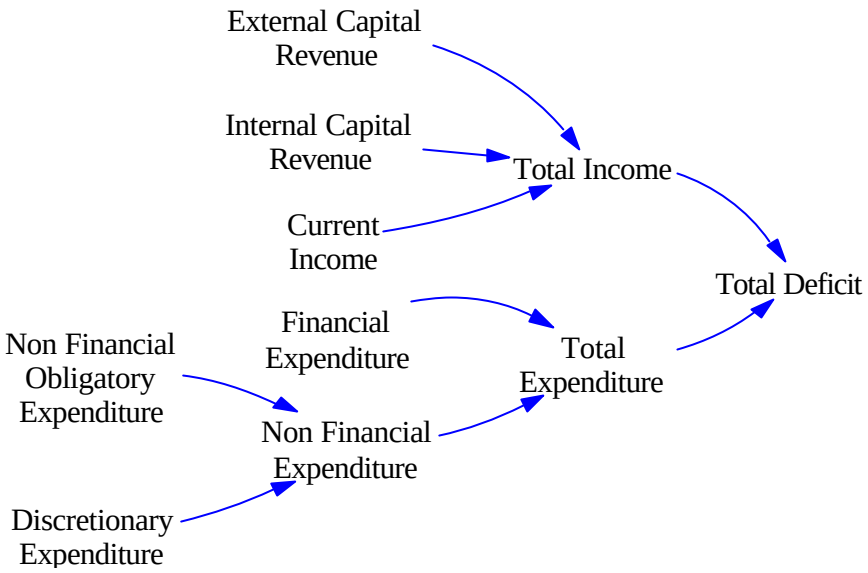

Figure 6. *Causal diagram of the "Debt Dynamics".*

Several variables are expressed as a fraction (percentage) of GDP:
- *Current Income*
- *Military Expenditure*
- *Non-financial Obligatory Expenditure*
- *Other Discretionary Expenditure*

In order to illustrate the variables in which GDP has influence, a Vensim Causes Tree of the model, for GDP, is shown in Figure 7.

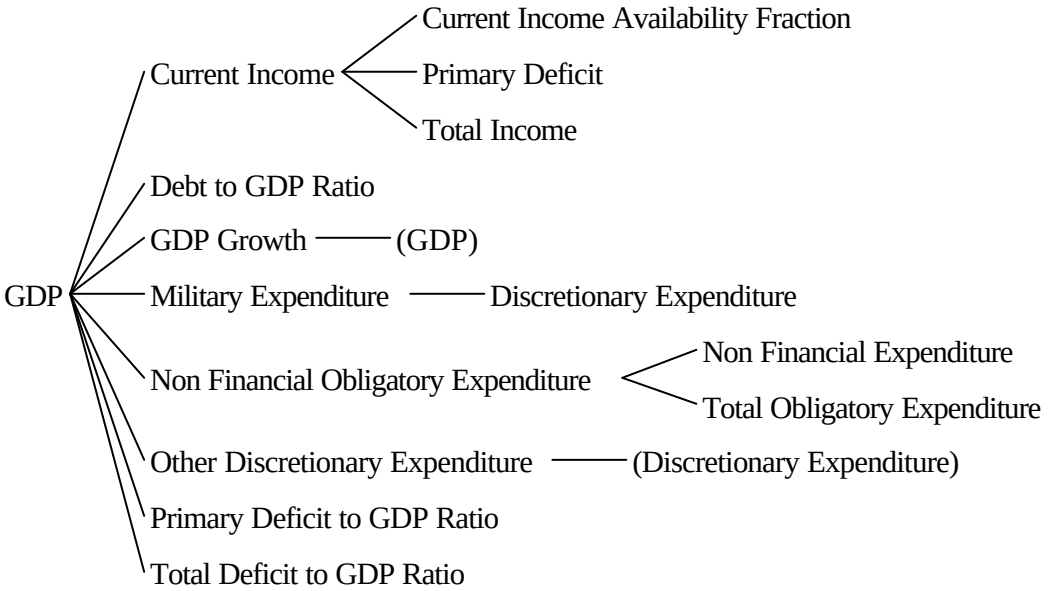

Figure 7. *Causes Tree for GNP*

Military Expenditure, a very important variable, taking into account the internal war in which Colombia is involved, is included in the model as part of the *Discretionary Expenditure*. Internal security and military expenditure have been viewed as determinant factors of the debt sustainability in Colombia (Sanchez, F., Barrera, C., 2002; Caballero, C.,2003). In a recent document, Caballero (2003), based on an econometric study carried out by Ramirez and Querubin (2003) and a study made by the Departamento de Programación Macroeconómica e Inflación del Banco de la República (2003), comes to the conclusion that a gradual increment of 1% of GDP in the military expenditure (currently 1.5% of GDP) until obtaining a level of 5% of GDP, is a necessary condition in order to achieve increments of 1.1% per year in the GDP Growth, in the period 2004-2010. This conclusion is taken as the basis for the structure of *Military Expenditure* in the model, shown in Figure 8, where

