

A stock-flow ecological model for Central America

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Abstract

This article presents a stock-flow consistent model for the Central American economies. It is part of a project to develop a stock-flow consistent workhorse model applicable to different country cases in Latin America and the Caribbean. The model's logical and behavioural relationships are based on a set of stylized facts characterizing the Central American economies. The model includes five institutional sectors (consumers, firms, the government, the central bank and the rest of the world). The five sectors trade in seven financial assets: (i) public debt issued in domestic and foreign currencies, (ii) private debt issued in domestic currency, (iii) debt issued by the rest of the world, (iv) bank loans to the private sector for investment and consumer credit, (v) government and private deposits, (vi) loans from the rest of the world borrowed by the domestic financial sector, and (vii) cash. Given the importance of climate-related effects for Central America, our stock-flow model includes an ecological module.

Keywords

Economic trends, economic conditions, macroeconomics, mathematical models, ecology, climate change, energy resources, energy policy, Central America

JEL classification

Q54, Q43, E12, N16

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I. Introduction

This article presents a stock-flow consistent model for the economies of Central America. The article builds on our previous work and is part of a longer-term project to develop a stock-flow consistent workhorse model for different country cases in Latin America and the Caribbean.²

The stock-flow modelling tradition builds on “a fundamental law of macroeconomics”: that stocks and flows must satisfy the constraints both of individuals and of the economy in the aggregate to ensure that all existing constraints are mutually compatible (Godley and Cripps, 1983, p. 18). This implies that only certain configurations of transactions can be mutually compatible for all economic agents considered in the model. The consistency framework does not require satisfying particular *ex ante* equilibrium conditions. There are no black holes or tacit assumptions in the model. As explained by Godley (1999, p. 394) “every flow comes from somewhere and goes somewhere”.

The logical and behavioural relationships specified in our consistent stock-flow model are largely based on a set of stylized facts characterizing the Central American economies. This builds on the notion that macroeconomic processes are dependent on the historical evolution of countries, their institutions, their productive structures and their international insertion patterns. Given the importance of climate-related effects in shaping the performance of smaller economies, including those of Central America, our stock-flow model includes an ecological and energy module.

The model includes five institutional sectors: (i) the private sector, comprising consumers and firms, (ii) the financial sector, (iii) the government, (iv) the central bank, and (v) the rest of the world. The five sectors trade in seven financial assets: (i) public debt issued in domestic and foreign currencies, (ii) private debt issued in domestic currency, (iii) debt issued by the rest of the world, (iv) bank loans to the private sector for investment and consumer credit, (v) government and private deposits, (vi) loans from the rest of the world borrowed by the domestic financial sector, and (vii) cash.

The paper is divided into eight sections. The second section explains the logic and main features of stock-flow modelling and our approach to modelling the Central American economies. The third section presents key stylized facts of Central American economies that are included in the model’s specification. The fourth section describes our stock-flow consistent model and its main equations by institutional sector. The fifth section delineates the working logic and causality of our model. Owing to space limitations, the paper does not include the specification of the full model, which comprises 214 equations.³ The sixth section incorporates the ecological module into the model through a damage function and makes explicit its linkages with real and monetary variables. The seventh section shows selected simulations of the model with climate change. The final section offers a series of conclusions.

II. Stock-flow consistent modelling and its underlying logic

Stock-flow consistent models have advantages over other modelling traditions and alternatives. The stock-flow modelling tradition builds on “a fundamental law of macroeconomics analogous to the principle of conservation of energy in physics” (Godley and Cripps, 1983, p. 18). Stocks and flows must satisfy both the constraints of individuals and of the economy in the aggregate, so that all the constraints are mutually compatible (Godley and Cripps, 1983, p. 18). Thus, only certain configurations of transactions are mutually compatible for all economic agents.

² See also Baltodano (2017) for an application of stock-flow models to Central America.

³ The authors can provide the full specification of the model on request.

The constraints placed on individuals and at the aggregate level are satisfied through the workings of one single behavioural axiom that states that the ratio of stock to flow variables, while not invariant, remains stable over time. Stock-flow norms have important implications for the model's internal working logic.⁴

One stock-flow norm is the average time the full effects of an expansion in aggregate demand are felt throughout an economy leading to the establishment of a steady state (Godley and Cripps, 1983). Another important stock-flow norm comes from treating the consumption function as a wealth function (Godley and Lavoie, 2007, pp. 74–75). In continuous terms, wealth accumulation $\left(\frac{dNW}{dt}\right)$ (where NW = net worth) is given by the difference between consumption (C) and disposable income (D), $C - D$.⁵ Consumption is specified as a function of disposable income and net worth, $C = \alpha_1 D + \alpha_2 NW$. $C - D = \alpha_1 D - \alpha_2 NW - D$. Rearranging terms we obtain: $C - D = D(1 - \alpha_1) - \alpha_2 NW \Leftrightarrow \alpha_3(\alpha_3 D - NW)$, where $\alpha_3 = \left(\frac{1 - \alpha_1}{\alpha_2}\right)$. As explained by Godley and Lavoie (2007, p. 75): “that wealth is being accumulated at a certain rate, determined by the partial adjustment parameter α_2 , towards some desired proportion α_3 of disposable income.” We set $C - D$ to obtain a target level of wealth \overline{NW} . The solution yields $\overline{NW} = \frac{\overline{D}(1 - \alpha_1)}{\alpha_2} = \alpha_3 \overline{D}$, where α_3 is the stock-flow norm for household consumption. A key implication of this stock-flow norm is that the level of savings depends on the difference between the target level of wealth (\overline{NW}) and the realized level of wealth (NW_R), $S = \overline{NW} - NW_R$.

Stock-flow norms are exogenous and, as a result, some of the model's major propositions are the result of logically inevitable conclusions. Logical relationships take precedence over behavioural ones. The former provide the framework for the functioning of behavioural relationships, making their specification in terms of microeconomic foundations redundant. The consistency between the plans and expectations of the different agents or sectors and the outcomes are reconciled through the financial system, which adapts endogenously to the demand for liquidity.⁶

Stock-flow consistent modelling begins by specifying transactions, flow-of-funds and balance sheet matrices that incorporate transactions between different agents (i.e. flows) and their corresponding balance sheet holding gains or losses (i.e. stocks).

The rows of the matrices represent money transactions between agents for each good, service or asset considered in the model. A negative sign in a row signifies a source of expenditure, and a positive sign indicates a destination of expenditure. As a result, as Godley (1999, p. 394) points out, “every flow comes from somewhere and goes somewhere”. To ensure the consistency of the macroeconomic framework, all rows must total zero. The columns are defined by the sectors or agents considered in the model and represent their budget constraint. For this reason, they must also total zero. The counterpart of each sector's budget constraint is the generation of changes in stocks of assets and liabilities. These appear as changes in agents' balance sheets.

Our paper focuses on smaller economies, exemplified by means of Central American country source cases.⁷ The analysis complements the existing literature on stock-flow models for Latin America and the Caribbean, which have focused mainly on the region's larger economies (see diagram 1).⁸

⁴ The following four are among the basic principles of stock-flow modelling: (i) flow consistency: every flow originates somewhere and goes somewhere; (ii) stock consistency: the liabilities of one sector are the assets of another sector; (iii) stock-flow consistency: end-of-period stocks include the accumulation of flows and capital gains; and (iv) every transaction implies a quadruple entry (Zeza, 2017).

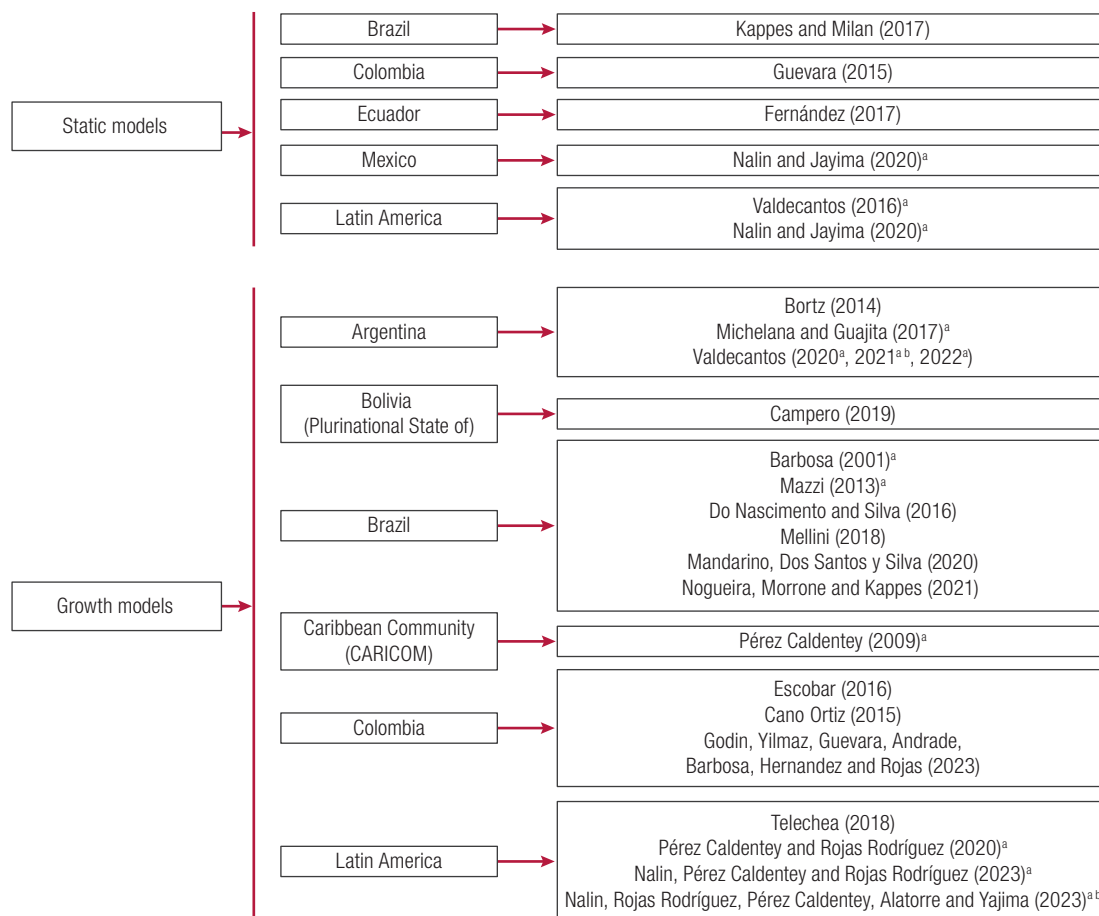
⁵ See Taylor (2008).

⁶ See Godley (2012). In neoclassical economics, the reconciliation of agents' consumption or production plans occurs in equilibrium through the workings of the anthropomorphic version of the invisible hand, the auctioneer. Trade does not occur in disequilibrium. Obviously, the financial system responds to the demand for loans, as long as they have collateral, so that there will be a “fringe of unsatisfied borrowers”.

⁷ Our analysis includes the Dominican Republic.

⁸ See annex A1 for a more complete description of these models.

