Implementing the Just Energy Transition (JET) in Colombia: a prototype Ecological Input Output Stock Flow Consistent Model (E-IO-SFC)

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[a] *UNAM* [b] *UNAL* [c] *Levy Economics Institute*

30th IIOA Conference - Assessing Industrial, Trade and Green Transition Policies Through SFC-IO Models

- This study aims to develop an **ecological Input Output Stock-flow consistent (SFC) model** based on the case of Colombia;
- We build upon Nalin et al. (2023) analysis of a Latin American economy highly integrated into financial markets as we include a simplified Input-Output structure;
- Model parameters, initial values and technical coefficients are calibrated using empirical data from DANE (2023);
- We provide an estimate of several scenarios that can affect the energy transition.

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Selected key stylized facts for Colombia

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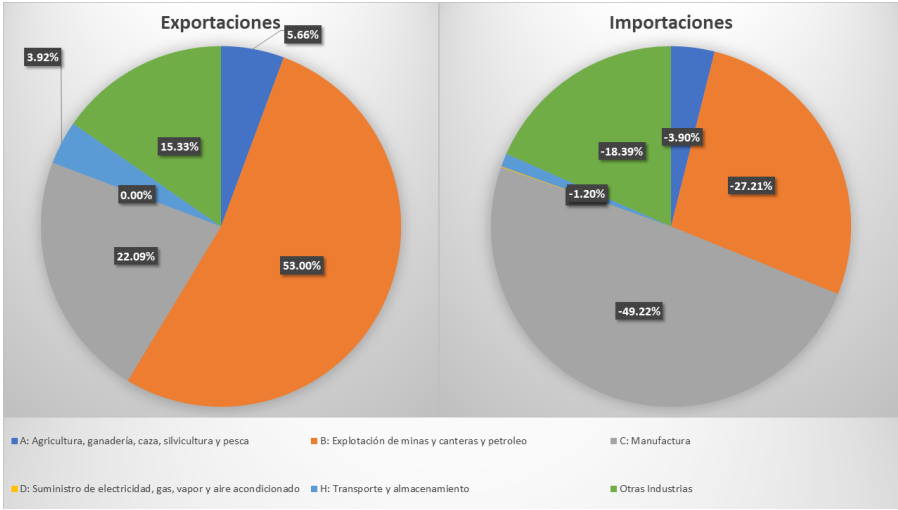

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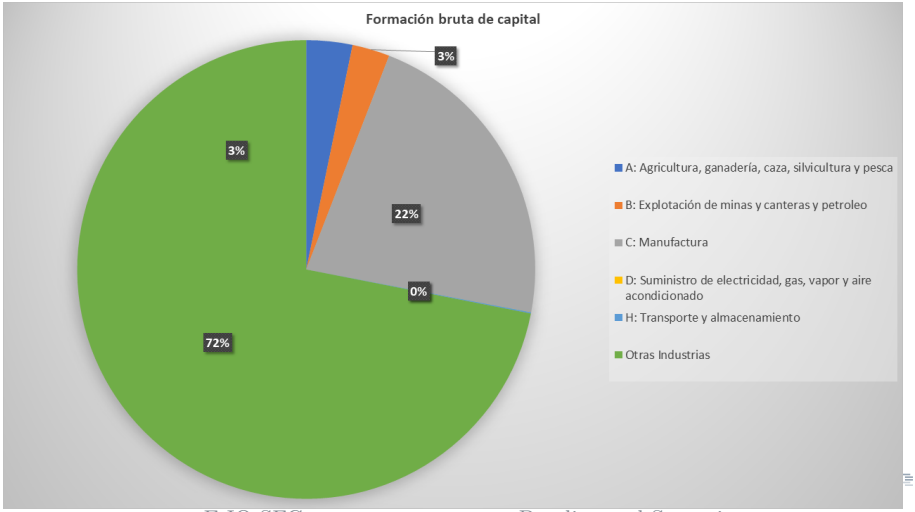

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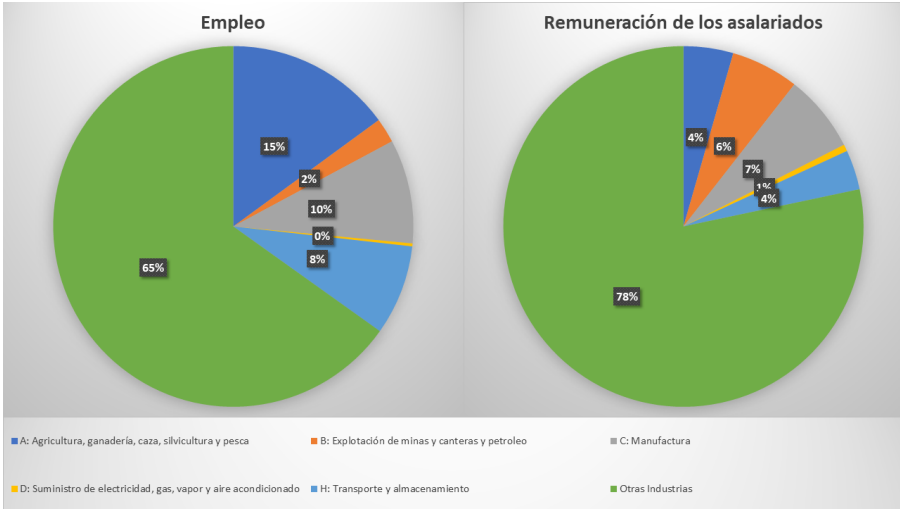

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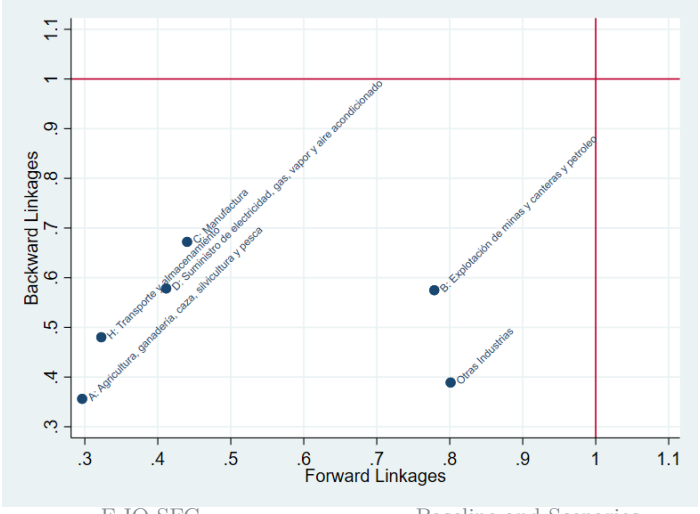

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SFC models for Latin America and the Caribbean

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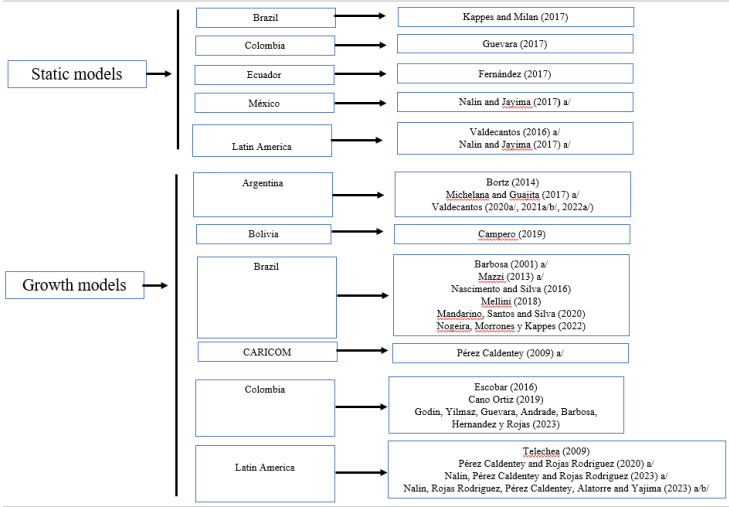

The model presented includes the following transmission mechanisms:

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- The positive correlation between exchange rate change and sovereign risk;
- The causality running from sovereign risk to risk of the non-financial corporate sector;
- The relationship between nominal and real variables (non-financial corporate sector):
  - Non-linear relationship between debt and investment;
  - Negative relationship between exchange rate and investment;
  - Balance sheet currency mismatches.
- The positive correlation between valuation of sovereign debt issued in foreign currency and in local currency;
- The greater presence of inter-company loans in foreign direct investment flows.

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We combine the macro-financial theoretical framework by Perez Caldentey et al. (2022) and the ecological modeling of Carnevali et al. (2021) and Dafermos (2017).