*Military Expenditure = GDP*Military Expenditure Factor*
Military Expenditure Factor = 0.015+STEP(0.005,2003)+RAMP(0.01,2004,2006)

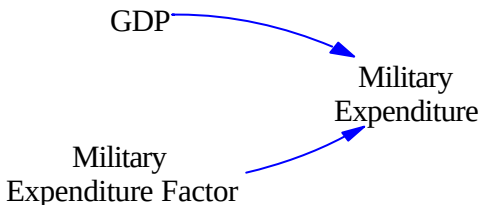

Figure 8. *Structure of Military Expenditure in the model*.

A main concern regarding military expense is its efficiency, defined as its capability to create the conditions for a consistent and significant economic growth. This concern has been included in the model as a new variable, *Military Expenditure Efficiency*, that affects the *Real GDP Growth Rate.* Another variable, *Maximum Growth Rate*, determines the maximum *Real GDP Growth Rate* achievable.
The *Military Expenditure Efficiency* structure is shown in Figure 9.

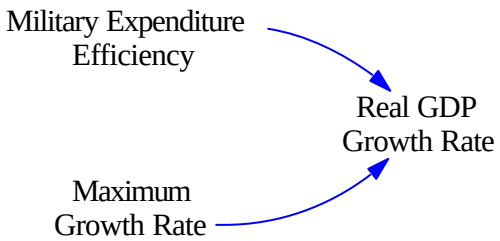

Figure 9. *"Military Expenditure Efficiency" structure.*

•*Real GDP Growth Rate = MIN(Maximum Growth Rate, 0.02+RAMP(0.01*Military Expenditure Efficiency, 2004,2014)*
• *Military Expenditure Efficiency = 1 (initial value – constant)*
• *Maximum Growth Rate = 0.045 (initial Value – constant)*

Ratios and other measures

Some variables in the model work as performance measures of the debt management. *Debt to GNP Ratio* is a standard measure, considered by international institutions in their analysis for granting credit and risk rating to developing countries. *Primary Deficit to GDP Ratio*, is a measure established and controlled by the International Monetary Fund (IMF) in all its credit agreements with developing countries because, from the point of view of the IMF, it gives an idea of how much a government is striving to maintain the debt in a sustainable level. *Total Deficit to GDP Ratio*, when compared with *Primary Deficit to GDP Ratio*, indicates the weight that the current debt service has in the debt performance. *Current Income Availability Fraction*, measures the "margin of maneuver" the government has in its fiscal decisions.

The equations for these measures are

• *Debt to GDP Ratio = Total Debt COP/ GDP*
• *Primary Deficit to GDP Ratio = Primary Deficit / GDP*
• *Total Deficit to GDP Ratio = Total Deficit / GDP*
• *Current Income Availability Fraction = (Current Income – Total Obligatory Expenses) / Current Income*

Initial Values

Where needed, initial values (for year 2002) were determined for several variables, gathering information from : Sanchez F., Barrera C. (2002), Banco de la República (2002), Departamento Nacional de Planeación (2003), Caballero C. (2003), Banco de la República (2003).

All the initial values were normalized with respect to an initial value of 100 for *GDP*.

•*GDP = 100*
• *Internal Debt = 24 (COP)*
• *External Debt = 0.008 (USD)*
• *Inflation Rate = 0.055*
•*Military Expenditure Efficiency = 1*
• *Maximum Growth Rate = 0.045*
• *Internal Debt Ratio = 0.5*
• *Average Int. Debt Maturity = 7*
• *Average Ext. Debt Maturity = 7*
•*Devaluation = 0.13*
• *Average External Interest Rate = 0.11*
• *Exchange Rate = 3000*

- *Current Income Growth Factor = 0.002*
- *Non-financial Obligatory Expenditure GDP Factor = 0.117*
- *Other Discretionary Expenditures GDP Factor = 0.044*
- *Military Expenditure = 0.015*

Sensitivity Analysis

In order to carry out a sensitivity analysis, a View named "Sensitivity Analysis" was constructed with sliders for each of the constants used in the model: *Maximum Growth Rate, Average External Interest Rate, Devaluation, Internal Debt Ratio, Average External Debt Maturity, Average Internal Debt Maturity, Current Income Growth Factor, Military Expenditure Efficiency, Non-financial Obligatory Expenditure GDP Factor, Other Discretionary Expenditure GNP Factor*. Additionally, a custom graph named "PERFORMANCE MEASURES" that shows the *Debt to GDP Ratio, Total Deficit to GNP Ratio*, *Primary Deficit to GNP Ratio* and *Current Income Availability Fraction*, is included. Figure 10 shows the "Sensitivity Analysis" View.