Diagram 1
Stock-flow consistent models for Latin America and the Caribbean



Source: Prepared by the authors, on the basis of S. A. Kappes and M. Milan, "Fiscal policy rules in a stock-flow consistent model", *Brazilian Keynesian Review*, vol. 3, No. 2, January 2017; D. A. Guevara Castañeda, "Auge de las finanzas y desigualdad en la distribución del ingreso: un estudio desde la perspectiva de la financiarización para Colombia 1980-2008", doctoral thesis, National University of Colombia, 2015; J. Fernández, "Elementos de análisis para la sostenibilidad de una economía dolarizada", *Revista Economía*, vol. 69, No. 109, May 2017; L. Nalin and G. T. Yajima, "Balance sheet effects of a currency devaluation: a stock-flow consistent framework for Mexico", *Working Paper*, No. 980, Levy Economics Institute, 2020; S. Valdecantos, "Estructura productiva y vulnerabilidad externa: un modelo estructuralista stock-flujo consistente", *Studies and Perspectives series-ECLAC Office in Buenos Aires*, No. 46 (LC/L.4171-LC/BUE/L.225), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2016; P. G. Bortz, "Foreign debt, distribution, inflation and growth in a SFC model", *European Journal of Economics and Economic Policies: Intervention*, vol. 11, No. 3, December 2014; G. Michelena and N. Guaita, "Modelo de stock-flujo consistente para el análisis macroeconómico (SFARG)", *Documento de Trabajo*, Ministry of Production of Argentina, 2017; S. Valdecantos, "Argentina's (macroeconomic?) trap", *Working Paper*, No. 975, Levy Economics Institute, 2020; S. Valdecantos, "Grasping Argentina's green transition: insights from a stock-flow consistent input-output model", *Working Paper Series*, No. 4, Macroeconomic Methodology, Theory and Economic Policy (MaMTEP), Aalborg University Business School, 2021; S. Valdecantos, "Endogenous exchange rates in empirical stock-flow consistent models for peripheral economies: an illustration from the case of Argentina", *Journal of Post Keynesian Economics*, vol. 45, No. 4, August 2022; S. Campero Encinas, "Modelo stock flow consistent (SFC) aplicado al caso del sector de los hidrocarburos en Bolivia", master's thesis, Latin American Faculty of Social Sciences in Ecuador (FLACSO Ecuador), 2019; N. H. Barbosa, "International liquidity and growth in Brazil", *CEPA Working Paper*, No. 2001.4, New York, Center for Economic Policy Analysis (CEPA), 2001; C. T. Mazzi, "Um modelo stock-flow consistent (SFC) com crescimento restrito pelo balanço de pagamentos", master's thesis, University of Campinas (UNICAMP), 2013; P. F. Do Nascimento and A. C. M. Silva, "Financeirização e crescimento: alguns experimentos stock-flow consistent", *Anais do XLII Encontro Nacional de Economia*, National Association of Postgraduate Programs in Economics (ANPEC), 2016; A. Mellini, "Política fiscal, equilíbrio externo e déficits gêmeos em um modelo stock-flow consistent póskeynesiano com economia aberta", master's thesis, Federal University of Uberlândia, 2018; G. V. Mandarino, C. H. Dos Santos and A. C. M. Silva, "Workers' debt-financed consumption: a supermultiplier stock-flow consistent model", *Review of Keynesian Economics*, vol. 8, No. 3, July 2020; D. Nogueira Silva, H. Morrone and S. Kappes, "Assessing pension system outcomes in Brazil: a stock-flow consistent analysis", *Brazilian Keynesian Review*, vol. 7, No. 2, 2021; E. Pérez Caldentey, "Balance of payments constrained growth within a consistent stock-flow framework: an application to the economies of

CARICOM”, *Caribbean Development Report. Volume I*, Project Documents (LC/W.249), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2009; A. Escobar, “Stock-flow consistent models for developing countries: the case of Colombia”, paper presented at the nineteenth Annual Conference on Global Economic Analysis, Washington, D.C., World Bank, 2016; D. Cano Ortiz, “Regla fiscal y choques externos en Colombia: un modelo de consistencia stock-flujo”, master’s thesis, National University of Colombia, 2015; A. Godin and others, “Can Colombia cope with a global low carbon transition?”, *Research Papers*, No. 285, Paris, French Development Agency (AFD), 2023; J. M. Telechea, “¿Cuál es el esquema macroeconómico adecuado para los países latinoamericanos?: una aproximación a partir de un modelo Stock Flujo Consistente”, master’s thesis, National University of San Martín (UNSAM), 2018; E. Pérez Caldentey and L. Rojas Rodríguez, “A stock-flow approach to investment requirements within balance-of-payments constrained growth”, *Project Documents* (LC/TS.2020/152), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2020; E. Pérez Caldentey, L. Nalin and L. Rojas, “A baseline stock-flow model for the analysis of macroprudential regulation guidelines and policies for Latin America and the Caribbean”, *Financial openness, financial fragility and policies for economic stability: a comparative analysis across regions of the developing world*, Project Documents (LC/TS.2022/139), E. Pérez Caldentey (ed.), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC), 2023; L. Nalin and others, “A stock flow ecological model from a Latin American perspective”, *Working Paper*, No. 1031, Levy Economics Institute, 2023.

Note: See also Lage, Romero and Villarreal (2023) for a hybrid stock-flow model applied to the Cuban economy.

^a Stock-flow consistent models that include Thirlwall’s law.

^b Stock-flow consistent models that include variables related to environmental or climate-change phenomena.

The logical and behavioural relationships of our consistent stock-flow model are largely based on a set of stylized facts characterizing smaller economies. This builds on the notion that macroeconomic processes are dependent on the historical evolution of countries, their institutions, their productive structures and their international insertion patterns.

Given the importance of climate-related effects in shaping the performance of smaller economies, including those of Central America, our stock-flow model includes an ecological and energy module based on the work of Carnevali and others (2021) and Dafermos, Nikolaidi and Galanis (2017). Natural disasters lead to the destruction of capital and productive capacity, economic divergence with persistent negative effects over time and increased debt. Economies that are more vulnerable to recurrent disasters can enter a vicious circle in which they tend to converge, in the long run, on lower levels of economic growth and poverty traps.⁹ Countries affected by natural disasters see their debt levels increase in the three subsequent years by, on average, between 2.3 and 3.6 percentage points of GDP compared to countries that do not experience such disasters.¹⁰

In the Latin American and Caribbean region, analyses based on stock-flow consistent models that include the ecological dimension remain embryonic. Only three papers address this issue (Godin and others, 2023; Nalin and others, 2023; and Valdecantos, 2021).

III. Selected key stylized facts of smaller economies in Latin America and the Caribbean

A key feature of developing economies is that they do not issue reserve currencies. Also, in general, for this group of economies —and especially for smaller economies— the import elasticity of income is higher than the export elasticity of income. As a result, these economies face a binding long-run balance-of-payments constraint. This prevents them from attaining the maximum expansion of output from the supply side and entails the existence of excess capacity, low rates of accumulation and of technical progress and the presence of unemployment, underemployment and informality. Informality is present in all economic sectors and is a central determinant of tax evasion and avoidance.

Depending on the time period and the specific circumstances, the external constraint may bite on the current account or on the financial side of the balance of payments. Smaller economies traditionally present recurrent current account deficits. They also depend heavily on external financial inflows; i.e. on flows of external debt.

⁹ See Rivas Valdivia (2014).

¹⁰ See Fan and others (2022).

This exposes countries' performance and the evolution of their debt to changes in the determinants of interest rate differentials, including country risk. Insofar as causality exists between sovereign risk and non-financial corporate sector risk, a change in sovereign risk levels also pushes up the cost of borrowing for the public and private non-financial corporate sector. This tightens the financial constraint of both sectors, while negatively impacting gross fixed capital formation and, consequently, the capacity to raise revenues. Most Central American countries have speculative or highly speculative sovereign credit ratings.

A key consequence of a binding external constraint is that for a given ratio of the income elasticity of exports relative to the income elasticity of imports, the long-term domestic rate of growth of a country's GDP is determined by the rate of growth of its most important bilateral economic partner. In the case of Central America, the rate of GDP growth of the United States is the best proxy for that of the rest of the world.

In addition, the economic cycles of most Central American countries closely follow that of the United States. With the exception of Panama and Nicaragua, the correlation coefficients between the GDP growth rate of the Central American countries and that of the United States are statistically significant. When real gross national disposable income (RGNDI) is used instead of GDP as a measure of economic activity for the Central American countries, all the correlation coefficients — without exception — are statistically significant (see table 1).¹¹ The rationale for using RGNDI is explained below.

Table 1
Correlation coefficient between rates of change in GDP and real gross national disposable income of Central American countries and rate of change in real GDP of United States, 1961–2022

Country	Gross domestic product (GDP) 1961–2022	Real gross national disposable income (RGNDI) 1991–2021
Costa Rica	0.61**	0.37**
Dominican Republic	0.19*	0.59**
El Salvador	0.51**	0.55**
Guatemala	0.39**	0.25*
Honduras	0.67**	0.61**
Nicaragua	0.13	0.25*
Panama	0.15	0.30**

Source: Prepared by the authors, on the basis of World Bank, "World Development Indicators", 2024 [online database] <https://databank.worldbank.org/source/world-development-indicators> and data from the Economic Commission for Latin America and the Caribbean (ECLAC).

Note: The statistical significance of the correlation coefficient was determined using the formula $\rho = \frac{r(\sqrt{n-2})}{\sqrt{1-r^2}}$, where r is the simple correlation coefficient and n the number of observations. ρ follows a student- t distribution with $n-2$ degrees of freedom. ** and * denote significance at the 5% and 1% levels, respectively. The Dominican Republic is included as a Central American country.

The external insertion of the Central American countries is driven in part by the export of labour to the United States, the counterpart of which is remittance inflows. In 2022, remittances represented 9%, 24%, 19%, 27% and 21% of GDP for the Dominican Republic, El Salvador, Guatemala, Honduras and Nicaragua, respectively.

¹¹ In the case of the United States, since the net factor of payments to the rest of the world ($NPRW_t$) current transfers (CT_t) and the terms-of-trade effect (TTE_t) do not have any significant impact on the economy's performance, the choice between GDP or RGNDI makes little difference to the analysis.

The importance of remittances suggests complementing GDP-based analyses of economic and debt performance with analyses based on RGNDI.¹² Real gross national disposable income ($RGNDI_t$) equals the sum of gross domestic product (GDP_t), the net factor of payments to the rest of the world ($NPRW_t$), current transfers (CT_t) and the terms-of-trade effect (TTE_t).¹³ Formally:

$$RGNDI_t = GDP_t + NPRW_t + CT_t + TTE_t \quad (1)$$

The terms-of-trade effect equals the volume of goods and services exports (X_t) (or exports at constant prices) multiplied by the change in the trade price index:

$$TTE_t = X_t \frac{(P_x - P_m)}{P_m} = X_t \left(\frac{P_x}{P_m} - 1 \right) \quad (2)^{14}$$

Where P_x , P_m unit price indices for exports and imports. Substituting equation (2) into equation (1) yields:

$$RGNDI_t = GDP_t + NPRW_t + CT_t + X_t \left(\frac{P_x}{P_m} - 1 \right) \quad (3)$$

According to equation (3), other factors remaining equal, an improvement in the terms of trade $\left(\Delta \frac{P_x}{P_m} \right)$ translates into a rise in real gross national disposable income ($RGNDI_t$). Through equation (3), the difference between gross national disposable income ($RGNDI_t$) and gross domestic product (GDP_t) can be broken down into net factor payments to the rest of the world ($NPRW_t$) current transfers (CT_t) and the terms-of-trade effect (TTE_t).

The importance of including real gross national disposable income in our analysis can be seen by comparing the impact of the coronavirus disease (COVID-19) pandemic on the rate of growth of the economies of Central America and the Dominican Republic in 2020 using GDP and RGNDI. In all cases, the use of GDP overstates the economic impact of COVID-19 because it does not account for the countercyclical role of remittances (see figure 1). Between 2019 and 2020, with the exception of Costa Rica, remittance inflows increased in all the countries of the study subset. Moreover, Costa Rica is the country that registered the smallest difference in the impact of COVID-19 measured by GDP versus RGNDI.

¹² Godley and Cripps (1983) emphasize the use of RGNDI in an open economy.

¹³ All the components of RGNDI are expressed in real terms.

¹⁴ The terms of trade effect can be derived from:

$$TTE = \left(\frac{X-M}{P} \right) - \left(\frac{X}{P_x} - \frac{M}{P_m} \right) \quad (4)$$

Where:

X = value of exports of goods and services

M = value of imports of goods and services

P = price deflator

p_x = export price index using a base value of 1

p_m = import price index using a base value of 1

$$\Leftrightarrow TTE = x \left(\frac{p_x}{P} - 1 \right) + m \left(1 - \frac{p_m}{P} \right) \quad (5)$$

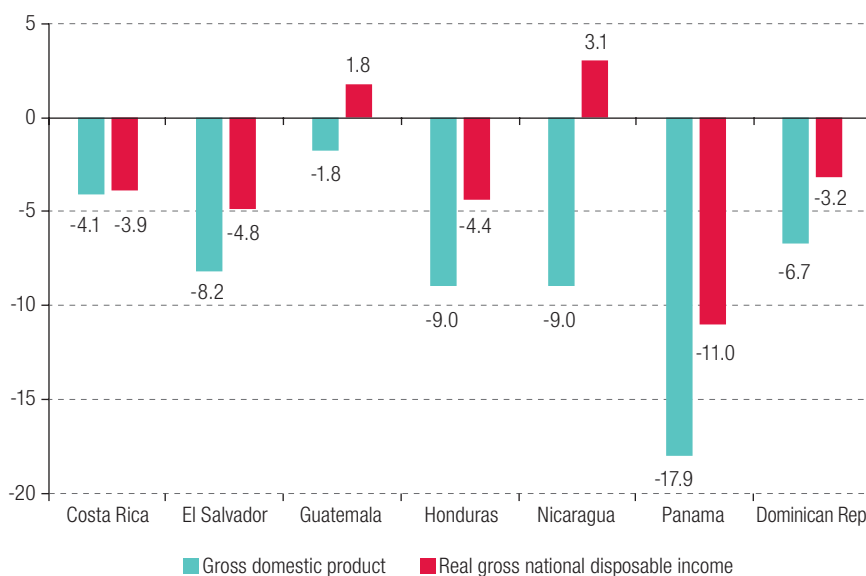
Where:

$$x = \frac{X}{P_x}; m = \frac{M}{P_m}$$

Assuming that the price deflator equals the price of imports, $P = p_m$, equation (4) can be simplified as:

$$TTE = x \left(\frac{p_x}{p_m} - 1 \right) \quad (6)$$

Figure 1
Rate of growth of GDP and real gross national disposable income
of Central American countries and the Dominican Republic, 2020
(Percentages)



Source: Prepared by the authors, on the basis of data from the Economic Commission for Latin America and the Caribbean (ECLAC).