Sectors:

I. Private sector;
II. Financial sector;
III. Public sector;
IV. Central Bank;
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Features of the model:

I. 514 equations, 195 exogenous;

II. Fully calibarted using DANE, BANREP , MinHacienda data;

III. Prices are a function of technical coefficients, historical ULC and imported inputs;

IV. The observed series and the country's fiscal institutions are replicated.

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Balance Sheet Matrix

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	Private Sector	Financial Sector	GovtSector	Central bank	ROW	Σ
Govt Bonds (domestic currency)	$+B^g_p$	$+B^g_{fs}$	$-B^g$	$+B^g_{bc}$	$+B^g_{row}$	0
Govt Bonds (FX currency)	$+B^{\$}_p g$	$+B^{\$}_{fs} g$	$-B^{\$} g$		$+B^{\$}_{row} g$	0
Private Debt	$-D^p$	$+D^p_{fs}$	$+D^p_g$		$+D^p_{row}$	0
Priv Debt FX	$-D^{\$}$				$+D^{\$}_{row}$	0
Bonds ROW	$+B^{row}_p$	$+B^r_{fs} ow$		$+B^{row}_{bc}$	$-B^{row}$	0
Public Deposits			$+M^g$	$-M^g$		0
Consumption Credit	$-Cc$	$+Cc$				0
Advances		$-A^{fs}$		$+A^{fs}$		0
Loans	$-L^{fs}_p$	$+L^{fs}_p$				0
Loans (FX)		$-L^{\$row}_{fs}$			$+L^{\$row}_{fs}$	0
Private Deposits	$+M^p$	$-M^p$				0
High power money	$+H^p$	$-H^{fs}$		$+H^{bc}$		0
Capital	$+K$					$+K$
Σ	0	0	0	0	0	0

Transaction Flow Matrix

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		Production	Private Sector		Financial Sector		GovtSector		Central bank		ROW	Σ
			Current	Capital	Current	Capital	Current	Capital	Current	Capital		
Consumption		$+C_d$	$-C_d$									0
Investment		$+I^g$		$-I^k$								0
Government Spending		$+G_d$					$-G_d$					0
Imports			$-IM$								$+IM$	0
Exports			$+X$								$-X$	0
$[GDP]$			$[-Y]$	$[+Y]$								0
Interest	Govt Bonds (domestic currency)		$+int^g_{\$}$		$+int^{\$}_{fx}$		$-int^g$		$+int^g_{bc}$		$+int^g_{row}$	0
on	Govt Bonds (FX currency)		$+int^{\$g}_p$		$+int^{fxg}_{fx}$		$-int^{\$g}$				$+int^{\$g}_{row}$	0
	Private Debt		$-int^p$		$+int^p_{fx}$		$+int^p_g$				$+int^p_{row}$	0
	Priv Debt FX		$-int^{\$p}$								$+int^{\$p}_{row}$	0
	Bonds ROW		$+int^{row}_p$		$+int^{row}_{fx}$				$+int^{row}_{bc}$		$-int^{row}$	0
	Public Deposits						$+int^{ch}_{(mm_p)}$		$-int^{ch}_{(mm_p)}$			0
	Private deposits		$+int^{fx}_{(mm_p)}$		$-int^{fx}_{(mm_p)}$							0
	Consumption Credit		$-int^{cr}$		$+int^{cr}_{fx}$							0
	Advances				$-int^{fx}$				$+int^{cr}_{ch}$			0
	Loans		$-int^l p$		$+int^{lp}$							0
	Loans (FX)				$-int^{\$l}{}_{fx}$						$+int^{\$l}{}_{fx}$	0
Financial gains(dividends)			$+F - fr - fdc$				$+FB^{bc}_g$		$-FB^{bc}$			0
$[GrossNationalIncome]$		$[GNI_{PS}]$		$[GNI_{FS}]$		$[GNI_{GS}]$						$[GNI]$
Taxes		$-T$		$-T$		$+T$						0
Savings		$[S_{PS}]$		$[S_{FS}]$		$[S_{GS}]$					$[S_{RoW\$}]$	0
Capital		$+K$										$-K$
Inventories		$+IN$										$-IN$
Govt Bonds (domestic currency)				$-\Delta B^g_{\$}$		$-\Delta B^g_{fx}$		$+\Delta B^g$		$-\Delta B^g_{bc}$	$-\Delta B^g_{row}$	0
Govt Bonds (FX currency)				$-\Delta B^{\$}_p g$		$-\Delta B^{\$}_{fx} g$		$+\Delta B^{\$} g$			$-\Delta B^{\$}_{row} g$	0
Private Debt				$+\Delta D^p$		$-\Delta D^p_{fx}$		$-\Delta D^p_g$			$-\Delta D^p_{row}$	0
Priv Debt FX				$+\Delta D^{\$}$							$-\Delta D^{\$}_{row}$	0
Bonds ROW				$-\Delta B^{row}_p$		$-\Delta B^r{}_{fx} ow$				$-\Delta B^{row}_{bc}$	ΔB^{row}	0
Public Deposits								$-\Delta M^g$		$+\Delta M^g$		0
Consumption Credit				$+\Delta Cc$		$-\Delta Cc$						0
Advances						$+\Delta A^{fx}$				$-\Delta A^{fx}$		0
Loans				$+\Delta L^{fx}_p$		$-\Delta L^{fx}_{\$}$						0
Loans (FX)						$+\Delta L^{\$row}_{fx}$					$-\Delta L^{\$row}_{fx}$	0
Private Deposits				$-\Delta M^p$		$+\Delta M^p$						0
High power money				$+\Delta H^{\$}$		$+\Delta H^{\$}$				$-\Delta H^{bc}$		0
Σ		0	0	0	0	0	0	0	0	0	0	0

Physical flow matrix

2 SFC approach for the energy transition of Colombia

	Material balance	Energy balance
Inputs		
Extracted matter	$+mat_{latam} + mat_{row}$	
Renewable energy		$+er_{latam} + er_{row}$
Non-renewable energy	$+cen_{latam} + cen_{row}$	$+en_{latam} + en_{row}$
Oxygen	$+o2_{latam} + o2_{row}$	
Outputs		
Industrial CO2 emissions	$-(emis_{latam} + emis_{row})$	
Waste	$-(wa_{latam} + wa_{row})$	
Dissipated energy		$-(ed_{latam} + ed_{row})$
Change in socio-economic stock	$-(\Delta k_{se}^{latam} + \Delta k_{se}^{row})$	
Total	0	0

Physical stock-flow matrix

2 SFC approach for the energy transition of Colombia

	Global material reserves	Global non-renewable energy reserves	Global atmospheric CO2 concentration	Global socio-economic stock
Opening stock	$+k^m_{(latam,(-1))} + k^m_{(row,(-1))}$ 1	$+k^e_{(latam,(-1))} + k^e_{(row,(-1))}$	$+co2_{(at,(-1))}$	$+k^{latam}_{(se,(-1))} + k^{row}_{(se,(-1))}$
Additions to stock				
Resources converted into reserves	$+conv^m_{latam} + conv^m_{row}$	$+conv^e_{latam} + conv^e_{row}$		
CO2 emissions			$emis_{latam} + emis_l + emis_{row}$	
Production of material goods				$+y^{mat}_{latam} + y^{mat}_{row}$
Reductions of stock				
Extraction/ use of matter/ energy	$-(mat_{latam} + mat_{row})$	$-(en_{row} + en_{latam})$		
Net transfer to oceans/biosphere			$(phi_{11-1}) * co2_{at(-1)} + phi_{21} * co2_{up(-1)}$	
Destruction of socio-economic stock				$-(dis_{latam} + dis_{row})$
Closing stock	$+k^m_{latam} + k^m_{row}$	$+k^e_{(latam,)} + k^e_{(row,)}$	$+co2_{(at,)}$	$+k^G_{se} + k^B_{se}$