An univariate sensitivity analysis was carried out using the sliders of the Sensitivity Analysis View and looking at the performance of the curves in the PERFORMANCE MEASURES custom graph. Afterwards, a multivariate analysis, using plausible combination of variables was made.

For the purpose of the analysis, a debt is considered sustainable when a constant, rather than ever increasing, *Debt to GDP Ratio* is generated. This definition of sustainability is used by Cuddington (1996) from what he call "an accounting point of view", which is compatible with the financial approach assumed in this document.

As was mentioned above, *Current Income Availability Fraction* determines the fiscal "margin of maneuver".

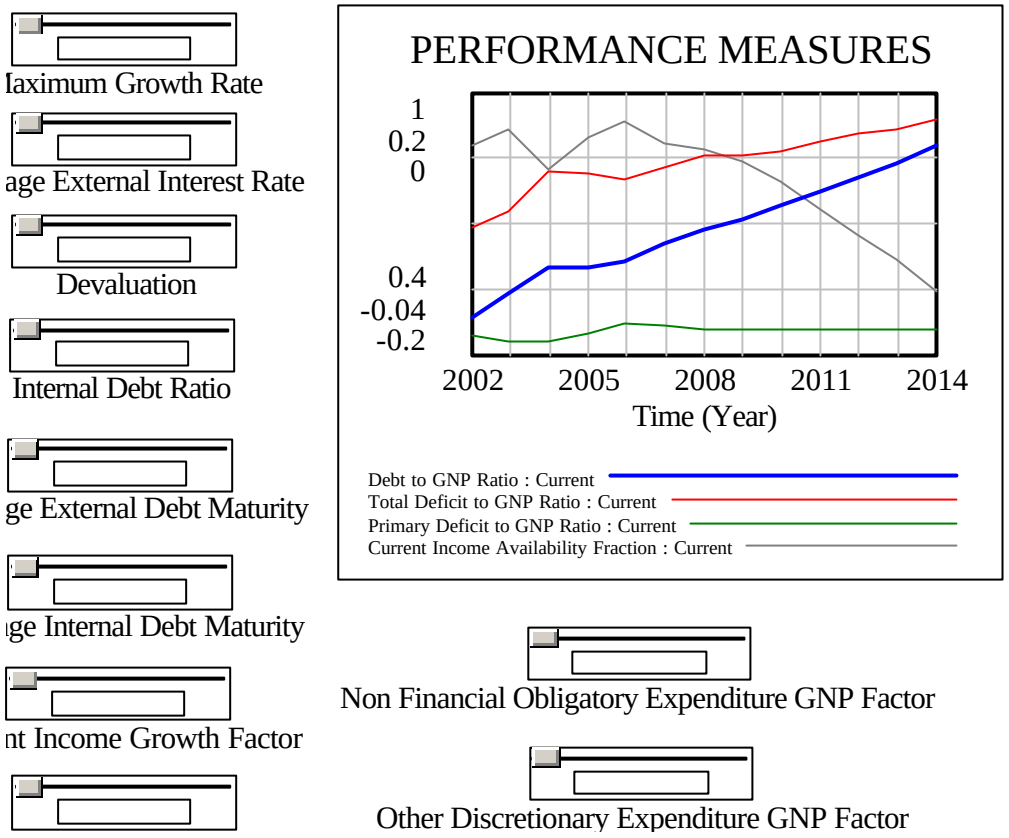

Figure 10. *Sensitivity Analysis View*

The results of the univariate analysis are shown in Table1. I have included those variables which, at a specific level, allow to obtain a sustainable *Debt/GDP Ratio* and *Total Deficit/GDP Ratio*. For example, *Maximum Growth Rate* at a level of 9.0%, produces a "sustainable" *Debt/GDP Ratio* of 71% and a "sustainable" *Total Deficit/GDP Ratio* of 14%.