The advantages of using RGNDI to complement GDP — or as an alternative to it— in gauging economic performance are also apparent when RGNDI is used to standardize the main macroeconomic ratios that are traditionally used to assess an economy's degree of disequilibrium or sustainability. These ratios include the fiscal deficit, account deficits and debt relative to output and income metrics (see table 2).

Table 2
Central America and the Dominican Republic: selected macroeconomic indicators, 1990–2021

Country	1990–2000	2000–2010	2010–2021
Rate of growth of real GDP			
Costa Rica	4.8	4.4	3.5
Dominican Republic	5.0	4.7	5.1
El Salvador	3.5	1.6	2.4
Guatemala	4.0	3.4	3.5
Honduras	3.2	4.4	3.4
Nicaragua	3.1	3.1	3.6
Panama	5.5	5.6	5.5
Rate of growth of RGNDI			
Costa Rica	4.7	4.3	3.2
Dominican Republic	6.8	4.5	5.4
El Salvador	4.1	1.3	2.2
Guatemala	4.8	4.0	4.3
Honduras	4.0	4.0	3.8
Nicaragua	3.9	3.0	4.1
Panama	4.5	4.8	4.8

Country	1990–2000	2000–2010	2010–2021
Current account as a percentage of GDP			
Costa Rica	-4.3	-4.5	-3.3
Dominican Republic	-2.4	-2.9	-3.3
El Salvador	-2.5	-4.3	-3.4
Guatemala	-5.1	-4.5	-0.4
Honduras	-4.8	-6.5	-4.9
Nicaragua	-17.6	-13.5	-6.2
Panama	-3.6	-4.8	-7.6
Current account as a percentage of RGNDI			
Costa Rica	-4.2	-4.6	-3.4
Dominican Republic	-2.3	-2.8	-3.2
El Salvador	-2.2	-3.7	-2.9
Guatemala	-4.8	-4.1	-0.4
Honduras	-4.8	-5.8	-4.4
Nicaragua	-17.9	-12.5	-5.7
Panama	-3.3	-4.8	-8.4
Government debt stock as a percentage of GDP			
Costa Rica	37.9	29.6	39.2
Dominican Republic	29.1	24.4	37.6
El Salvador	34.6	57.2	66.5
Guatemala	28.0	31.9	33.0
Honduras	96.4	49.5	35.7
Nicaragua	222.4	90.6	94.1
Panama	70.3	86.3	147.8
Government debt stock as a percentage of RGNDI			
Costa Rica	37.5	30.2	40.4
Dominican Republic	28.3	23.6	36.3
El Salvador	31.1	49.7	57.6
Guatemala	26.4	28.5	29.8
Honduras	95.8	44.8	31.4
Nicaragua	228.3	84.2	86.5
Panama	65.5	85.7	166.8

Source: Prepared by the authors, on the basis of World Bank, “World Development Indicators”, 2024 [online database] <https://databank.worldbank.org/source/world-development-indicators> and data from the Economic Commission for Latin America and the Caribbean (ECLAC).

Note: The figures in bold highlight the different results obtained when using GDP and RGNDI to assess the economic performance of an economy.

Besides playing a countercyclical role and thus dampening the impact of external shocks on the domestic economy, remittances are essential in maintaining nominal exchange rate stability. Generally, remittance recipients change United States dollars into local currency through the local banking system. In turn, the banking system must surrender a significant part of its foreign currency holdings to the central bank, allowing the latter to strengthen its international reserve stock and to intervene, when necessary, in the foreign exchange market.¹⁵

In smaller economies, such as those of the Central American isthmus, the nominal exchange rate plays the role of a “nominal anchor”. At the same time, the stability of the exchange rate is central in avoiding unwanted increases in the central government’s external debt and debt service payments, which could constrain its capacity to deliver public goods. Maintaining the stability of the exchange rate also helps maintain the financial stability of the non-financial corporate sector.

¹⁵ The percentage of foreign currency that banks must surrender to the central bank can amount to 50% or more of their total foreign currency holdings.

IV. The description of the stock-flow consistent (SFC) model

Our stock-flow consistent (SFC) model includes five institutional sectors: (i) the private sector, comprising consumers and firms, (ii) the financial sector, (iii) the government, (iv) the central bank, and (v) the rest of the world. These five sectors trade in seven financial assets: (i) public debt issued in domestic and foreign currencies, (ii) private debt issued in domestic currency, (iii) debt issued by the rest of the world, (iv) bank loans to the private sector for investment and consumer credit, (v) government and private deposits, (vi) loans from the rest of the world borrowed by the domestic financial sector, and (vii) cash.

The transactions among the five institutional sectors with their respective instruments are captured in the transactions flow matrix (see table 3). As explained in section II, all rows (money flows by expenditure categories) and columns (budget constraint plus savings or dissaving sources) must add up to zero. A minus sign indicates the use of funds and a plus sign indicates a source of funds. The main assumptions and behavioural relationships of each of the five sectors is described in the remainder of this section.

Table 3
Transactions and balance sheet matrices

	Production	Private sector		Financial sector		Government sector		Central bank		Rest of the world	Σ
		Current	Capital	Current	Capital	Current	Capital	Current	Capital		
Consumption	$+C_d$	$-C_d$									0
[Wage bill]	$[-WB]$	$[+WB]$									
Investment	$+I^k$		$-I^k$								0
[Taxes]		$[-T_p]$		$[-T_{fs}]$		$[+T]$					
Government spending	$+G_d$					$-G_d$					0
Imports	$-IM$									$+IM$	0
Exports	$+X$									$-X$	0
[GDP]	$[-Y]$	$[+Y]$									$[Y]$
Interest on											
Government bonds (domestic currency)		$+int_p^g$		$+int_{fs}^g$		$-int^g$		$+int_{bc}^g$		$+int_{row}^g$	0
Government bonds (foreign currency)		$+int_p^{sg}$		$+int_{fs}^{sg}$		$-int^{sg}$				$+int_{row}^{sg}$	0
Private debt		$-int^p$		$+int_{fs}^p$		$+int_g^p$				$+int_{row}^p$	0
Private debt in foreign currency		$-int^{sp}$								$+int_{row}^{sp}$	0
Bonds from the rest of the world		$+int_p^{row}$		$+int_{fs}^{row}$				$+int_{bc}^{row}$		$-int^{row}$	0
Public deposits						$+int_{mm_g}^{cb}$		$-int_{mm_g}^{cb}$			0
Private deposits		$+int_{mm_p}^{fs}$		$-int_{mm_p}^{fs}$							0
Consumption credit		$-intc^p$		$+intc_{fs}^p$							0
Advances				$-int^{afs}$				$+int_{cb}^{afs}$			0
Loans		$-int^{lp}$		$+int^{lp}$							0
Loans (foreign currency)				$-int^{slfs}$						$+int^{slfs}$	0

Production	Private sector		Financial sector		Government sector		Central bank		Rest of the world	Σ
	Current	Capital	Current	Capital	Current	Capital	Current	Capital		
Financial gains (dividends)	$+F-fr-fdc$				$+FB_g^{bc}$		$-FB^{bc}$			0
Remittances	$+rem$									$-rem$
[Gross national income]	$[GNI]$		$[GNI_{fs}]$		$[GNI_g]$					$[GNI]$
Taxes	$-T$		$-T$		$+T$					0
Capital	$+K$									$-K$
Inventories	$+IN$									$-IN$
Government bonds (domestic currency)		$-B_p^g$		$-B_{fs}^g$	$+B^g$		$-B_{bc}^g$		$-B_{row}^g$	0
Government bonds (foreign currency)		$-B_p^{sg}$		$-B_{fs}^{sg}$	$+B^{sg}$				$-B_{row}^{sg}$	0
Private debt		$+D^p$		$-D_{fs}^p$	$-D_g^p$				$-D_{ro}^p$	0
Private debt (foreign currency)		$+D^s$							$-D_{row}^s$	0
Bonds from the rest of the world		$-B_p^{row}$		$-B_{fs}^{row}$			$-B_{bc}^{row}$		B^{row}	0
Public deposits						$-M^g$		$+M^g$		0
Consumption credit		$+Cc$		$-Cc$						
Advances				$+A^{fs}$				$-A^{fs}$		0
Loans		$+L_p^{fs}$		$-L_p^{fs}$						0
Loans (foreign currency)				$+L_{fs}^{srow}$					$-L_{fs}^{srow}$	
Private deposits		$-M^p$		$+M^p$						0
High power money		$+H^p$		$+H^{fs}$				$-H^{bc}$		
Σ	0	0	0	0	0	0	0	0	0	0

Source: Prepared by the authors.

1. Households

Household economic activity is circumscribed to consumption. Consumption depends on three factors. The first is past consumption, which implies that consumers' expenditure is partly driven by inertia. The second factor is the difference between actual disposable income and expected disposable income: consumers adjust their expenditures to the difference between those two amounts. The third factor is wealth.

As discussed in the first section, the consumption function can be modelled as a wealth accumulation function, which implies that households have a target level of wealth equal to $V^T = \alpha_4 y d^{h,*}$, where $\alpha_4 = \frac{1-\alpha_{1c}-\alpha_{2c}}{\alpha_2}$ ¹⁶. α_4 is the stock-flow norm of households in our model. The target level of wealth is a function of the difference between expected and actual disposable income.

Disposable income depends on wages, interest payments (deposits are assumed to be the only asset in the hands of households) and remittances. Households do not engage in arbitrage activities, and the interest rate relating to credit or deposits does not have a direct influence on determining real consumption. Households demand credit to finance consumption that exceeds disposable income (see table 4).

¹⁶ The target level of wealth takes on this specification in the steady state as long as expected disposable income equals realized income. For the sake of simplicity, we also assume that the environmental dummy is zero.

Table 4
Main equations for the household sector

Function	Specification	
Real consumption	$c = \alpha_{1c}c_{-1} + \alpha_{2c}c_{-1} * \left(1 + \alpha_{3c} * \frac{(y d^e - y d^h)}{y d^h}\right) + \alpha_2 v_{-1} + \alpha_2 \text{Dummy}$	(7)
Disposable income	$y d^h = WB + Fd_c + intfs_{mm} + rem$	(8)
Wealth	$v = mm - cc$	(9)

Source: Prepared by the authors.

Note: c = consumption; $y d^e$, $y d^h$ = expected and actual disposable income; WB = wage bill; Fd_c = profits distributed by firms to consumers; $intfs_{mm}$ = interest paid to households by the financial sector; rem = remittances; mm = stock of deposits held by households; cc = consumer credit.

Wealth is not only a key determinant of consumption; it is also an important channel through which the effect of climate change on the economy is transmitted (tables 10 and 13). Households may lose net wealth directly through damage suffered by physical capital as a result of extreme weather events. In addition, they may also suffer losses in net wealth from price drops in financial assets linked to sectors whose returns decrease with global warming (such as agriculture) or that come from activities that will be left stranded by transition policies.

In our model, households' loss of wealth leads to a demand shock in consumption, as agents tend to reduce consumption to compensate for the loss of wealth. Lower consumption will cause lower revenue inflows for firms, exacerbating the physical damage to their productive capacity caused by climate change.

2. Firms

Total production in the economy is determined by firms' activities. The equations depicting firms' behaviour are classified into four broad categories, relating to: (i) real output, (ii) costing decisions, (iii) pricing decisions, and (iv) the firm's financial relations (see table 5).

Table 5
Main equations for firms

Function	Specification	
Total production	$y = (1 - (D^y + \vartheta_y \text{ dummy})) \cdot (s^e + (in^T - in_{-1}))$	(10)
Target inventories	$in^T = \gamma \cdot s^e$	(11)
Expected sales	$s^e = \beta \cdot s_{-1} + (1 - \beta) \cdot \Delta Y_{row}$	(12)
Investment function	$i = ((dp + D^k + A) \cdot k_{-1}) \cdot p_d + i_{-1} \cdot ic$	(13)

Source: Prepared by the authors.

Note: y = production; s^e = expected sales; in^T = target inventories; in_{-1} = real inventories; Y_{row} = GDP of the rest of the world; i = real investment; p = price level; D^k = damage function impact on the capital stock; A = central bank advances to the private sector; p_d = price index of domestic sales; ic = confidence index.

Real output (the actual production of each year) is specified as a function of expected sales plus an adjustment between the target stock of inventories and the stock of inventories inherited from the end of the previous period. The target stock of inventories depends on the expected level of sales. In turn, the latter is determined by the past level of sales adjusted for GDP growth in the rest of the world.