Input Output Table

2 SFC approach for the energy transition of Colombia

	A: Agriculture, livestock, hunting, forestry and fishing	B: Mining, quarrying, petroleum	C: Manufacturing	D: Electricity, gas, steam and air conditioning supply	H: Transport & Storage	Other Industries	**Total Intermediate Consumption**	Final Consumption Expenditure (Households and NPIs)	Final Consumption Expenditure (Government)	Gross capital formation	Exports	Imports	**Total**
A: Agriculture, livestock, hunting, forestry and fishing	X_{aa}	X_{ab}	X_{ac}	X_{ad}	X_{ah}	X_{aet}	IC_a	C_a	G_a	I_a	X_a	M_a	Y_a
B: Mining and quarrying and petroleum	X_{ba}	X_{bb}	X_{bc}	X_{bd}	X_{bh}	X_{bet}	IC_b	C_b	G_b	I_b	X_b	M_b	Y_b
C: Manufacturing	X_{ca}	X_{cb}	X_{cc}	X_{cd}	X_{ch}	X_{cet}	IC_c	C_c	G_c	I_c	X_c	M_c	Y_c
D: Electricity, gas, steam and air conditioning supply	X_{da}	X_{db}	X_{dc}	X_{dd}	X_{dh}	X_{det}	IC_d	C_d	G_d	I_d	X_d	M_d	Y_d
H: Transport & Storage	X_{ha}	X_{hb}	X_{hc}	X_{hd}	X_{hh}	X_{het}	IC_h	C_h	G_h	I_h	X_h	M_h	Y_h
Other Industries	X_{eta}	X_{etb}	X_{etc}	X_{etd}	X_{eth}	X_{etet}	IC_{et}	C_{et}	G_{et}	I_{et}	X_{et}	M_{et}	Y_{et}
Value Added	VA_a	VA_b	VA_c	VA_d	VA_h	VA_{et}							
Remuneration of employees	W_a	W_b	W_c	W_d	W_h	W_{et}							
Taxes minus subsidies on production and import	T_a	T_b	T_c	T_d	T_h	T_{et}							
Gross operating surplus and Mixed Income	Π_a	Π_b	Π_c	Π_d	Π_h	Π_{et}							
Total	Y_a	Y_b	Y_c	Y_d	Y_h	Y_{et}							

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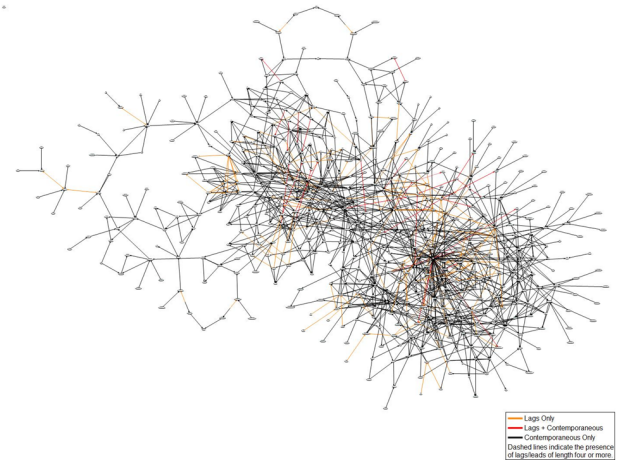
3 Baseline Results and scenario analysis

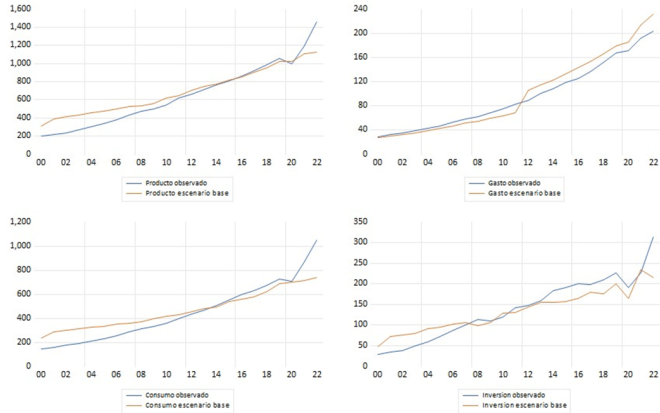
Model Dependecy Graph

3 Baseline Results and scenario analysis



Baseline and observed variables

3 Baseline Results and scenario analysis



Scenarios Analyzed

3 Baseline Results and scenario analysis

We assess eight scenarios resulting from a combination of three type of shocks:

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II. The arising (or lack of) of supply constraints for the oil industry;

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3 Baseline Results and scenario analysis

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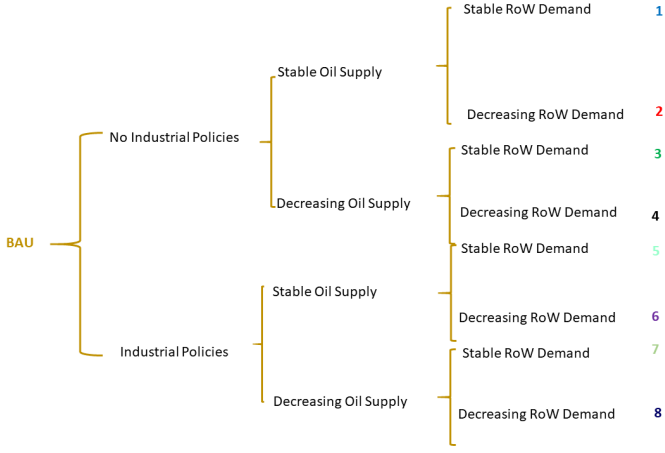
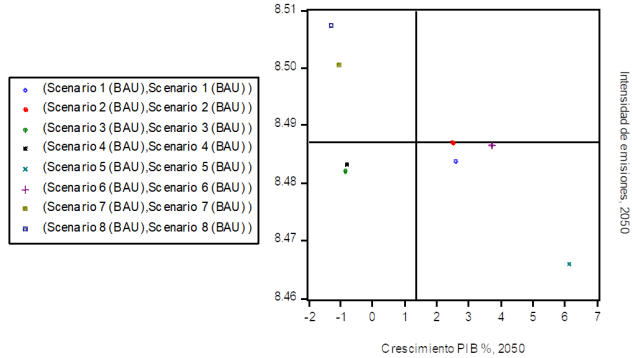


GDP Growth - Emission Intensity - 2050

3 Baseline Results and scenario analysis

- Reindustrialization scenarios where domestic oil supply is stable (5, 6) are related to greater growth and lower emissions intensity.



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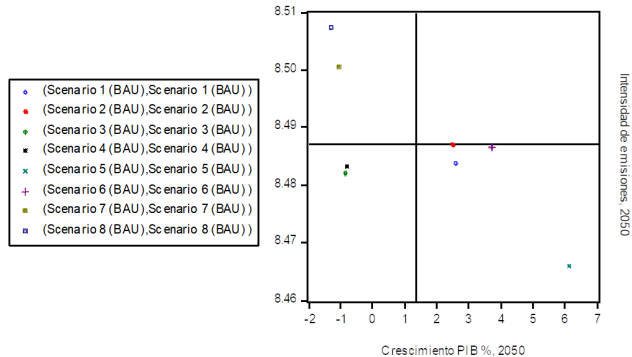

GDP Growth - Current Account - 2050

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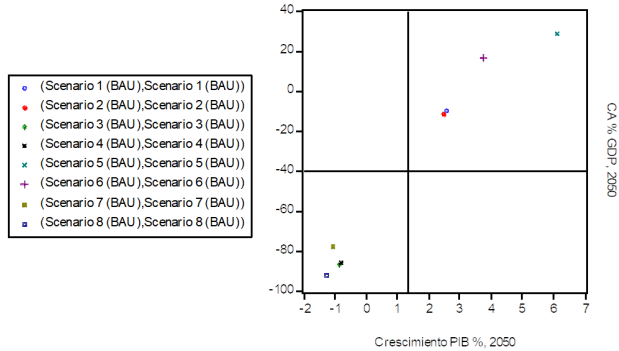
- Scenarios where domestic supply is stable (5, 2, 6, 1), are related to a better balance in the current account.



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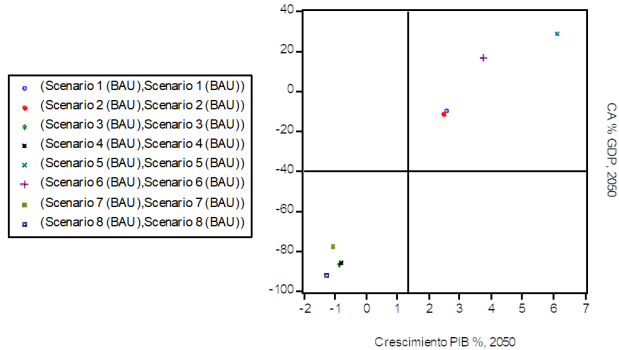
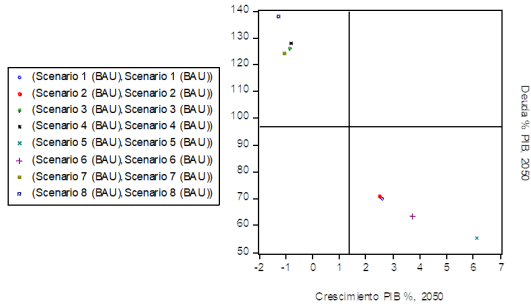


GDP Growth - Debt/GDP ratio - 2050

3 Baseline Results and scenario analysis

- Scenarios where domestic supply changes (3, 4, 7, 8), are related to a higher level of debt and lower GDP growth.