Variable	Value	Debt/GDP sustainable level	Deficit/GDP sustainable level
Maximum Growth Rate	0.09	0.71	0.14
External Interest Rate	0.04	0.58	0.08
Devaluation	0.11	0.53	0.10
Internal Debt Ratio	0.76	0.60	0.11
External Debt Maturity	3.0	0.52	0.15
Current Income Growth Factor	0.015	0.68	0.09
Non financial Obligatory Expenditure Factor	0.074	0.55	0.07

Table 1. *Results obtained modifying only one variable each time (univariate analysis)*

The results of one multivariate analysis are summarized in Table 2. Based on the results of the univariate analysis, *Devaluation* and *Internal Debt Ratio* were chosen for the analysis and changed to a value of 0.09 and 0.6 respectively. *Devaluation* was chosen due to its high influence over the sustainability level. *Internal Debt Ratio* was chosen because, given an unrestricted acces to domestic and foreign sources of credit, this variable depends only on a fiscal decision. Sustainable levels of *Debt/GDP Ratio* (52%) and *Deficit/GDP Ratio* (10%) were obtained, even with a reduction of *Maximum Growth Rate* to 3% and *Military Expenditure Efficiency* to 60%, and with an increase in *Other Discretionary Expenditures GDP Factor* to 6% (from 4.4.%). The custom graph RATIOS AND INDEXES for this analysis, is shown in Figure 11.

Variable	Value	Debt/GDP sustainable level	Deficit/GDP sustainable level
Maximum Growth Rate	0.03	**0.52**	**0.10**
External Interest Rate	0.11		
Devaluation	**0.09**		
Internal Debt Ratio	**0.60**		
External Debt Maturity Current Income Growth Factor	7.0 0.002		
Non financial Obligatory Expenditure Factor	0.117		

Table 2. *Results of one multivariate analysis. Maximum Growth Rate was reduced to 0.03, Military Expenditure Efficiency was reduced to 0.6, and Other Discretionary Expenditures GDP Factor was increased to 0.06*

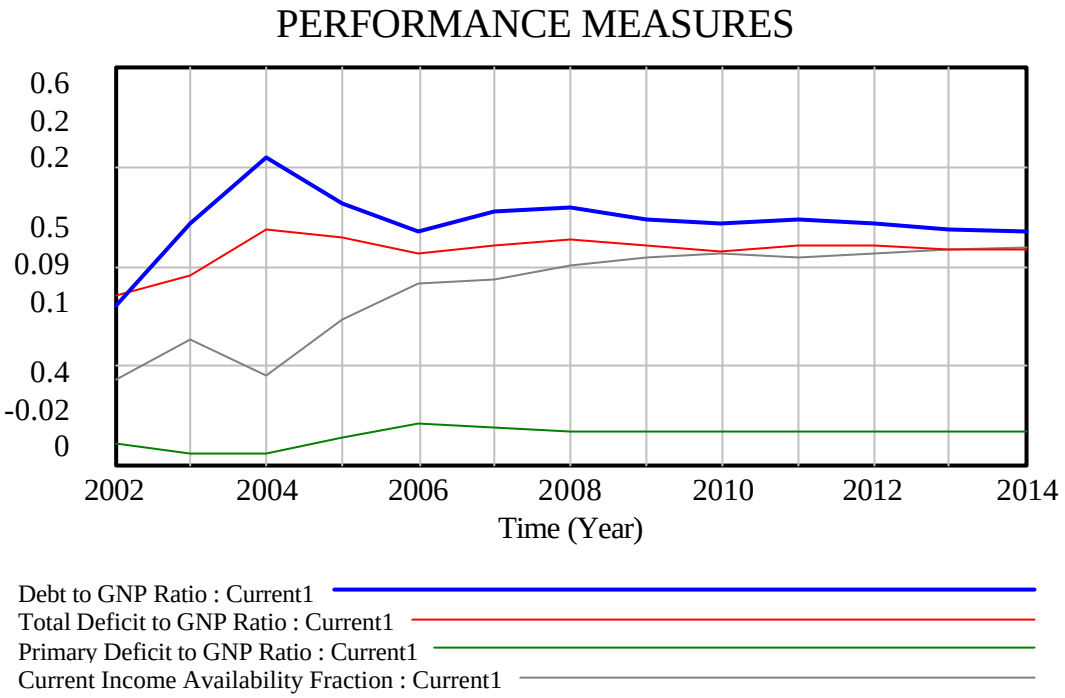

Figure 11. *Ratios and Indexes graph for the multivariate analysis described in Table 2.*

Conclusions

System dynamics models permit the simultaneous inclusion of variables and feedback relationships that have high importance in the analysis of public debt sustainability, allowing us to look at their dynamic patterns.

Models based on system dynamics can be a powerful tool for policy makers striving to formulate policies that result in a sustainable management of the public debt in developing countries. These policies can give policy makers insights that help them to identify high leverage variables in order to obtain an adequate management of the debt with the minimum possible sacrifice of people's well being.

In the case of Colombia, the influence of military expenditure and its efficiency, on macroeconomic variables, should be a matter of further research.

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