Consumption, private investment, public spending and trade with the rest of the world determine firms' sales levels. In turn, firms' sales expectations depend on the previous level of sales adjusted for world GDP growth.

As the system does not operate at full employment, in each period there is a target of inventories that the production sector accumulates. Expected sales and the misalignment of inventories from their target determine the production level. Private sector consumption is specified as a function of expected private disposable income and households' wealth. The former is a proportion of household disposable income, which is in turn defined as the sum of wages and profits distributed from firms to households. Households' earnings determine the consumption level, the demand for money and the demand for financial assets.

Firms' profits are fundamental in determining investment and corporate debt issuance levels. A proportion of firms' net profits is retained for investment in physical capital. If retained profits exceed investment, the surplus will be used to acquire financial assets. In addition, a portion of non-retained profits is used for consumption. An important contribution of the model is the role of expectations in investment decisions. In each period, investment flows vary according to the evolution of capital depreciation and the performance of the investment confidence index.

Prospects of future returns, together with the growth rates of the domestic and foreign economies, are the determinants of the investment confidence index. Profit expectations are a function of two elements: the return on investment (ROI) and the corporate risk premium (CEMBI). The impact of profit expectations and domestic and rest-of-the-world growth rates on the investment confidence index depends on specific sensitivities, a non-linear function of a firm's leverage-to-output ratio and domestic and rest-of-the-world growth. If the investment level exceeds profits retained for investment, firms issue debt, and a proportion of that debt is issued in local currency and the remainder in foreign currency. Local currency debt can take the form of loans or corporate bonds.

3. Government

In this model, references to the government mean the central government. The government generates public expenditure but only through direct purchases from firms. There are no transfers to households, nor is cash held as an asset in the economy. The government issues bills to finance its deficits and buys foreign bonds (equivalent to international reserve assets) in which to invest its surpluses.

The most important equations for the government sector describe the public sector deficit trends (see table 6). The public sector deficit is determined by the difference between government sector expenditures (public spending and interest payments on bills issued in the previous period) and revenues (taxes and returns on foreign assets). The issuance of bonds is determined by the stock of public bonds plus the variation of the deficit if it is greater than zero. In turn, external bond purchases depend on the public deficit being less than zero (i.e. in surplus).

Table 6
Main equations for the public sector

Function	Specification	
Public sector budget restriction	$PSBR = G - T - int_B^g - int_{Bfx}^g + int_{dg}^p + int_{Bg}^{row} + -FB^{bc}$	(14)
Government debt supply (local currency)	$\Delta B = \zeta . PSBR$	(15)
Government debt supply (foreign currency)	$\Delta B^s = (1 - \zeta) . PSBR$	(16)

Source: Prepared by the authors.

Note: $PSBR$ = public sector borrowing requirement; G = public sector expenditure; T = taxes; int_B^g = interest paid by the government to the rest of the world; int_{Bfx}^g = interest paid by the government on bond issues to the rest of the world in local currency; int_{dg}^p = interest paid by the private sector for government deposits; int_{Bg}^{row} = interest paid by the rest of the world to the government for foreign bonds; FB^{bc} = central bank profits that are not invested; B = bonds issued by the government.

4. Rest of the world

The external sector —and, more precisely, the long-term sustainability of the balance of payments— places a long-term binding constraint on the domestic rate of growth (see table 7). We follow the balance-of-payments constrained growth literature and specify the export and import equation as functions of the rate of growth of income in the rest of the world and the rate of growth of domestic income, the real exchange rate and terms of trade. In its most simple expression, the balance of payments constrained growth is revealed by Thirlwall's law. Thirlwall's law states that the rate of growth of an economy is determined by the rate of growth of the world economy and the ratio of the income elasticity of export demand to the income elasticity of import demand of the national economy in question.¹⁷

Table 7
Main equations for the rest of the world

Function	Specification	
Growth of exports	$\Delta x = \eta_0 \cdot Y_{row}^{\eta_1} \cdot (TOT)^{\eta_2}$	(17)
Growth of imports	$\Delta_m = \eta_3 \cdot \frac{Y^{\eta_4}}{(TOT)^{\eta_5}}$	(18)
Balance of payments current account	$FCAB = X - M - int_{B_{row}}^g - int_{dFX_{row}}^g - int_{d_{row}}^p - int_{dFX_{row}}^p + int_B^{row} + rem$	(19)
Balance of payments capital account	$KAB = \Delta B_{row} + \Delta B_{row}^s + \Delta D_{row} + \Delta D_{row}^s - \Delta B^{row}$	(20)

Source: Prepared by the authors.

Note: x = level of exports in real terms; $Y_{row}^{\eta_1}$ = level of real GDP of the rest of the world; TOT = terms of trade; m = level of imports in real terms; Y^{η_4} = level of real domestic GDP; $FCAB$ = balance of payments current account; X = level of exports in nominal terms; M = level of imports in nominal terms; $int_{B_{row}}^g$ = interest paid by the government to the rest of the world; $int_{dFX_{row}}^g$ = interest paid by the government on bonds issued in foreign currency; $int_{d_{row}}^p$ = interest paid by the private sector to the rest of the world for debt issued in local currency; $int_{dFX_{row}}^p$ = interest paid by the private sector to the rest of the world for debt issued in foreign currency; int_B^{row} = interest payments received by the government from the rest of the world; rem = remittances; KAB = balance of payments financial account; B_{row} = total stock of government bonds held by the rest of the world (in domestic currency); B_{row}^s = total stock of government bonds held by the rest of the world (in foreign currency); B^{row} = stock of bonds issued by the rest of the world; D_{row} = demand for private debt (in domestic currency) by the rest of the world; D_{row}^s = demand for private debt (in foreign currency) by the rest of the world.

In the short term, movements in the balance of payments financial account affect the rate of growth. World financial inflows are equal to the sum of government and private bonds purchased by the rest of the world. The demand for government bonds issued in local currency depends on global GDP growth, interest spreads and exchange rate expectations. The demand for government bonds issued in foreign currency is determined by interest rate differentials. Our model postulates that the supply of financial flows always matches demand and that the international interest rate is exogenous, as the rate of economic growth of the world.

5. Financial sector

The financial sector's main function is to provide the private sector with loans. First, it provides consumer credit when households' wages are lower than their consumption. Second, it finances private sector investment through lending. In this case, the demand for loans depends on profits and capital expenditures. It is assumed, for simplicity, that the financial sector's supply of consumer credit and loans always matches demand. The sum of consumer credit and loans corresponds to the total volume of private sector deposits in the financial sector. Interest payments received on holdings of financial assets and foreign reserves represent the financial sector's inflows, while interest paid on foreign loans and central

¹⁷ In a simpler expression, the long-run growth rate of an economy compatible with a sustainable balance-of-payments position is given by the ratio of that economy's export growth rate to income elasticity.

bank advances makes up its outflows. The difference between inflows and outflows determines profits. A portion of those profits is used to accumulate wealth through financial assets: government bonds (in local and foreign currency), private debt (in local currency only) and foreign debt used as reserves. The demand for each type of asset reflects the arbitrage conditions postulated by Yilmaz and Godin (2020). The financial sector covers its financial needs by issuing two types of liabilities. These are advances from the central bank and foreign currency bonds bought by the rest of the world. The advances are calculated as a proportion of the sector's financial needs, which is exogenously given. The remaining financial needs are covered by bonds issued in foreign currency and sold to the rest of the world (see table 8).

Table 8
Main equations for the financial sector

Function	Specification
Financial sector profit	$f_{fs} = int_{fs}^g + int_{fs}^{sg} + int_{fs}^p + int_{fs}^{row} - int_{mm,p}^{fs} + int_{fs}^p + int^{ofS} + int^{lp} - int^{slS} + (CP_d - D_{CP_d}) + rem_f$ (21)
Demand for consumer credit	$Cc_d^p = cons + intcp_{fs} - fdc - wb - intfs_{mm} + rem_h$ (22)
Financial sector demand for government bonds (local currency)	$\Delta B_{fs,d}^g = \epsilon_{f_1} \cdot fa_{fs}$ (23)
Sensitivity of financial sector demand for government bonds (local currency)	$\epsilon_{f_1} = \epsilon_{f_{1o}} + \epsilon_{f_{1i}} \left(\frac{1+i^g}{1+i^{g^*}} \right)^{\theta_{fs}}$ (24)

Source: Prepared by the authors.

Note: f_{fs} = financial sector profits; $int_{fs}^g, int_{fs}^{sg}$ = interest paid by the government to the financial sector in domestic and foreign currency; int_{fs}^p = interest paid to the financial sector by the private sector in domestic currency; $int_{mm,p}^{fs}$ = interest on deposits paid by the financial sector; int_{fs}^p = interest on consumer credit paid to the financial sector; int^{ofS} = interest paid to the financial sector by the private sector for advances; int^{lp} = interest paid to the financial sector by the private sector for loans in domestic currency; int^{slS} = interest paid to the financial sector by the private sector for loans in foreign currency; CP_d = capital payments on loans to firms; D_{CP_d} = default of capital payments on loans to firms; rem_f = remittances received by the financial sector; Cc_d^p = demand for consumer credit; $cons$ = demand for consumption; $intcp_{fs}$ = interest paid on consumer credit; fdc = profits distributed to consumers; wb = wage bill; $intfs_{mm}$ = interest paid by the financial sector on consumer deposits; rem_h = remittances received by households; $B_{fs,d}^g$ = financial sector demand for government bonds; fa_{fs} = financial share of assets bought by the financial sector; i^g and i^{g^*} = government nominal interest rate on domestic and foreign currency; ϵ_{f_1} = sensitivity of financial sector demand for government bonds (local currency).

Empirical estimates (Hilscher and Nosbusch, 2010) suggest that the debt-to-GDP ratio, foreign debt-to-GDP ratio, reserves and exchange rate variations are the main determinants of sovereign premium (here defined by the emerging markets bond index (EMBI)). In turn, corporate risk is a function of EMBI, of the currency mismatch — a growing concern in the Latin American region (Pérez Caldentey, Favreau Negront and Méndez Lobos, 2019; Nalin and Yajima, 2021)— in the ratios of foreign liabilities to foreign assets, and of the loans-to-GDP ratio. The nominal exchange rate follows an autoregressive process of the first order, affected by foreign exchange traders' expectations — we include speculative versus fundamentalist traders (Lavoie and Daigle, 2011)— and by financial flows from the rest of the world, sovereign risk and the terms of trade. The domestic interest rate depends on the international rate and government risk (EMBI). It also varies according to the demand for and supply of bonds (Yilmaz and Godin, 2020): whenever excess demand exists, the interest rate will decrease as a consequence. The nominal interest rate on foreign-denominated debt is obtained by adding a premium to the international interest rate, where the latter is a function of EMBI. Private sector nominal rates on domestic and foreign debt work similarly.

6. Central bank

The central bank follows an augmented Taylor rule: it determines its desired monetary policy rate according to inflation and deviations in both output and exchange rate growth from their target levels. Monetary policy functions through government bond purchases. The central bank demands domestic bonds according to a target level, which depends on the behaviour of the credit market and exchange rates (see table 9).

Table 9
Main equations for the central bank

Function	Specification	
Taylor rule	$i^{cb} = \pi_t + i_t^{cb*} + \vartheta_1(\pi_t - \pi_t^*) + \vartheta_2(\Delta y_t - \Delta y_t^*) + \vartheta_3(\dot{e}_t - \dot{e}_t^*)$	(25)
Interest rate target	$i_t^{cb*} = i^{row} + \varphi^{cb}$	(26)
Central bank profits	$FB^{bcp} = int_{bc}^g + int_{bc}^{row} + int_{bc}^{g\$} + int_{bc}^{gfs} - int_{mm_g}^{cb} + dep_{cb} + rem_{cb}$	(27)
Rest-of-the-world supply of debt to the central bank	$\Delta B_g^{row} = -CAB + WFF + B_p^{row} \cdot E - depreciation_{Row}$	(28)

Source: Prepared by the authors.

Note: i^{cb} = monetary policy interest rate; π_t = inflation rate; i_t^{cb*} = target monetary policy rate; y_t = level of real GDP; y_t^* = target level of real GDP; \dot{e}_t = rate of change of the actual nominal exchange rate; \dot{e}_t^* = rate of change of the target nominal exchange rate; i^{row} = external nominal interest rate; φ^{cb} = private risk premium; FB^{bcp} = central bank profits; int_{bc}^g = interest paid to the central bank by the government in domestic currency; int_{bc}^{row} = interest paid to the government by the rest of the world in domestic currency; $int_{bc}^{g\$}$ = interest paid to the central bank by the government in foreign currency; int_{bc}^{gfs} = interest paid to the central bank by the financial sector for advances; $int_{mm_g}^{cb}$ = interest paid to the government by the central bank for deposits; dep_{cb} = change in the value of the central bank's foreign assets; rem_{cb} = central bank remittances; B_g^{row} = supply of the rest of the world's bonds to the government; B_p^{row} = supply of the rest of the world's bonds to the private sector; CAB = balance of payments current account; WFF = world fund flows; E = nominal exchange rate level; $depreciation_{Row}$ = rest of the world stock depreciation due to nominal exchange rate fluctuations.