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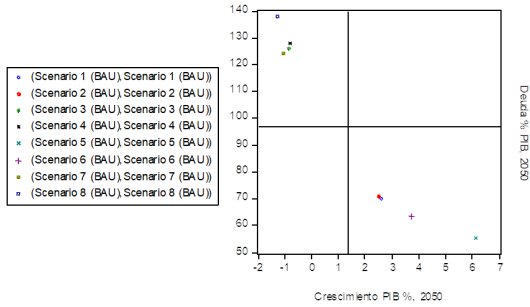
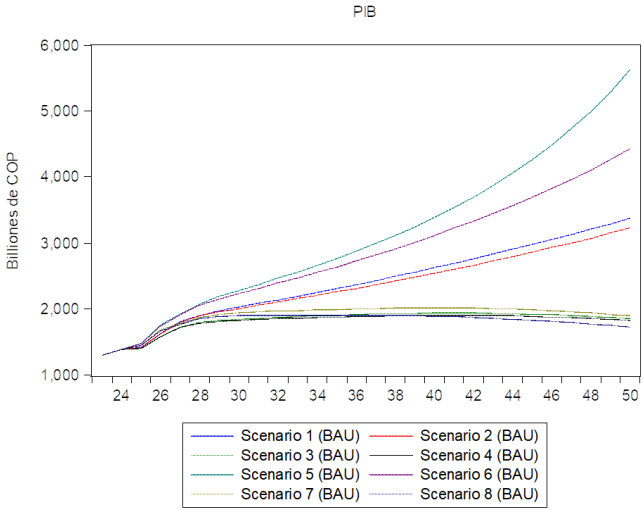


Simulated and Baseline variables

3 Baseline Results and scenario analysis



Conclusions

3 Baseline Results and scenario analysis

All in all, reindustrialization scenarios with stable oil supply yield better results (5, 2, 6)

Reindustrialization scenarios where domestic supply is stable, bring about higher growth and lower emissions intensity (5, 6);

Scenarios where domestic supply is stable, are related to a better current account balance (5, 2, 6, 1);

Scenarios with stable domestic supply outperform the ones in which domestic supply changes.

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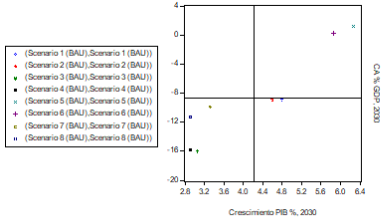
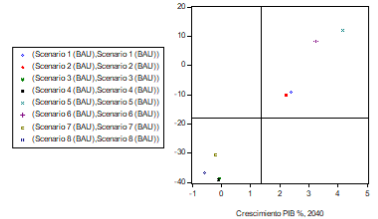
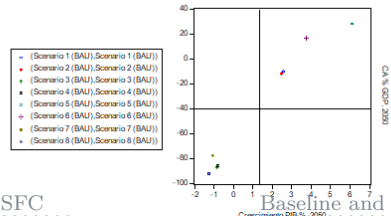
4 Appendix

GDP Growth - Current Account

4 Appendix

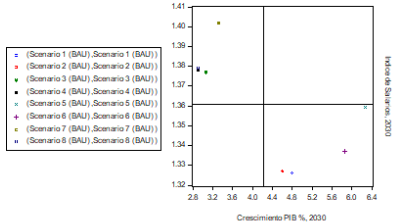


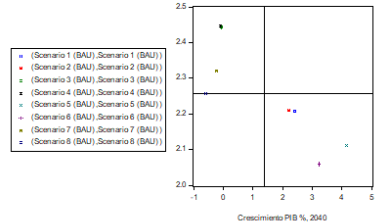


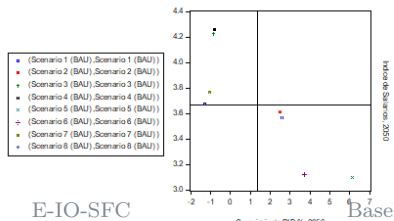


GDP Growth - Wages

4 Appendix

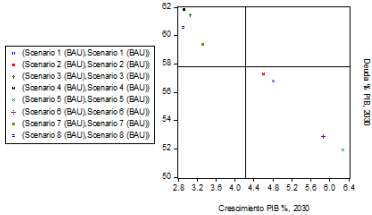


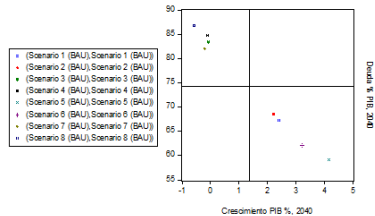


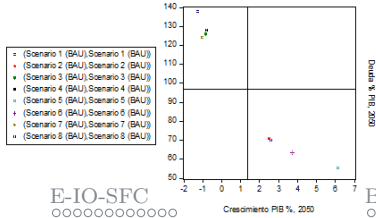


GDP Growth - Debt/GDP ratio

4 Appendix

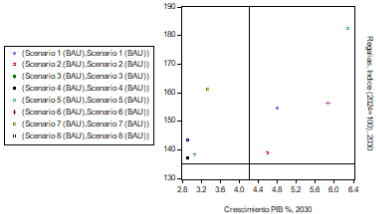


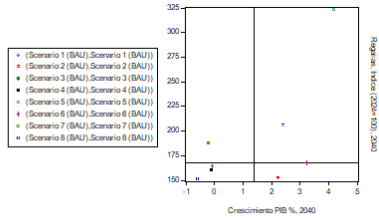


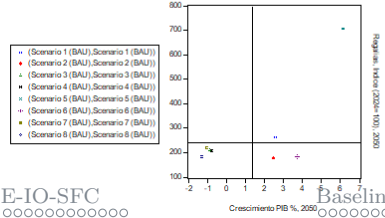


GDP Growth - Royalties

4 Appendix







GDP Growth - Employment

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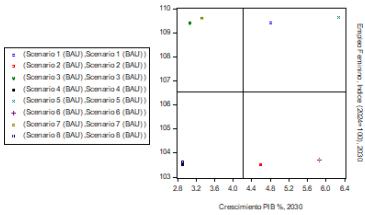

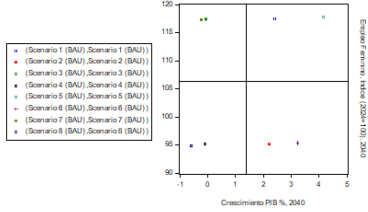

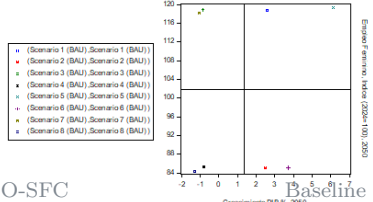

Model Equations

4 Appendix

Income Identities

Real Sales

1. $s_{real} = \frac{c+\ i+g+m}{p\_d}$

Real Consumption

2. $c_{real} = \frac{c}{p\_d}$

Real Inventories

3. $inv_{real} = Y\ - r\_s$

Real Investment

4. $i_{real} = \frac{i}{p\_d}$

Real public Spending

5. $g_{real} = \frac{g}{p\_d}$

Model Equations

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Real disposable income

6. $yd_{real} = \frac{yd}{p\_d}$

I. PRODUCTION

Total Production

7. $y = (1 - (D^y + \vartheta_y.dummy))_{.}(s^e + (in^T - in_{-1}))$

Target Inventories

8. $in^T = \gamma.s^e$

Expected Inventories

9. $inv^e = inv_{s-1} + {}_{inv_1}.\ (in^T - inv_{s-1})$

Expected Sales

Model Equations

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10. $\mathbf{s^e = SS \ .s_{-1} + (1 - SS) \ . \ \Delta Y_{row}}$

Nominal Inventories

11. $\mathbf{inv = inv_{real} * uc}$

II. PRIVATE SECTOR

Private sector: income and consumption

Households' disposable income

12. $yd^h = WB + Fd_c + \ intfs_{mm} + rem$

Remittances

13. $rem = (Dummy + \alpha_{rem}) * E * Y_{row}$
14. $rem_h = \beta_{rem,h} rem$
15. $rem_f = (1 - \beta_{rem,h})(1 - \theta_{rem,f}) rem$

Model Equations

4 Appendix

16. $rem_{cb} = (\theta_{rem,f})rem_f$

Consumption

17. $c = \alpha_{1c}c_{-1} + \alpha_{2c}c_{-1} * \left(1 + \alpha_{3c} * \frac{(yd^e_{-1} - yd^h_{-1})}{yd^h_{-1}}\right) + \alpha_2 v_{-1} + \alpha_2.Dummy$

Sales

18. $s = c + i + g + (x - m) + rem$

Expected Income

19. $yd^e = .yd^h_{-1} + (1 -).yd^h_{-1}.(1 + \Delta Y_{row})$

Wealth

20. $v = mm - cc$

Model Equations

4 Appendix

Private sector: capital accumulation

Sales Price

21. $p_{s,x} = (1+\pi) * (\sum_{j=1}^{6} a_{ij} p_j + \eta_i p_i + HUC), \quad \forall x \in \{a, b, c, d, h, et\}$

Sales Price

22. $\pi_x = f(ue,\ um), \quad \forall x \in \{a, b, c, d, h, et\}$

Historical Unitary Cost (HUC)

23. $HUC_x = (1 - \gamma_{nuc}) * NUC + \gamma_{nuc} * N_{-1}, \quad \forall x \in \{a, b, c, d, h, et\}$

Nominal Unitary Cost

24. $NUC_x = \frac{W_x}{pr}, \quad \forall x \in \{a, b, c, d, h, et\}$

Unitary Cost

25. $UC_x = \frac{(WB_x + M_x)}{y_x}, \quad \forall x \in \{a, b, c, d, h, et\}$

Model Equations

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Wage Bill

26. $WB_x = W_x.N_x, \quad \forall x \in \{a, b, c, d, h, et\}$

Employment Level

27. $N_x = N_{x,-1} * (1 + \Delta Y_{RoW}) + \Omega_n . \left(N_{x,-1} - N_x^T\right), \quad \forall x \in \{a, b, c, d, h, et\}$

Employment Target

28. $N_x^T = N_{x,-1}^T + \Omega_{n_1}(\Delta y - gr), \quad \forall x \in \{a, b, c, d, h, et\}$

Productivity

29. $pr_x = pr_{x,\ -1}. \left(1 + gr - D^l\right), \quad \forall x \in \{a, b, c, d, h, et\}$

Nominal Wage

30. $W_x = W_{x,-1}.(1 + gr), \quad \forall x \in \{a, b, c, d, h, et\}$

Model Equations

4 Appendix

Capital Accumulation

31. $\Delta k_x = i_x - (d_x + D^k).k_{-1}, \quad \forall x \in \{a, b, c, d, h, et\}$

Private Investment

32. $i_x = \left(\left(dp + D^k + A\right).k_{-1}\right).p_d + i_{x,-1}.ic, \quad \forall x \in \{a, b, c, d, h, et\}$

Confidence Index

33. $i_c = \delta.\pi^e + \delta_1.\Delta Y_{RoW} + \delta_2.\Delta Y - \delta_3.dummy$

Confidence Index Sensibility to Expected profits

34. $\delta = \left\{ \begin{array}{ll} if\ \frac{D^T_{-1}}{Y_{-1}} > 0,6 & 0,55 \\ & . \\ if\ \frac{D^T_{-1}}{Y_{-1}} \leq 0,6 & 0,65 \end{array} \right\}$

Model Equations

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Confidence Index Sensibility to World growth rate

$$35.\ \delta_1 = \begin{cases} if\ \Delta y_{RoW} > 0 & 0,3 \\ . & \\ if\ \Delta y_{RoW} \leq 0 & 2,5 \end{cases}$$

Confidence Index Sensibility to domestic growth rate

$$36.\ \delta_2 = \begin{cases} if\ \Delta y > 0 & 0,3 \\ . & \\ if\ \Delta y \leq 0 & 2,5 \end{cases}$$

Expected Profits

$$37.\ \pi^e = \varsigma_1 . \frac{F_{-1}}{I_{-1}} + (1 - \varsigma_1) . \Delta cembi_{-1}$$

Constraint on Investment

Model Equations

4 Appendix

38. $A = A_0 - \gamma_1 (um_{-1} - um_r) - \gamma_2 (ue_{-1} - ue_r)$
39. $\gamma_1 = \gamma_{10} \qquad if\ um_{-1} > um_r;\ else\ \gamma_1 = 0$
40. $\gamma_2 = \gamma_{20} \qquad if\ ue_{-1} > ue_r;\ else\ \gamma_2 = 0$
41. $um = \frac{Y}{Y^*_M}$
42. $ue = \frac{Y}{Y^*_E}$
43. $Y^*_M = \frac{k^m_{latam,-1} + rec_{latam}}{mu_{latam}}$
44. $Y^*_E = \frac{k^e_{latam,-1}}{(1 - eta_{latam}) epsilon_{latam}}$

Private Sector: retained and distributed profits

Private Sector's profits before depreciation and taxes

45. $Fp = F + F_h$

Model Equations

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Firms Profits

46. $F_{firm} = c + \ i + g + (x - m) - (int^p + int^p_{row} + int^p_{loan}) - WB + inv + (int^g_p + int^g_{pFX} + int^{row}_p) + (D_{CP_d} - CP_d)$

Firms' profits after taxes

47. $F = F_{firm} - tax - depr$

Households Profits

48. $F_{hog} = WB - c + int^{fs}_{mm_p} - intc^p_{fs} + rem_h$

Retained Profits

49. $Fr = \theta_f.F$

Retained Profits

50. $Fd = (1 - \theta_{fdc}).Fdt$

Model Equations

4 Appendix

Non-retained profits

51. $Fdt = (1 - \theta_{f)}.F$

Profits distributed for consumption

52. $Fdc = \theta_{fdc}.Fdt$

Excess Profits (retained profits not invest in capital)

53. $Frn = Fr - i \qquad if\ Fr > i$

Private Sector: retained and distributed profits

Private budget constraint (equivalent to total private debt issued in each period)

54. $\Delta \mathbf{D^t} = \mathbf{I} + \mathbf{inv} - \mathbf{Fr}$

Total Private debt (local currency)

55. $\Delta \mathbf{D^{tlc}} = \delta_{\mathbf{cd}}.\Delta \mathbf{D^t}$

Model Equations

4 Appendix

Bonds issued by firms (local currency)

56. $\mathbf{\Delta D^{p} = \delta_{d} . \Delta D^{tlc}}$

Loans demanded by firms (local currency)

57. $\Delta L_p^d = \delta_{cd} . \Delta D^{tlc}$
58. $CP_d = \theta_{cp} . L_{-1}^f$
59. $D_{CP_d} = \theta_{d_{cp}} . CP_d$
60. $\theta_{d_{cp}}$=¿?

Bonds issued by firms (in local currency) held by the financial sector

61. $\mathbf{\Delta D^{p}_{fs} = min[\Delta D^{p}_{fsd}, \Delta D^{p}]}$

Bonds issued by firms (in local currency) held by RoW

Model Equations

4 Appendix

62. $\Delta \mathbf{D^p_{row}} = \Delta \mathbf{D^p} - \Delta \mathbf{D^p_{fs}}$

Total Private debt in foreign currency

63. $\Delta \mathbf{D^{\$p}} = (\mathbf{1} - \delta_{\mathbf{cd}}).\Delta \mathbf{D^t}$

Private Sector: portfolio

Private Sector Demand for Govt bonds (local currency)

64. $\Delta B^g_{p\_d} = \epsilon_1.F_d$

Private Sector Demand Sensitivity for govt bonds (local currency)

65. $\epsilon_1 = \epsilon_{10} + \epsilon_{11}\left(\frac{1+i^g}{1+\pi^e}\right)^{\sigma_b}$

Private Sector Demand for govt bonds (foreign currency)

66. $\Delta B^{\$g}_{p\_d} = \epsilon_2.F_d$

Model Equations

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Private sector demand sensitivity for domestic bonds (foreign currency)

67. $\epsilon_2 = \epsilon_{20} + \epsilon_{21}\left(\frac{1+i^{g\$}}{1+i^{row}}\right)^{\sigma_{b\$}}$

Private sector demand for ROW bonds

68. $\Delta B_{pd}^{row} = \epsilon_3 . F_d$

Private sector demand sensitivity for ROW bonds

69. $\epsilon_3 = \epsilon_{30} + \epsilon_{31}\left(\frac{1+i^{row}}{1+i^{g\$}}\right)^{\sigma_{row}}$