As the interest rate is a function of interactions between the demand for and supply of bonds, an increase in the target of domestic bonds purchased by the central bank will put downward pressure on rates, which will adjust consequently, changing the demand for domestic bonds and influencing the behaviour of the exchange rate. The ideal amount of bonds the central bank is willing to hold depends on the differential between the current interest rate and the central bank's target rate and the observed volatility in the exchange rate (calculated as the moving average standard deviation of the nominal exchange rate).

When volatility exceeds three standard deviations, its coefficient will take a value of one and the demand for bonds will adjust accordingly. The amount of domestic government bonds allocated to the central bank is the maximum between its demand for bonds and the unallocated residual to the financial sector, private and external. The supply of international reserves to the central bank from the rest of the world is unlimited. Central bank profits are used to purchase financial assets. Central bank savings correspond to uninvested profits. Finally, the amount of money issued is the residual of the central bank's budget constraint; that is, it is issued to finance the difference between profits before portfolio investment and portfolio purchase.

V. Working logic and causality of the model with some simulation results

In line with our stylized facts, the workings of the model are largely driven by external factors, including rates of growth in the rest of the world and in remittances. Changes in the rest-of-the-world growth rate and in export demand and variations in international financial rates and/or financial flows directly affect the external sector. These impulses are transmitted to firms, employment and consumption levels and the government sector.

The transmission mechanisms include: (i) the close relation between sovereign risk and sovereign premium and the feedback between the two variables, (ii) the influence of the risk premium on the corporate risk premium, (iii) the role of currency mismatches in the private non-financial sector and their links with risk premiums and the nominal exchange rate, (iv) the importance of expectations for investment, which is registered by including an investment confidence index,¹⁸ (v) the non-linear relation that exists between debt and investment for the Latin American non-financial sector,¹⁹ (vi) the role of

¹⁸ See Pérez Caldentey, Nalin and Rojas Rodríguez (2022 and 2023).

¹⁹ See Pérez Caldentey, Favreau Negront and Méndez Lobos (2019).

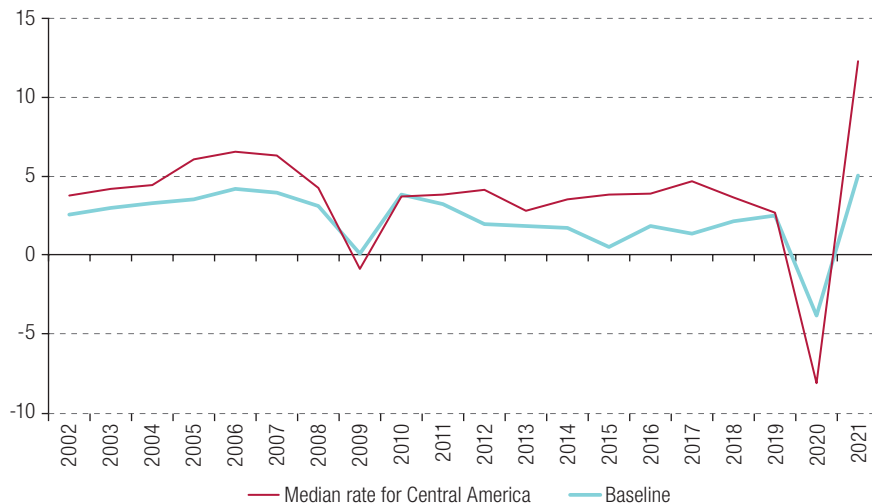
terms of trade in determining Thirlwall's law, nominal exchange rate (NER), short-term cross-border flows and risk premiums, (vii) the high penetration of foreign investors in domestic markets and whose shifts in preferences are often followed by outflows and currency depreciation, and (viii) the concern of central banks in Central America regarding the level of exchange-rate volatility, here indicated by means of a volatility index that, together with the Taylor rule, determines the target level for central bank bond holdings.

The model's dependency graph is provided in annex A3. Despite its dimensions (464 variables, 313 of them endogenous and 151 exogenous), it is possible to grasp the main nodes of our simulation, represented by the nominal exchange rate. Other important nodes include the corporate and sovereign risk premiums, which in turn are also influenced by the nominal exchange rate. As previously discussed, these premiums influence both real and financial variables. In particular, the corporate risk index (CEMBI) affects business confidence and therefore investment and accumulation decisions. Total output, disposable income and decisions regarding consumption (and savings) adjust accordingly. The sovereign risk index (EMBI) directly influences public finance as it raises (lowers) yields, thus increasing (decreasing) the debt burden and its servicing. In turn, the sovereign risk perception and the value of the currency is heightened (diminished), thereby triggering balance-sheet effects on the stock of foreign-denominated debt (both private and public). Conversely, demand from the rest of the world acts as an important (exogenous) transmission channel as it drives up (lowers) both export and remittances inflows, both of which act as a stabilizer (destabilizer) for the currency.

In the case of climate shocks, the channels are different: the damage function responds to global conditions (especially global temperature), but adaptation actions are local. For that reason, changes in the damage function primarily affect local variables (capital stock, labour, consumption, public spending and so on). Shocks or changes in global conditions affect both real variables (components of GDP) and financial variables (debt levels, EMBI, CEMBI and NER).

It should be noted that our model has been calibrated in accordance with our baseline assumptions for GDP growth in the rest of the world, foreign interest rates, terms of trade and — for the extended model with the environmental interactions — the occurrence of extreme weather events. The data used for calibration were drawn from the CEPALSTAT database (2024).²⁰ As shown in figure 2, our simulation captures some of the broad trends in the selected economies, which are exemplified by comparing the trend in median GDP growth for Central America with our model's baseline simulation.

Figure 2
GDP growth: baseline simulation and median rate for Central America, 2002–2021
(Percentages)



Source: Prepared by the authors.

Note: The median rate for Central America includes the Dominican Republic.

²⁰ See [online] <https://statistics.cepal.org/portal/cepalstat/index.html?lang=en>.

VI. Introducing ecological feedbacks in the stock-flow consistent model

Table 10 presents a graphical depiction of the first and second laws of thermodynamics, where the sum of material inputs (resources such as matter and both renewable and non-renewable energy) equals the change in the socioeconomic stock (such as the sum of CO₂ emissions, waste and dissipated energy). The fact that some energy inputs, such as fossil fuels, are dissipated introduces the second law of thermodynamics into the model. Table 10 depicts the evolution of the human-related stock of matter, for material and non-renewable energy reserves, atmospheric CO₂ concentration and the socioeconomic stock. Each year's opening stock of matter is augmented by its net additions, such as emissions (plus the absorption of the biosphere) or the conversion of reserves into resources (net use or extraction of energy and matter) to obtain the final stock. Similarly, the difference between the socioeconomic stock for each year is given by the production of material goods minus their disposal. Conversely, hazardous waste is accumulated over time by non-recyclables. In open economy conditions, the physical stocks and flows for the local economy or region and the rest of the world should be incorporated into the two matrices.

Table 10
Physical flow matrix of the two-area economy (consolidated)

	Worldwide material balance	Worldwide energy balance
Inputs		
Extracted matter	$+ mat_{CA} + mat_{row}$	
Renewable energy		$+ er_{CA} + er_{row}$
Non-renewable energy	$+ cen_{row} + cen_{CA}$	$+ en_{row} + en_{CA}$
Oxygen	$+ o2_{CA} + o2_{row}$	
Outputs		
Industrial CO ₂ emissions	$-(emis_{CA} + emis_{row})$	
Waste	$-(wa_{CA} + wa_{row})$	
Dissipated energy		$-(ed_{CA} + ed_{row})$
Change in socioeconomic stock	$-(\Delta k_{se}^{CA} + \Delta k_{se}^{row})$	
Sum	0	0

Source: Prepared by the authors.

Note: mat_{CA} , mat_{row} = extraction of matter in Central America and in the rest of the world; cen_{row} , cen_{CA} = carbon mass of (non-renewables) in the rest of the world and in Central America. $o2_{CA}$, $o2_{row}$ = mass of oxygen in Central America and in the rest of the world; $emis_{CA}$, $emis_{row}$ = industrial emissions of CO₂ in Central America and in the rest of the world; wa_{CA} , wa_{row} = waste generated by production activities in Central America and in the rest of the world; k_{se}^{CA} , k_{se}^{row} = socioeconomic stock in central America and in the rest of the world; er_{CA} , er_{row} = renewable energy in Central America and in the rest of the world; en_{row} , en_{CA} = non-renewable energy in Central America and in the rest of the world; ed_{CA} , ed_{row} = dissipated energy at the end of the period in Central America and in the rest of the world.

Looking at the behaviour of material resources and reserves, the production of material goods and the extraction of matter in each area depend on their respective activity levels. The recycled socioeconomic stock is a fraction of the discarded socioeconomic stock, which depends on flows of durable goods. The latter evolves according to local demand net of the trade balance. Hence, the accumulation of the socioeconomic stock is given by the production of material goods net of the depletion of the socioeconomic stock. Waste is given by matter extraction minus the change in socioeconomic stock. The conversion of material resources into reserves takes place at an exogenous rate. Finally, the mass of oxygen is given by emissions minus the carbon mass of non-renewable energy, which is also a fraction of the emissions.

The activity level gives the energy requirement for production in each area. Energy is both renewable and non-renewable, and the shares of both types within total energy demand are given exogenously. The evolution of the stock of energy reserves depends on their conversion minus the demand for non-renewables, as their conversion into reserves reduces the stock of energy over time. Industrial emissions are a function of non-renewable demand, while worldwide emissions are augmented by annual CO₂ emissions from land, which grow at an exogenous rate. CO₂ concentrations at the three global layers (atmosphere, biosphere or upper ocean and deep ocean) are interrelated but driven by the atmospheric concentration of CO₂, which depends on their emissions. Finally, the atmospheric temperature adjusts to its previous values corrected by the radiative forcing over pre-industrial levels, as lower ocean temperatures follow.

Energy and material resources feedback into the economic system via two channels: (i) they constrain investment decisions and thus output once the utilization of the matter- and energy-determined capacity surpasses their normal or equilibrium level, where the former is defined as the ratio of output over the matter- or energy-determined potential output; (ii) they affect prices via mark-ups on historical unit costs, which are modelled as a positive function of the utilization of both the matter- and energy-determined capacity.

Following Dafermos, Nikolaidi and Galanis (2017) and Carnevali and others (2021), we postulate a damage function similar to that given by Nordhaus (2018), which describes the impact of the increase in atmospheric temperature overflow variables such as real consumption, labour productivity and private investment (see table 11). All these variables are affected negatively by a rise in temperatures. Although the modelling of environmental variables must include an adaptation component, this method shows the resilience capability of economies to address the impacts of climate change.

Table 11
Damage function

$D = 1 - \frac{1}{1 + \pi_d T + \pi_{d_1} T^2 + \pi_{d_2} T^{3d_3}} \pi_1 ; \pi_2 ; \pi_3 ; \zeta_3 \geq 0$	(1)
$D^k := f_K \cdot Df_K \in (0;1)$	(2)
$D^l = f_l \cdot Df_l \in (0;1)$	(3)

Source: Prepared by the authors.

Note: D = damage function; D^k = damage function impact on the capital stock; D^l = damage function impact on the workforce. The parameters in the denominator are based on Bovari, Giraud and Mc Isaac (2018) relating temperatures to the potential damage inflicted on the economy.

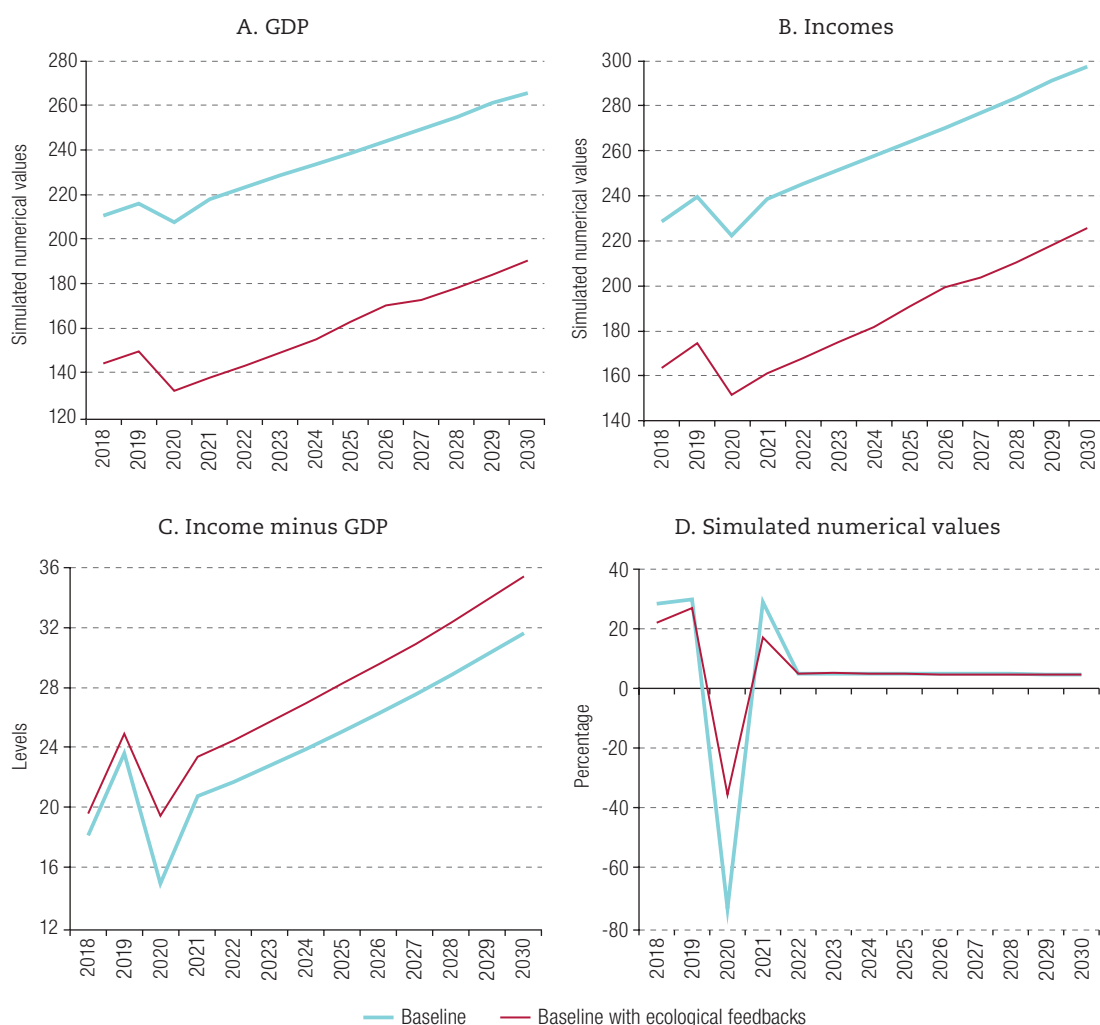
We recognize the limitations and criticisms of this methodology; most particularly, the issues highlighted by Keen and others (2021), who use the literature to highlight some economists' errors with respect to different assumptions, such as the idea that the tipping points would not come before 2100, notwithstanding that the global economy is currently at or above those limits (Lenton and others, 2023). Therefore, the Nordhaus (2018) damage function can underestimate the real effects of climate change in the short run. While we understand that an optimal approach to the relationship between economic and environmental variables would include tipping points, we see this as a reference approach for analysing risks and opportunities that would be modified by the real results.

One important innovation in the present model is the inclusion of a dummy variable that accounts for extreme weather events. The dummy variable takes a value from 1 to 5 according to the intensity of floods, hurricanes and drought. If included, the dummy negatively affects real consumption, business sales confidence and the elasticity of rest-of-the-world demand for government debt denominated in both local and foreign currency. The introduction of the dummy also allows the system to increase short-term government spending following disasters and the risk premiums for both the public and the private sectors.

VII. Model simulations including climate change

In this section, we will compare the performance of the two iterations of our model: i.e. with and without the ecological module. Both versions have been calibrated in accordance with our baseline assumptions for GDP growth for the rest of the world, foreign interest rates, terms of trade and —in the case of the extended model that includes environmental interactions— the occurrence of extreme weather events. As shown in figure 3, both GDP and RGNDI levels are lower in our baseline model with the ecological feedback. Nevertheless, RGNDI in level terms is consistently higher than GDP in the two baselines, as is the case for many Caribbean economies.

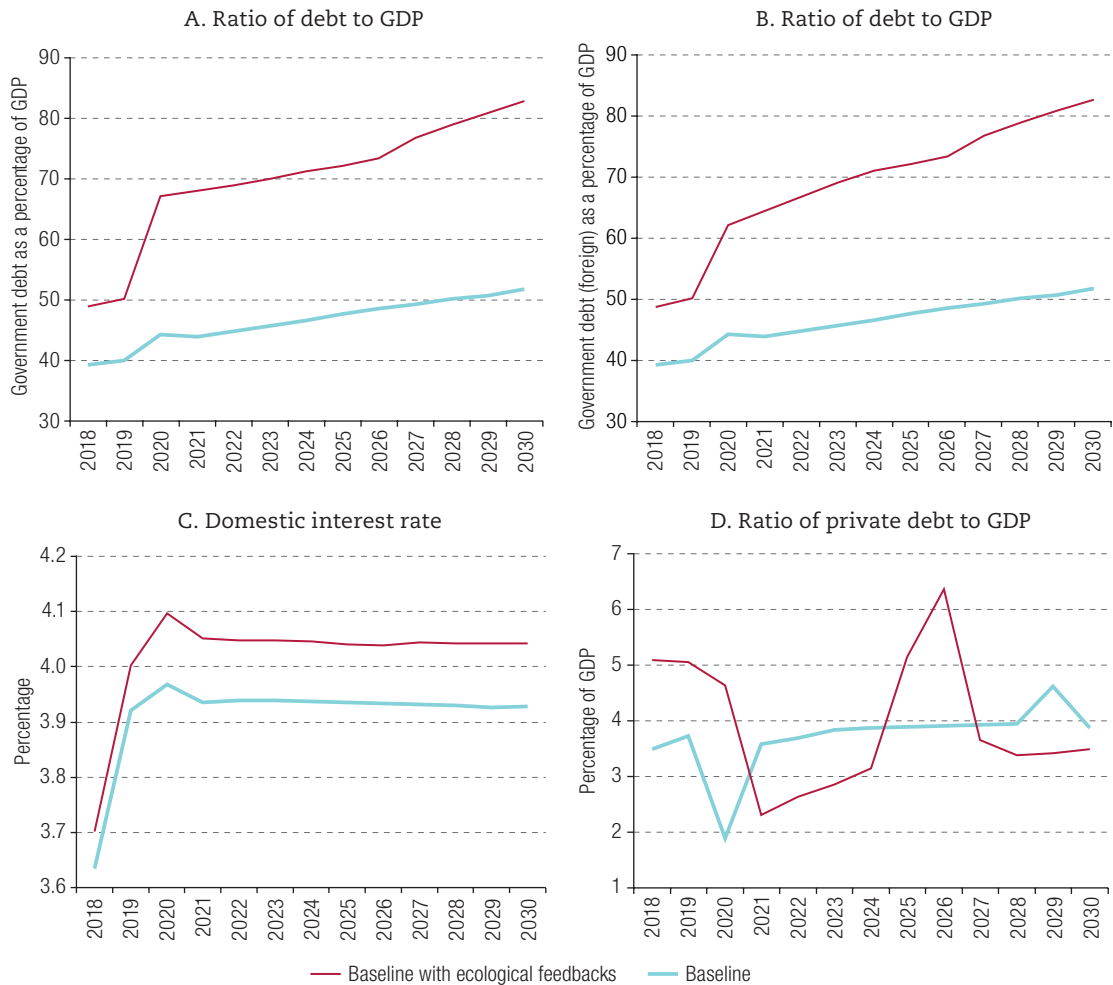
Figure 3
Comparison of GDP and income simulated with baseline model,
with and without climate change, 2018–2030



Source: Prepared by the authors, on the basis of Economic Commission for Latin America and the Caribbean (ECLAC), "Geoportal", CEPALSTAT [online database] <https://statistics.cepal.org/geo/geo-cepalstat/?lang=es>.

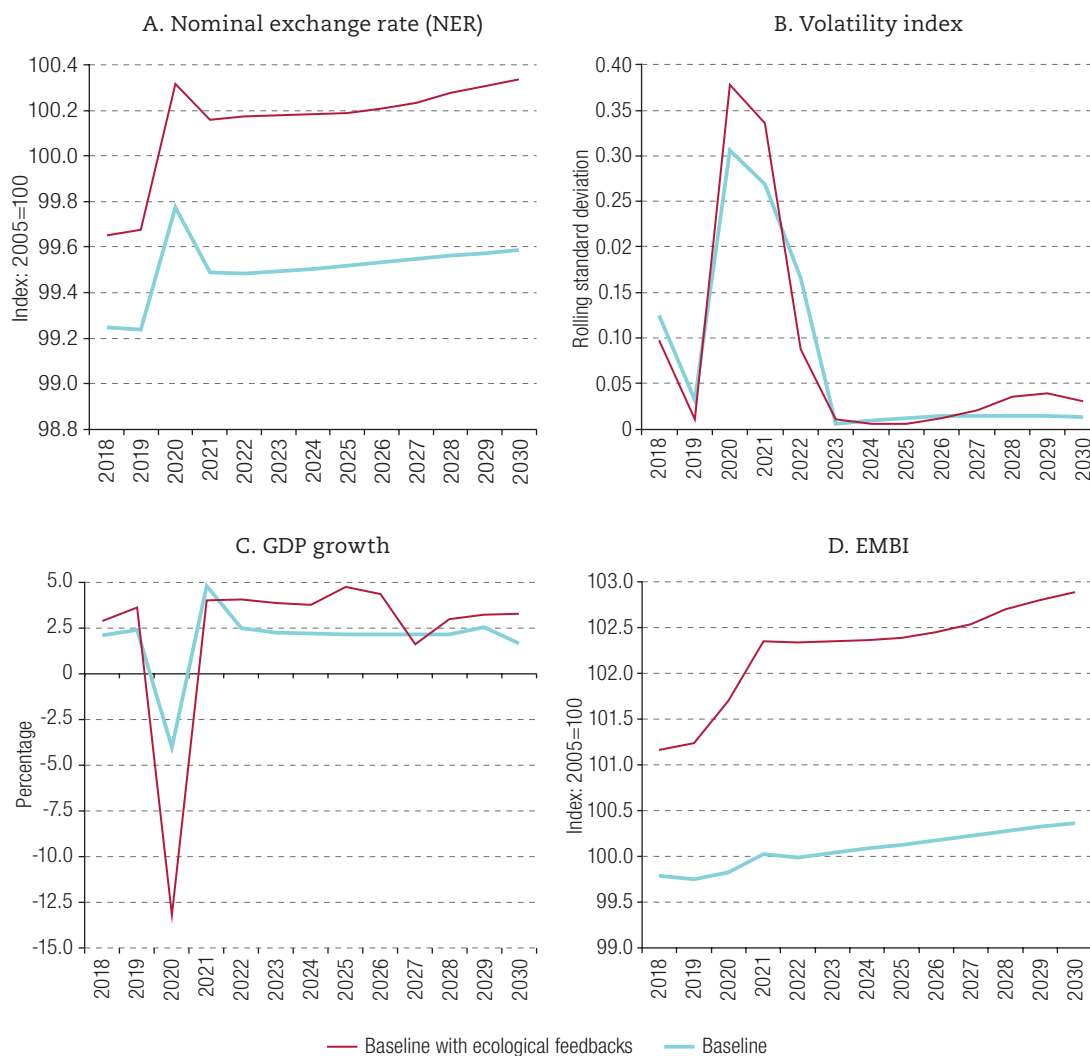
The differential between RGNDI and GDP growth — i.e. the sum of net factor payments from the rest of the world, remittances, donations and terms of trade adjustments— is consistently positive in terms of both levels and average growth. As argued in the previous section, RGNDI tends to be higher than GDP in Caribbean economies owing to remittance inflows. Furthermore, figure 4 captures the trend in debt-to-GDP ratios for both the government and the private sector. In our ecological model, government debt to GDP (both total and foreign denominated) tends to grow over time because of higher government outlays to compensate for the damage caused by climate change and the drop in private spending, especially investment (see figure 5).

Figure 4
Comparison of debt-to-GDP ratios simulated with baseline model, with and without climate change, 2018–2030



Source: Prepared by the authors, on the basis of Economic Commission for Latin America and the Caribbean (ECLAC), “Geoportal”, CEPALSTAT [online database] <https://statistics.cepal.org/geo/geo-cepalstat/?lang=es>.