Private sector demand for Cash

70. $\Delta H_h^{bc} = \left(\Delta B_{p_d}^{g} - \Delta B_{p}^{g}\right) + \left(\Delta B_{p_d}^{\$g} - \Delta B_{p}^{\$g}\right).E + \left(\Delta B_{p_d}^{row} + \Delta B_{p}^{row}\right).E + Frn$

Model Equations

4 Appendix

III. PUBLIC SECTOR

a. CENTRAL GOVERNMENT

Government: Taxes and Spending

Govt spending

71. $G = G_{-1} + gr^{g}$

Government spending growth rate

72. $gr_g = \varphi_0 + \varphi_1.\Delta Y + \varphi_3.dummy$

Taxes

73. $T = \theta.Y$

Tax used for debt repayment

74. $T_d = \theta_{T_d}.T$

Model Equations

4 Appendix

Budget and debt supply

Public sector budget restriction

75. $PSBR = G - T - int^{g}_{B} - int^{g}_{Bfx} + int^{p}_{d_g} + int^{row}_{Bg} + -FB^{bc}$

Govt Debt Supply (local currency)

76. $\Delta B = \zeta . PSBR$

Govt Debt Supply (foreign currency currency)

77. $\Delta B^{\$} = (1 - \zeta) . PSBR$

Govt Debt Supply to Financial Sector (Local Currency)

78. $\Delta B^{g}_{fs} = min[\Delta B^{g}_{fsd}, \Delta B]$

Govt Debt Supply to Private Sector (Local Currency)

79. $\Delta B^{g}_{p} = min[(\Delta B - \Delta B^{g}_{fs}), \Delta B^{g}_{pd}]$

Model Equations

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Govt Debt Supply to ROW (Local Currency)

80. $\Delta B^{g}_{row} = \min\left[\varsigma_{row}.(\Delta B - \Delta B^{g}_{fs} - \Delta B^{g}_{p}),\ \Delta B^{g}_{rowd}\right]$

Govt Debt Supply to ROW (foreign currency)

81. $\Delta B^{g\$}_{row} = \min\left[\Delta B^{\$}, \Delta B^{g\$}_{rowd}\right]$

Govt Debt Supply to Financial sector (foreign currency)

82. $\Delta B^{g\$}_{fs} = min[\varsigma_{fs}.\left(\Delta B^{\$} - \Delta B^{g\$}_{row}\right), \Delta B^{g\$}_{fsd}]$

Govt Debt Supply to Private Sector (Foreign Currency)

83. $\Delta B^{g\$}_{p} = min[(\Delta B^{\$} - \Delta B^{g\$}_{fs} - \Delta B^{g\$}_{row}), \Delta B^{g\$}_{pd}]$

Govt deposits to financial sector

84. $M^{g} = public\ supervit$

Model Equations

4 Appendix

b. CENTRAL BANK

Central Bank Profits

85. $FB^{bcp} = int^{g}_{bc} + int^{row}_{bc} + int^{g\$}_{bc} + int^{afs}_{bc} - int^{cb}_{mm_g} + dep_{cb} + rem_{cb}$

Central Bank's profits not invested (after asset accumulation)

86. $FB^{bc} = FB^{bcp} - afs - B^{g}_{cb}.E - B^{g}_{cb} + M^{g}$

High power money supplied

87. $H = -FB^{bc} \quad si \quad FB^{bc} < 0$

Central bank target demand for domestic government bonds

88. $B^{g*}_{cb} = B * (\vartheta_{bc}\left(i^{g}_{-1} - i^{cb}_{-1}\right) + \vartheta_{e^{risk}}.\, e^{risk})$

Taylor's Rule

89. $i^{cb} = \pi_t + i^{cb*}_t + \vartheta_1 (\pi_t - \pi^*_t) + \vartheta_2 \ (\Delta y_t - \Delta y^*_t) + \vartheta_3 \ (\dot{e}_t - \dot{e}^*_t)$

Model Equations

4 Appendix

Potential Output

90. $\Delta y_t^* = 5\ years\ moving\ average\ y\ growth\ rate$

Central Bank interest rate target

91. $i_t^{cb*} = i^{row} + \varphi^{cb}$

Currency volatility indicator

92. $e^{risk} = \left\{ \begin{array}{cc} if\ s.d.\ of\ E \geq 3, & 1 \\ if\ s.d.\ of\ E < 3, & 0 \\ if\ s.d.\ of\ E \geq -3, & -1 \end{array} \right\}$

Public sector supply of bond to Central Bank

93. $\Delta \mathbf{B^g_{cb}} = \mathbf{max}[\Delta \mathbf{B} - \Delta \mathbf{B^g_{fs}} - \Delta \mathbf{B^g_{row}} - \Delta \mathbf{B^g_p},\ \mathbf{B^{g*}_{cb}}]$

RoW supply of debt to CB

Model Equations

4 Appendix

94. $\Delta \mathbf{B_g^{row}} = -\mathbf{CAB} + \mathbf{WFF} + \mathbf{B_P^{row}}.\mathbf{E} - \mathbf{depreciation_{RoW}}$

Public sector supply of bonds to Central Bank

95. $\Delta B_{cb}^{g} = max[\Delta B - \Delta B_{fs}^{g} - \Delta B_{row}^{g} - \Delta B_{p}^{g},\ B_{cb}^{g*}]$

ROW supply of bonds to Central Bank

96. $\Delta B_{g}^{row} = -CAB + WFF + B_{P}^{row}.E - dep_{RoW}$

Domestic Inflation

97. $\pi_t = \left(\frac{\Delta p_s}{p_{s_{-1}}}\right)$

Public deposits to Central Bank

98. $mm_g = -PSBR \quad \text{if} \quad PSBR < 0$

Model Equations

4 Appendix

IV. FINANCIAL SECTOR

Financial Sector: profits and budget constraint

Financial sector's profit

99. $f_{fs} = int^{g}_{fs} + int^{\$g}_{fs} + int^{p}_{fs} + int^{row}_{fs} - int^{fs}_{mm_p} + intc^{p}_{fs} - int^{afs} + int^{lp} - int^{\$lfs} + (CP_d - D_{CP_d}) + rem_f$

Financial sector's Budget constraint

100. $$\Delta \mathbf{FN^{t}_{fs}} = \mathbf{T} + \Delta \mathbf{B^{g}_{fs}} + \Delta \mathbf{B^{\$g}_{fs}} + \Delta \mathbf{D^{p}_{fs}} + \Delta \mathbf{D^{\$}_{fs}} + \Delta \mathbf{B^{row}_{fs}} + \Delta \mathbf{L^{fs}_{p}} + \Delta \mathbf{Cc^{p}_{fs}} - (\mathbf{1} - \sigma_{\mathbf{Rb}})\,\mathbf{M^{p}} - \mathbf{f_{fs}}$$

Financial sector's retained profit

101. $fr_{fs} = if_{fs}.\vartheta_{fs}$

Loans demanded by financial sector in foreign currency

Model Equations

4 Appendix

102. $\Delta L_{fs}^{\$row} = \frac{\left((1-\delta_{afs}).\Delta FN_{fs}^{t}\right)}{E}$ where δ_{afs} *is exogenous*

Financial Sector's Advances from Central Bank

103. $\Delta A^{fs} = \delta_{afs}.\Delta FN_{fs}^{t}$

Financial Credit supply (consumer credit and loans)

Deposits

104. $\mathbf{mm} = \mathbf{cc} + (\mathbf{f_{hog}} - \mathbf{cc}) \qquad \mathbf{if} \quad \mathbf{f_{hog}} - \mathbf{cc} > 0$

Demand for consumer credit

105. $\mathbf{Cc_d^p} = \mathbf{cons} + \mathbf{intcp_{fs}} - \mathbf{fdc} - \mathbf{wb} - \mathbf{intfs_{mm}} + \mathbf{rem_h}$

106. $\mathbf{CC_{D_{CP}}} = \theta_{\mathbf{CC_{D_{CP}}}} \mathbf{CC_{D_{CP}}}$

Supply of consumer credit

107. $\mathbf{Cc_s^p} = \mathbf{Cc_d^p}$

Model Equations

4 Appendix

Loans supplied by financial sector to private sector (local currency)

108. $\Delta L_p^s = \Delta L_p^d$

Financial sector's portfolio

Financial Proportion of assets bought by the financial sector

109. $\mathbf{fa_{fs}} = \sigma_{\mathbf{Rb}}.\mathbf{fr_{fs}}$

Financial Sector Demand for government bonds (local currency)

110. $\Delta B^g_{fs\_d} = \epsilon_{f1}.fa_{fs}$

Financial Sector Demand sensitivity for government bonds (local currency)