Figure 5
Comparison of nominal exchange rate, GDP growth, volatility index and EMBI
with baseline model, with and without climate change, 2018–2030

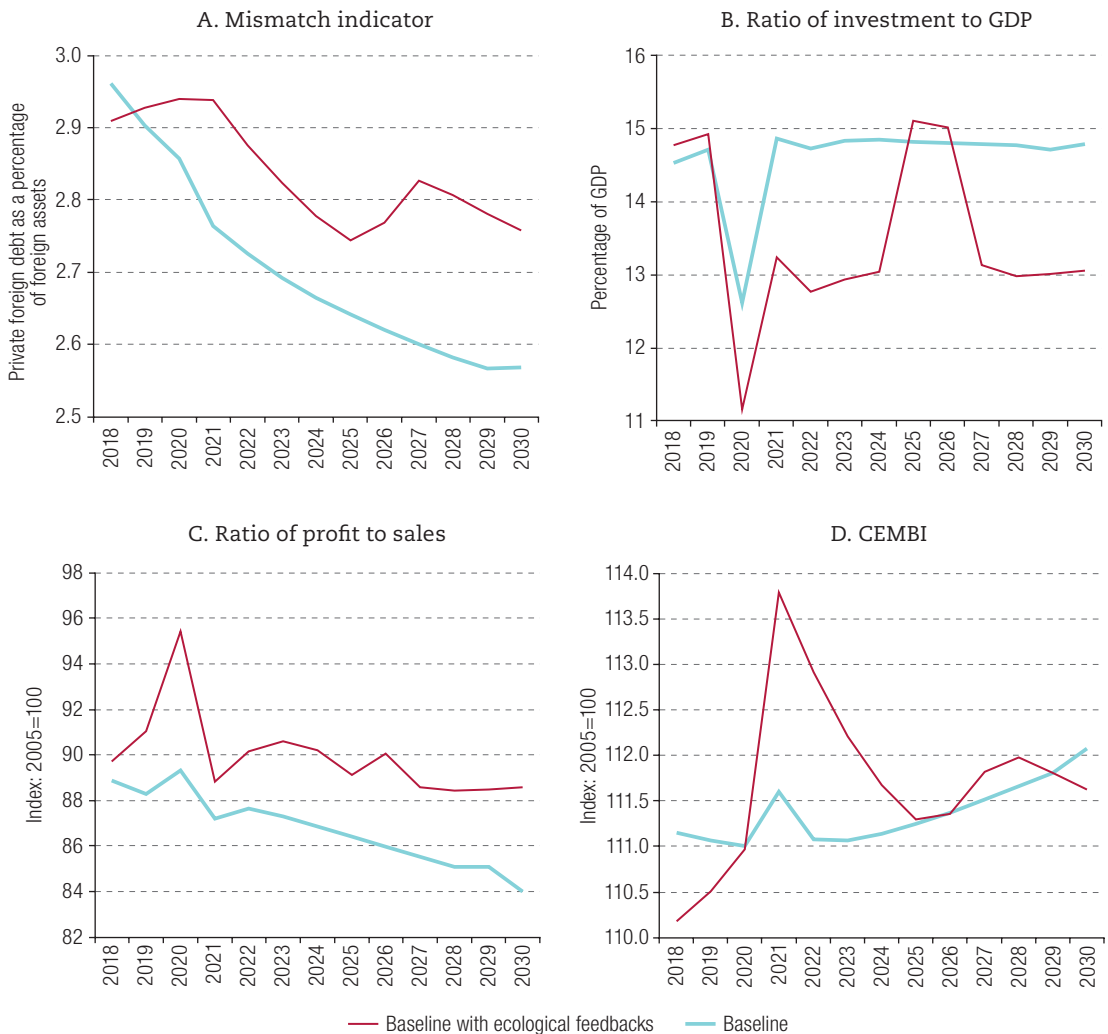


Source: Prepared by the authors, on the basis of Economic Commission for Latin America and the Caribbean (ECLAC), “Geoportal”, CEPALSTAT [online database] <https://statistics.cepal.org/geo/geo-cepalstat/?lang=es>.

Depending on the likelihood of these events, private debt may also spike following the destruction of physical capital and the drop in business confidence. As a consequence, the domestic interest rate tends to be higher. External vulnerability is heightened once climate feedbacks are factored in, as shown in figure 5, where both NER and EMBI tend to rise over time as currency volatility increases. As a result, GDP fluctuations tends to be stronger, despite average GDP growth being higher when government outlays to cope with disasters are taken into account.

The consequences of climate change affect firms intensely, as the ratio of investment to GDP drops sharply, causing corporate premiums to spike and currency mismatches in their portfolios to rise. Both our mismatch indicator and CEMBI tend to decrease afterwards, partly because of lower economic activity and lower revenues (see figure 6). Interestingly, the ratio of profits to sales tends to remain stable in the ecological model, mainly on account of higher cash transfers from the government providing a backstop for the fall in private investment.

Figure 6
Comparison of selected indicators of non-financial corporate sector with baseline model, with and without climate change, 2018–2030



Source: Prepared by the authors, on the basis of Economic Commission for Latin America and the Caribbean (ECLAC), "Geoportal", CEPALSTAT [online database] <https://statistics.cepal.org/geo/geo-cepalstat/?lang=es>.

VIII. Conclusions

This article applies a more general stock-flow consistent model to the economies of Central America in order to reveal and explain the broad macroeconomic trends of Latin America and the Caribbean. Following a recovery in the aftermath of the global financial crisis (2008–2009), regional GDP growth has, since around 2013–2014, tended to decline and to converge on a long-term rate of growth of about 2% (1% in GDP per capita growth).

This regional performance hides important differences from one country to the next. Whereas the region's larger economies did indeed record lower growth rates between 2010 and 2023, some of its smaller economies —including those of Central America— improved their growth performance. Growth differentials can be traced to real factors such as the evolution of labour productivity and the production structure.

The latter factor is incorporated into our model by distinguishing between GDP and RGNDI. In the case of Central America, the use of RGNDI captures the effects of remittances on the economy whereas GDP does not. The use of GDP can overstate the volatility of the business cycle, economic vulnerability and the degree to which economies are constrained in their policy space. The productive structure is tied to the pattern of international insertion. The business cycle of Central American economies generally correlates with that of the United States.

An explanation of the performance of Latin American and Caribbean economies since the end of the global financial crisis would not be complete without including the relationship between real and financial factors. We capture those linkages through several causal relationships including the relation between remittances and the nominal exchange rates, the EMBI and the CEMBI, leverage and investment.

The importance to these economies of factors related to climate change led to the inclusion of an ecological module in the model. Because of its cross-cutting effects across different sectors and agents, we believe that climate change related effects can only be captured through a model for an economy in the aggregate.

Bibliography

- Baltodano, O. (2017), "Alternative closures for an open economy model in a stock and flow consistent framework: the case of Central America", *Documentos de Trabajo*, No. 061, Central Bank of Nicaragua, December.
- Barbosa, N. H. (2001), "International liquidity and growth in Brazil", *CEPA Working Paper*, No. 2001.4, New York, Center for Economic Policy Analysis (CEPA).
- Bortz, P. G. (2014), "Foreign debt, distribution, inflation and growth in a SFC model", *European Journal of Economics and Economic Policies: Intervention*, vol. 11, No. 3, December.
- Bovari, E., G. Giraud and F. Mc Isaac (2018), "Coping with collapse: a stock-flow consistent monetary macrodynamics of global warming", *Ecological Economics*, No. 147, May.
- Campero Encinas, S. (2019), "Modelo stock flow consistent (SFC) aplicado al caso del sector de los hidrocarburos en Bolivia", master's thesis, Latin American Faculty of Social Sciences in Ecuador (FLACSO Ecuador).
- Cano Ortiz, D. (2015), "Regla fiscal y choques externos en Colombia: un modelo de consistencia stock-flujo", master's thesis, National University of Colombia.
- Carnevali, E. and others (2021), "Cross-border financial flows and global warming in a two-area ecological SFC model", *Socio-Economic Planning Sciences*, vol. 75, June.
- Dafermos, Y., M. Nikolaidi and G. Galanis (2017), "A stock-flow-fund ecological macroeconomic model", *Ecological Economics*, vol. 131, January.
- Do Nascimento, P. F. and A. C. M. Silva (2016), "Financeirização e crescimento: alguns experimentos stock-flow consistent", *Anais do XLII Encontro Nacional de Economia*, National Association of Postgraduate Programs in Economics (ANPEC).
- ECLAC (Economic Commission for Latin America and the Caribbean) (2024), "Geoportal", CEPALSTAT [online database] <https://statistics.cepal.org/geo/geo-cepalstat/?lang=es>.
- Escobar, A. (2016), "Stock-flow consistent models for developing countries: the case of Colombia", paper presented at the nineteenth Annual Conference on Global Economic Analysis, Washington, D.C., World Bank.
- Fan, R. Y. and others (2022), "Calamities, debt, and growth in developing countries", *Policy Research Working Paper*, No. 10015, World Bank.
- Fernández, J. (2017), "Elementos de análisis para la sostenibilidad de una economía dolarizada", *Revista Economía*, vol. 69, No. 109, May.
- Godin, A. and others (2023), "Can Colombia cope with a global low carbon transition?", *Research Papers*, No. 285, Paris, French Development Agency (AFD).
- Godley, W. (2012), "Macroeconomics without equilibrium or disequilibrium", *The Stock-Flow Consistent Approach*, M. Lavoie and G. Zezza (eds.), New York, Palgrave Macmillan.
- (1999) "Money and credit in a Keynesian model of income determination", *Cambridge Journal of Economics*, vol. 23, No. 4, July.
- Godley, W. and F. Cripps (1983), *Macroeconomics*, New York, Oxford University Press.

- Godley, W. and M. Lavoie (2007), *Monetary Economics: An Integrated Approach to Credit, Money, Income, Production and Wealth*, New York, Palgrave Macmillan.
- Guevara Castañeda, D. A. (2015), “Auge de las finanzas y desigualdad en la distribución del ingreso: un estudio desde la perspectiva de la financiarización para Colombia 1980-2008”, doctoral thesis, National University of Colombia.
- Hilscher, J. and Y. Nosbusch (2010), “Determinants of sovereign risk: macroeconomic fundamentals and the pricing of sovereign debt”, *Review of Finance*, vol. 14, No. 2, April.
- Kappes, S. A. and M. Milan (2017), “Fiscal policy rules in a stock-flow consistent model”, *Brazilian Keynesian Review*, vol. 3, No. 2, January.
- Keen, S. and others (2021), “Economists’ erroneous estimates of damages from climate change”, The Royal Society Publishing [online] <https://arxiv.org/abs/2108.07847>.
- Lage, C., I. Romero and F. Villarreal (2023), *Modelo macroeconómico para Cuba* (LC/MEX/TS.2023/28), Mexico City, Economic Commission for Latin America and the Caribbean (ECLAC).
- Lavoie, M. and G. Daigle (2011), “A behavioural finance model of exchange rate expectations within a stock-flow consistent framework”, *Metroeconomica*, vol. 62, No. 3, July.
- Lenton, T. and others (eds.) (2023), *Global Tipping Points Report 2023*, University of Exeter.
- Mandarino, G. V., C. H. Dos Santos and A. C. M. Silva (2020), “Workers’ debt-financed consumption: a supermultiplier stock-flow consistent model”, *Review of Keynesian Economics*, vol. 8, No. 3, July.
- Mazzi, C. T. (2013), “Um modelo stock-flow consistente (SFC) com crescimento restrito pelo balanço de pagamentos”, master’s thesis, University of Campinas (UNICAMP).
- Mellini, A. (2018), “Política fiscal, equilibrio externo e déficits gêmeos em um modelo stock-flow consistente póskeynesiano com economia aberta”, master’s thesis, Federal University of Uberlândia.
- Michelena G. and N. Guaita (2017), “Modelo de Stock-Flujo Consistente para el Análisis Macroeconómico (SFARG)”, *Documento de Trabajo*, Ministry of Production of Argentina.
- Nalin, L. and G. T. Yajima (2021), “Commodities fluctuations, cross border flows and financial innovation: a stock-flow analysis”, *Metroeconomica*, vol. 72, No. 3, July.
- (2020), “Balance sheet effects of a currency devaluation: a stock-flow consistent framework for Mexico”, *Working Paper*, No. 980, Levy Economics Institute.
- Nalin, L. and others (2023), “A stock flow ecological model from a Latin American perspective”, *Working Paper*, No. 1031, Levy Economics Institute.
- Nogueira Silva, D., H. Morrone and S. Kappes (2021), “Assessing pension system outcomes in Brazil: a stock-flow consistent analysis”, *Brazilian Keynesian Review*, vol. 7, No. 2.
- Nordhaus, W. (2018), “Projections and uncertainties about climate change in an era of minimal climate policies”, *American Economic Journal: Economic Policy*, vol. 10, No. 3, August.
- Pérez Caldentey, E. (2009), “Balance of payments constrained growth within a consistent stock-flow framework: an application to the economies of CARICOM”, *Caribbean Development Report. Volume I*, Project Documents (LC/W.249), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).
- Pérez Caldentey, E. and L. Rojas Rodríguez (2020), “A stock-flow approach to investment requirements within balance-of-payments constrained growth”, *Project Documents* (LC/TS.2020/152), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).
- Pérez Caldentey, E., N. Favreau Negrón and L. Méndez Lobos (2019), “Corporate debt in Latin America and its macroeconomic implications”, *Journal of Post Keynesian Economics*, vol. 42, No. 3.
- Pérez Caldentey, E., L. Nalin and L. Rojas Rodríguez (2023), “A baseline stock-flow model for the analysis of macroprudential regulation guidelines and policies for Latin America and the Caribbean”, *Financial openness, financial fragility and policies for economic stability: a comparative analysis across regions of the developing world*, Project Documents (LC/TS.2022/139), E. Pérez Caldentey (ed.), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).
- (2022), “A baseline stock-flow model for the analysis of macroprudential regulation for Latin America and the Caribbean”, *Working Paper*, No. 2217, Post-Keynesian Economics Society (PKES).
- Rivas Valdivia, J. C. (2014), “Divergencia económica estocástica y el rol de los desastres naturales en México y Centroamérica, 1980-2011”, PhD thesis, National Autonomous University of Mexico (UNAM).
- Taylor, L. (2008), “A foxy hedgehog: Wynne Godley and macroeconomic modelling”, *Cambridge Journal of Economics*, vol. 32, No. 4, July.
- Telechea, J. M. (2018), “¿Cuál es el esquema macroeconómico adecuado para los países latinoamericanos?: una aproximación a partir de un modelo Stock Flujo Consistente”, master’s thesis, National University of San Martín (UNSAM).