111. $\epsilon_{f1} = \epsilon_{f10} + \epsilon_{f11}\left(\frac{1+i^g}{1+i^{g\$}}\right)^{\sigma_{fb}}$

Financial Sector Demand for government bonds (foreign currency)

Model Equations

4 Appendix

112. $\Delta B^{\$g}_{fs\_d} = \epsilon_{f_2}.fa_{fs}$

Financial Sector Demand sensitivity for government bonds (foreign currency)

113. $\epsilon_{f_2} = \epsilon_{f_{20}} + \epsilon_{f_{21}} \left(\frac{1+i^{g\$}}{1+i^{row}}\right)^{\sigma_{f_{b\$}}}$

Financial Sector demand for ROW bonds

114. $\Delta B^{row}_{fsd} = \epsilon_{f_3}.fa_{fs}$

Financial Sector Demand sensitivity for ROW bonds

115. $\epsilon_{f_3} = \epsilon_{f_{30}} + \epsilon_{f_{31}} \left(\frac{1+i^{row}}{1+i^{g\$}}\right)^{\sigma_{f_{row}}}$

116. $\Delta D^{p}_{fs\_d} = \epsilon_{f_4}.fa_{fs}$

Model Equations

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Financial Sector Demand Sensitivity for govt bonds

$$\epsilon_{\mathbf{f4}} = \epsilon_{\mathbf{f40}} + \epsilon_{\mathbf{f41}} \left(\frac{\mathbf{1+i^p}}{\mathbf{1+i^g}} \right)^{\sigma_{\mathbf{fd}}}$$

V. EXTERNAL SECTOR

External sector: trade

Exports growth

117. $\Delta x = \eta_0 \, . \, Y_{row}^{\eta_1} . (TOT)^{\eta_2}$

Imports growth

118. $\Delta m = \eta_3 \cdot \frac{Y^{\eta_4}}{(TOT)^{\eta_5}}$

Real Exports

119. $X = x.p$

Real Imports

Model Equations

120. $M = m.p_i$

Imports prices

121. $X = x.p$

World Growth Rate

122. $Y_{row} = Y_{row-1} + gr_{row} + \dot{A}_{row}$

Current Account

123. $CAB = X - M - int^g_{B_{row}} - int^g_{BFX_{row}} - int^p_{d_{row}} - int^p_{dFX_{row}} + int^{row}_B + rem$

Capital Account

124. $KAB = \Delta B_{row} + \Delta B^{\$}_{row} + \Delta D_{row} + \Delta D^{\$}_{row} - \Delta B^{row}$

External sector: portfolio

RoW Demand for Private Debt (local currency)

Model Equations

4 Appendix

125. $\Delta D^{p}_{row} = (1-\lambda).D^{p}$

ROW demand for Private Debt (foreign currency)

126. $\Delta D^{\$p}_{row} = \Delta D^{\$p}$

RoW demand for Govt Debt (local currency)

127. $\Delta B^{g}_{row\_d} = \xi_1.(Y^{row})$

128. $\xi_1 = \xi_{1_0} + \xi_{1_1}.(i^{\$g} - i^{\$}) + \xi_{1_2}.\Delta E^{e} - \xi_{1_3}.dummy$

RoW demand for Govt Debt (foreign currency)

129. $\Delta B^{g\$}_{row\_d} = \xi_2.^{Grow}$

130. $\xi_2 = \xi_{2_0} + \xi_{2_1}.(i^{\$g} - i^{\$}) - \xi_{2_2}.dummy$

RoW supply of debt

Model Equations

131. $\Delta B^{row} = \Delta B_p^{row} + \Delta B_g^{row} + \Delta B_{fs}^{row}$

World Financial Flows (WFF)

132. $WFF = \Delta B_{row}^{g\$} + \Delta B_{row}^{g} + \Delta D_{row}^{\$p} + \Delta D_{row}^{p}$

RoW GDP

133. $Y^{row} = exogenous$

International interest rate

134. $i^{row} = exogenous$

Constraint on Investment RoW

135. $A_{row} = A_{0,\ row} - \gamma_{1,row}\,(um_{row,-1} - um_{row,\ r}) - \gamma_2(ue_{row,\ -1} - ue_{row,\ r})$

136. $\gamma_{1,row} = \gamma_{10,\ row}\ iff\ um_{row,-1} > um_{row,\ r};\ else\ \gamma_{1,row} = 0$

137. $\gamma_{2,\ row} = \gamma_{20,\ row}\ iff\ ue_{row,\ -1} > ue_{row,\ r};\ else\ \gamma_{2,\ row} = 0$

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138. $um_{row} = \frac{Y}{Y^*_{M,\ row}}$

139. $ue_{row} = \frac{Y}{Y^*_{E,\ row}}$

140. $Y^*_{M,\ row} = \frac{k^m_{row,-1} + rec_{row}}{mu_{row}}$

141. $Y^*_{E,\ row} = \frac{k^e_{row,-1}}{(1 - eta_{row}) epsilon_{row}}$

VI. RISK PREMIUMS, INTEREST RATES, AND EXCHANGE RATE

Risk premiums

142. $embi = \varepsilon_0 + \varepsilon_1 . \left(\frac{B^g}{Y}\right) + \varepsilon_2 . \left(\frac{B^{\$g}}{B^{row}_g}\right) + \varepsilon_3 . \Delta E + \varepsilon_4 . dummy$

143. $cembi = \phi_0 + \phi_1 \left(\frac{D^{\$p}}{B^{row}_p + B^{\$g}_p}\right) + \phi_2 . embi + \phi_3 . \left(\frac{D^{\$p} + D^p}{Y}\right) + \phi_3 . \left(\frac{L^{\$row}_{fs}}{Y}\right) + \phi_3 . dummy$

Model Equations

Interest rates

Govt Nominal Rate (domestic currency)

144. $i^g = i^{row} + \tau_1 . \left(\frac{\Delta B - \Delta B^g_{p\_d} - \Delta B^g_{row\_d} - \Delta B^g_{cb\_d}}{\Delta B} \right) + (1 - \tau_1) . \Delta embi + \varphi^g$

Govt Nominal Rate (foreign currency)

145. $i^{\$g} = i^{row} + \varphi^{\$g}$, *where* $\varphi^{\$g} = \varphi_0^{\$g} + \varphi_1^{\$g} \Delta embi_g$

Private Nominal Rate (domestic currency)

146. $i^p = i^g + \varphi^p$, *where* $\varphi^p = \varphi_0^p + \varphi_1^p . \Delta cembi_p$

Private Nominal Rate (foreign currency)

147. $i^{\$p} = i^{\$g} + \varphi^{\$p}$, *where* $\varphi^{\$p} = \varphi_0^{\$p} + \varphi_1^{\$p} . \Delta cembi_p$

Model Equations

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Nominal Exchange Rate

Nominal Exchange Rate

148. $E = E_{-1} + \psi.\Delta E^e + \psi_{wff}.\Delta WFF^*$

Nominal exchange rate expectations(fundamentalist)

149. $\Delta E^e_f = \psi_{f1}\left(E_{-1} - E^T_{-1}\right) + \psi_{f_2}.\Delta EMBI_{-1} + \psi_{f_3}\ .\Delta TOT$

Nominal exchange rate expectations(chartist)

150. $\Delta E^e_c = \psi_{c1}\Delta E_{-1} + \ \psi_{c_2}.\Delta EMBI_{-1} + \ \psi_{c_3}.\Delta TOT$

Total Expectations

151. $\Delta E^e = \omega_f.\Delta E^e_f + \omega_c.\Delta E^e_c$

Exchange Rate Target

152. $E^T = 5\ year\ Moving\ Average$

Model Equations

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Stock: depreciation due to nominal exchange rate fluctuations

153. $depreciation_p = \Delta E.\ B_p^{RoW}{}_{-1} + \Delta E.B_p^{\$g}{}_{-1} - \Delta E.\ D_{row-1}^{\$p}$

154. $depreciation_g = -\Delta E.B_{-1}^{\$g}$

155. $depreciation_{row} = -\Delta E.\ B_{-1}^{RoW} + \Delta E.B_{row-1}^{\$g} + \Delta E.\ D_{row-1}^{\$p} + \Delta E.L_{fs}^{\$row}$

156. $depreciation_{cb} = \Delta E.\ B_{cb}^{RoW}{}_{-1}$

157. $depreciation_p = \Delta E.\ B_{fs}^{RoW}{}_{-1} + \Delta E.B_{fs-1}^{\$g} - \Delta E.L_{fs}^{\$row}$

Damage Function

158. $D = 1 - \frac{1}{1+\pi_{d1}T+\pi_{d2}T^2+\pi_{d3}T^{\varsigma_{d3}}} \quad \pi_1;\ \pi_2;\ \pi_3;\ \zeta_3 \ \geq\ 0.$

159. $D^k \ :=\ f_K.D \qquad f_K \ \in\ (0;\ 1)$

160. $D^l =\ f_l.D \qquad f_l \ \in\ (0;\ 1)$

161.