- Valdecantos, S. (2022), "Endogenous exchange rates in empirical stock-flow consistent models for peripheral economies: an illustration from the case of Argentina", *Journal of Post Keynesian Economics*, vol. 45, No. 4, August.
- (2021), "Grasping Argentina's green transition: insights from a stock-flow consistent input-output model", *Working Paper Series*, No. 4, Macroeconomic Methodology, Theory and Economic Policy (MaMTEP), Aalborg University Business School.
- (2020), "Argentina's (macroeconomic?) trap", *Working Paper*, No. 975, Levy Economics Institute.
- (2016), "Estructura productiva y vulnerabilidad externa: un modelo estructuralista stock-flujo consistente", *Studies and Perspectives series-ECLAC Office in Buenos Aires*, No. 46 (LC/L.4171-LC/BUE/L.225), Santiago, Economic Commission for Latin America and the Caribbean (ECLAC).
- Yilmaz, S. D. and A. Godin (2020), "Modelling small open developing economies in a financialized world: a stock-flow consistent prototype growth model", *Research Papers*, No. 125, French Development Agency (AFD).
- Zeza, F. (2017), "Stock-flow consistent macroeconomic models: from theory to practice", unpublished.

Annex A1

Table A1.1

Review of selected literature on stock-flow modelling in Latin America and the Caribbean

Author	Region/country	Model type	External sector	Conclusions
Barbosa (2001)	Brazil	Growth	Thirlwall's law with liquidity constraint	Small open economies tend to adjust their current account, especially their trade balance, to the availability of external finance.
Bortz (2014)	Argentina	Growth	Two economies	The results point towards the dismissal of the "twin deficit" view, and support an active management of the exchange rate, in light of contradictory effects of fixed and flexible exchange rate regimes, according to the circumstances.
Campero Encinas (2019)	Bolivia (Plurinational State of)	Growth	...	External hydrocarbon and mineral shocks have a low impact on the economy because of the industrialization of those sectors.
Cano Ortiz (2015)	Colombia	Growth	Rest of the world linked with elasticities	A fiscal rule over the government's structural deficit reduces the effect of external shocks on fiscal balances but amplifies the effect of demand shocks.
Do Nascimento and Silva (2016)	Brazil	Growth	...	The results obtained indicate that they depend both on the neo-Kaleckian investment functions and on the simplifying assumptions that, <i>a priori</i> , create nirvanic financial conditions for the rentier class.
Escobar (2016)	Colombia	Growth	Rest of the world linked with elasticities	A twin deficit is observed between the private and external sectors. There is no evidence that improvements in the United States economy will improve the Colombian economy's export figures.
Fernández (2017)	Ecuador	Static	Rest of the world with the same currency	The observed effects of fiscal policy are as expected, but reduced public spending has more impact on aggregate demand.
Guevara Castañeda (2015)	Colombia	Static	...	Rising interest rates produce a redistribution of income from low-income households to the households with the highest incomes.
Kappes and Milan (2017)	Brazil	Static	...	The <i>a priori</i> more expansionist (or less contractionist) rules present higher growth rates, <i>ex post</i> ; there is an inverse relationship between government debt and firms' debt, with the former being higher under the first rule, and lower in the balanced budget rule, the opposite happening in the case of firms' debt.
Mazzi (2013)	Brazil	Growth	Thirlwall's law with capital flows	The impact of capital inflow on the economy is dependent on the kind of capital.
Mellini (2018)	Brazil	Growth	Twin deficits	Corroborated the hypothesis of twin deficits is and refuted the possibility of negative consequences through an increase in fiscal stance.
Michelena and Guaita (2017)	Argentina	Growth	Thirlwall's law	Increased public spending has positive effects on economic growth, but those increases are restrained by external constraints.
Pérez Caldentey (2009)	Caribbean Community (CARICOM)	Growth	Thirlwall's law	The model highlights the binding character of the external constraint and argues that government expenditures do not necessarily result in low growth or high debt levels. The outcome depends on the interaction between government, external, and the private sector, an interaction that is the basis for stock-flow modelling.
Telechea (2018)	Latin America	Growth	Twin deficits	The outcomes confirm the twin deficit hypothesis, with causality from the external balance to the fiscal balance.
Valdecantos (2016)	Latin America	Static	Thirlwall's law	The impact of different kinds of external shock on Latin American economies is dependent on their type of productive structure.

Source: Prepared by the authors, on the basis of the references cited.

Annex A2

Environmental physical matrix

Table A2.1
Physical stock-flow matrix of two-area economy (consolidated)

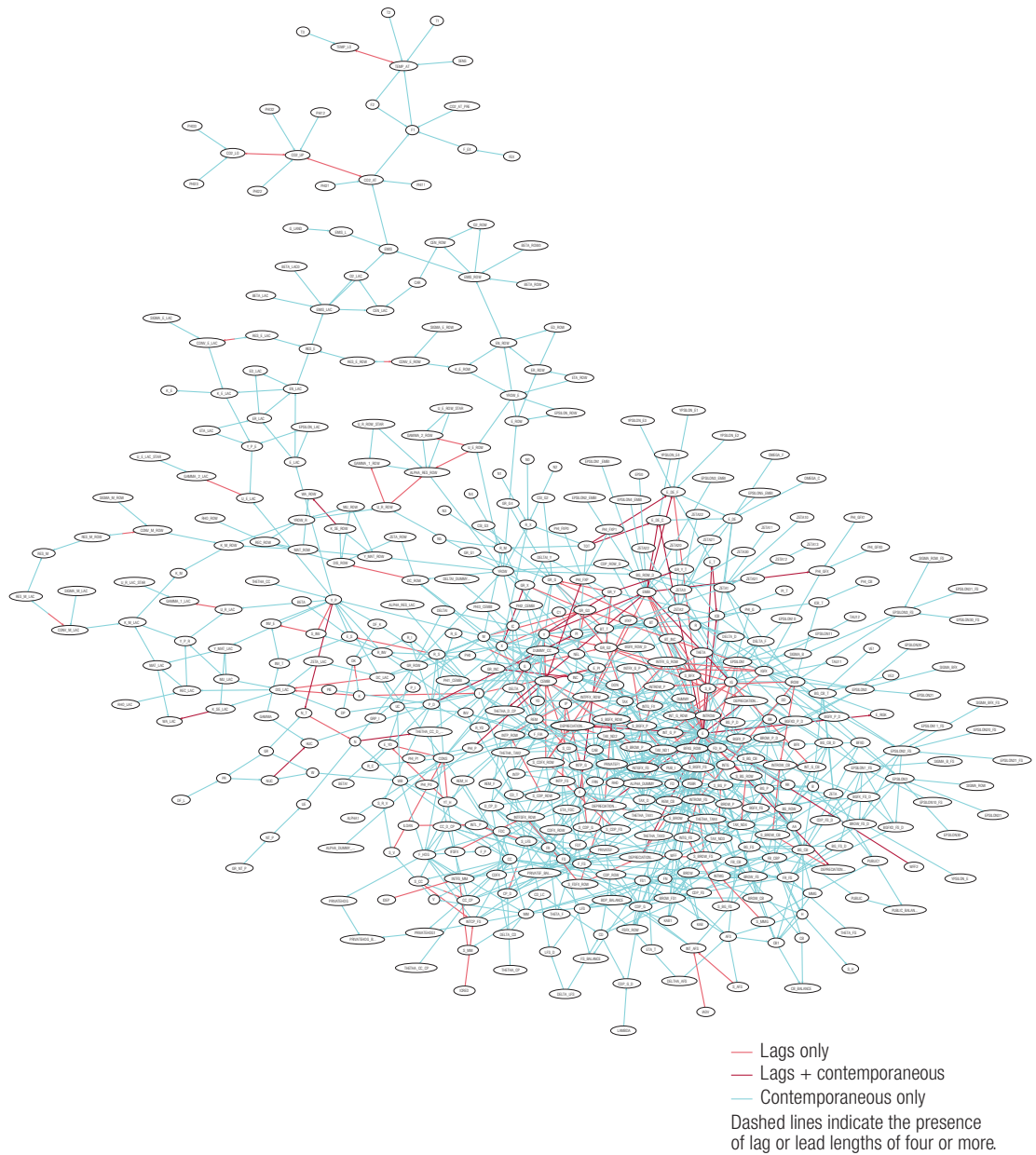
	Global material reserves	Global non-renewable energy reserves	Global atmospheric CO ₂ concentration	Global socioeconomic stock
Initial stock	$+k_{CA,(-1)}^m + k_{row,(-1)}^m$	$+k_{CA,(-1)}^e + k_{row,(-1)}^e$	$+co2_{at,(-1)}$	$+k_{se,(-1)}^{CA} + k_{se,(-1)}^{row}$
Resources converted into reserves	$+conv_{CA}^m + conv_{row}^m$	$+conv_{CA}^e + conv_{row}^e$		
CO ₂ emissions (global)			$emis_{CA} + emis_l + emis_{row}$	
Production of material goods				$+y_{CA}^{mat} + y_{row}^{mat}$
Extraction/use of matter/energy	$-(mat_{CA} + mat_{row})$	$-(en_{row} + en_{CA})$		
Net transfer to oceans/biosphere			$(phi_{11} - 1)*co2_{at(-1)} + phi_{21}*co2_{up(-1)}$	
Destruction of socioeconomic stock				$-(dis_{CA} + dis_{row})$
Final stock	$+k_{CA}^m + k_{row}^m$	$+k_{CA}^e + k_{row}^e$	$+co2_{at}$	$+k_{se}^G + k_{se}^B$

Source: Prepared by the authors.

Note: $k_{CA,(-1)}^m, k_{row,(-1)}^m$ = stock of material reserves in Central America and in the rest of the world; $conv_{CA}^m, conv_{row}^m$ = material resources converted to reserves in Central America and in the rest of the world; mat_{CA}, mat_{row} = extraction of matter in Central America and in the rest of the world; k_{CA}^m, k_{row}^m = stock of material reserves in Central America and in the rest of the world; $k_{CA,(-1)}^e, k_{row,(-1)}^e$ = stock of energy reserves in Central America and the rest of the world; $conv_{CA}^e, conv_{row}^e$ = energy resources converted to reserves in Central America and in the rest of the world; en_{row}, en_{CA} = non-renewable energy in the rest of the world and in Central America; k_{CA}^e, k_{row}^e = stock of energy reserves in Central America and in the rest of the world; $co2_{at(-1)}, co2_{up(-1)}$ = atmospheric CO₂ concentration; $emis_{CA}, emis_l, emis_{row}$ = industrial emissions in Central America, annual emissions of CO₂ from land, and industrial emissions from the rest of the world; $co2_{at(-1)}, +co2_{up(-1)}$ = atmospheric CO₂ concentration and upper ocean or biosphere CO₂ concentration; $k_{se,(-1)}^{CA}, k_{se,(-1)}^{row}$ = socioeconomic stock in Central America and in the rest of the world; $y_{CA}^{mat} + y_{row}^{mat}$ = production of material goods in Central America and in the rest of the world; dis_{CA}, dis_{row} = discarded socioeconomic stock in Central America and in the rest of the world; k_{se}^G, k_{se}^B = global socioeconomic stock at the end of the period (year) for Central America and the rest of the world.

Annex A3

Diagram A3.1
Dependency graph



Source: Prepared by the authors.