VII. THE ECOSYSTEM

I - MATERIAL RESOURCES AND RESERVES

Production of material goods in Latin America

162. $y^{mat}_{latam} = mu_{latam} * y_{latam}$

Production of material goods in Rest of the World

163. $y^{mat}_{row} = mu_{row} * (y_{row})$

Extraction of matter in Latin America

164. $mat_{latam} = y^{mat}_{latam} - rec_{latam}$

Extraction of matter in Rest of the World

165. $mat_{row} = y^{mat}_{row} - rec_{row}$

Model Equations

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Recycled socio-economic stock in Latin America

166. $rec_{latam} = rho_{latam} * dis_{latam}$

Recycle d socio-economic stock in Rest of the World

167. $rec_{row} = rho_{row} * dis_{row}$

Discarded socio-economic stock in Latin America

168. $dis_{latam} = mu_{latam} * (dp * k_{-1} + zeta_{latam} * dc_{latam_{-1}})$

Discarded socio-economic stock in Rest of the World

169. $dis_{row} = mu_{row} * (zeta_{row} * dc_{row_{-1}})$

Stock of durable goods in Latin America

170. $dc_{latam} = dc_{latam_{-1}} + cons - (x - m) - zeta_{latam} * dc_{latam_{-1}}$

Stock of durable goods in Rest of the World

Model Equations

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171. $dc_{green} = dc_{row_{-1}} + (y_{row}) + (x - m) - zeta_{row} * dc_{row_{-1}}$

Socio-economic stock in Latin America

172. $k^{se}_{latam} = k_{se_{latam_{-1}}} + y_{mat_{latam}} - dis_{latam}$

Socio-economic stock in Rest of the World

173. $k^{se}_{row} = k_{se_{row_{-1}}} + y_{mat_{row}} - dis_{row}$

Waste generated by production activities in Latin America

174. $wa_{latam} = mat_{latam} - d(k^{se}_{latam})$

Waste generated by production activities in Rest of the World

175. $wa_{row} = mat_{row} - d(k^{se}_{row})$

Stock of material reserves in Latin America

176. $k^{m}_{latam} = k^{m}_{latam(-1)} + conv^{m}_{latam} - mat_{latam}$

Model Equations

Stock of material reserves in Rest of the World

177. $k^m_{row} = k^m_{row(-1)} + conv^m_{row} - mat_{row}$

Worldwide stock of material reserves

178. $k^m = k^m_{latam} + k^m_{row}$

Material resources converted to reserves in Latin America

179. $conv^m_{latam} = sigma^m_{latam} * res^m_{latam(-1)}$

Material resources converted to reserves in Rest of the World

180. $conv^m_{row} = sigma^m_{row} * res^m_{row(-1)}$

Stock of material resources in Latin America

181. $res^m_{latam} = res^m_{latam(-1)} - conv^m_{latam}$

Stock of material resources in Rest of the World

Model Equations

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182. $res^m_{row} = res^m_{row(-1)} - conv^m_{row}$

Worldwide stock of material resources

183. $res^m = res^m_{brown} + res^m_{green}$

Carbon mass of (non-renewable) energy in Latin America

184. $cen_{latam} = \frac{emis_{latam}}{car}$

Carbon mass of (non-renewable) energy in Rest of the World

185. $cen_{row} = \frac{emis_{row}}{car}$

Mass of oxygen in Latin America

186. $o2_{latam} = emis_{latam} - cen_{latam}$

Mass of oxygen in Rest of the World

187. $o2_{row} = emis_{row} - cen_{row}$

Model Equations

4 Appendix

II - ENERGY RESOURCES AND RESERVES

Energy required for production in Latin America

188. $e_{latam} = epsilon_{latam} * y_{latam}$

Renewable energy in Latin America

189. $er_{latam} = eta_{latam} * e_{latam}$

Non-renewable energy in Latin America

190. $en_{latam} = e_{latam} - er_{latam}$

Dissipated energy at the end of the period in Latin America

191. $ed_{latam} = er_{latam} + en_{latam}$

Energy required for production in Rest of the World

192. $e_{row} = epsilon_{row} * (y_{row})$

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Renewable energy in Rest of the World

193. $er_{row} = eta_{row} * e_{row}$

Non-renewable energy in Rest of the World

194. $en_{row} = e_{row} - er_{ror}$

Dissipated energy at the end of the period in Rest of the World

195. $ed_{row} = er_{row} + en_{row}$

Stock of energy reserves in Latin America

196. $k^e_{latam} = k^e_{latam_{-1}} + conv^e_{latam} - en_{latam}$

Stock of energy reserves in Rest of the World

197. $k^e_{row} = k^e_{row(-1)} + conv^e_{row} - en_{row}$

Worldwide stock of energy reserves

Model Equations

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198. $k^e = k^e_{latam} + k^e row$

Energy resources converted to reserves in Latin America

199. $conv^e_{latam} = sigma^e_{latam} * res^e_{latam_{-1}}$

Energy resources converted to reserves in Rest of the World

200. $conv^e_{row} = sigma^e_{row} * res^e_{row_{-1}}$

Stock of energy resources in Latin America

201. $res^e_{latam} = res^e_{latam}(-1) - conv^e_{latam}$

Stock of energy resources in Rest of the World

202. $res^e_{row} = res^e_{row(-1)} - conv^e_{row}$

Worldwide stock of energy resources

203. $res^e = res^e_{latam} + res^e_{row}$

Model Equations

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III - EMISSIONS AND CLIMATE CHANGE

Industrial emissions of CO2 in Latin America

204. $emis_{latam} = beta^{0}_{latam} + beta_{latam} * en_{latam}$

Industrial emissions of CO2 in Rest of the World

205. $emis_{row} = beta^{0}_{row} + beta_{row} * en_{row}$

Annual CO2 emissions from land

206. $emis_{l} = emis_{l(-1)} * (1 - g_{land})$

Worldwide industrial emissions of CO2

207. $emis = emis_{latam} + emis_{l} + emis_{row}$

Atmospheric CO2 concentration

208. $co2_{at} = emis + phi_{11} * co2_{at(-1)} + phi_{21} * co2_{up(-1)}$

Model Equations

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Upper ocean/biosphere CO2 concentration

209. $co2_{up} = phi_{12} * co2_{at(-1)} + phi_{22} * co2_{up(-1)} + phi_{32} * co2_{lo(-1)}$

Lower ocean CO2 concentration

210. $co2_{lo} = phi_{23} * co2_{up(-1)} + phi_{33} * co2_{lo(-1)}$

Radiative forcing over pre-industrial levels (W/m^2)

211. $f_1 = f_2 * @logx\left(\frac{co2_{at}}{co2_{at_{pre}}}, 2\right) + f_{ex}$

Radiative forcing over pre-industrial levels (W/m^2) due to non-CO2 greenhouse gases (W/m^2)

212. $f_{ex} = f_{ex(-1)} + fex$

Atmospheric temperature

Model Equations

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213. $temp_{at} = temp_{at(-1)} + t_1 * \left(f1 - \left(\frac{f2}{sens}\right) * temp_{at(-1)} - t_2 * \left(temp_{at(-1)} - temp_{lo(-1)}\right)\right)$

Lower ocean temperature

214. $temp_{lo} = temp_{lo(-1)} + t_3 * \left(temp_{at(-1)} - temp_{lo(-1)}\right)$

VIII. SCENARIO-RELATED EQUATIONS

Endogenous government-led change in the technical coefficient

215. $a_{ij} = a_{ij,\ -1} + \gamma_i * \left(a_{ij,\ t} - a_{ij,\ -1}\right), \quad \forall i, j \in \{a, b, c, d, h, et\}$

Change in the coefficient weighting the structural change effect

216. $\gamma_i = \Gamma_i a_{g,i} g_{-1}, \quad \forall i \in \{a, b, c, d, h, et\}$

Endogenous resource-led change in the technical coefficient

217. $a_{ij} = a_{ij,\ -1} + \Upsilon_i * \left(\widehat{mat}\right), \quad \forall i, j \in \{b\}$

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Q&A

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