MACROFINANCIAL AND ECOLOGICAL SUSTAINABILITY? GEMMES PROJECTS IN DEVELOPING AND EMERGING ECONOMIES

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THE GEMMES RESEARCH PROGRAMS

- **Objective**
  - We aim at contributing to national and international public policy dialogue around a **just transition and adaptation**, with special regards to developing countries.

- **Methods**
  - **Strong sustainability**: non-substitutability between political objectives and factors of production – need for complex analytical models
  - Each project aims at improving our understanding of **interactions between economic and socio-ecological topics** (agronomy, hydrology, climatology, energy, etc.)

- **Types of models (GEMMES and ESTEEM)**
  - **World models:** theoretical models to discuss international topics such as damage functions, demography, green jobs or EROI constraints
  - **Country models:** applied models to discuss country-specific issues, such as physical and economic constraints

https://www.afd.fr/fr/ressources/afd-outils-modelisation-macroeconomique-transition-ecologique

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MODELLING GREEN TRANSITIONS – EMDE PERSPECTIVES

- **Real sector interacts with financial sector**
  - There are **feedback loops** between the financial and the real sector, where financial constraints may lead to physical constraints and vice-versa

- **Long-term perspective and scenario testing**
  - Models should be able to provide long-term perspective and allow for **testing different scenarios** and policies
  - Rather than forecasting, they provide information about the consequences of adopting different types of policies

GEMMES

GENERAL MONETARY AND MULTI-SECTORAL MACRO-DYNAMICS FOR THE ECOLOGICAL SHIFT

MODELLING PRINCIPLES

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GEMMES

- GEMMES comes from a family of models called 'Stock-Flow-Consistent' models.
- GEMMES models directly specify dynamic equations like macroeconometric models.
- We work in continuous time so we specify the model equations in ***differential equations***.
- ***GEMMES is not micro-founded*** and does not have optimizing behaviour like CGEs but rather bounded rationality.
- We specify ***structural*** equations which derive from economic theory directly. (marginal propensity to consume depends on real interest rates, investment depends on profit rates, etc.)

MODELLING SMALL OPEN DEVELOPING ECONOMIES IN A FINANCIALIZED WORLD: A STOCK-FLOW CONSISTENT PROTOTYPE GROWTH MODEL

- The model Yilmaz & Godin (2020) outlines the features of our approach and serves as the basis for our Tunisian and Moroccan multi-sectoral empirical country models for climate damages and Colombian and Mexican single-sector empirical models for energy transition/physical risk analyses.

- The purpose is to build the least complicated possible model in order to capture the dynamics of small open economies we work on.

- Methodological framework stresses Stock-Flow Consistency, continuous time disequilibrium dynamics, monetary nature.
- https://www.afd.fr/en/ressources/modelling-small-open-developing-economies-financialized-world-stock-flow-consistent-prototype-growth-model

CAPTURING BALANCE SHEET AND LIQUIDITY CHANNELS IN OPEN ECONOMIES

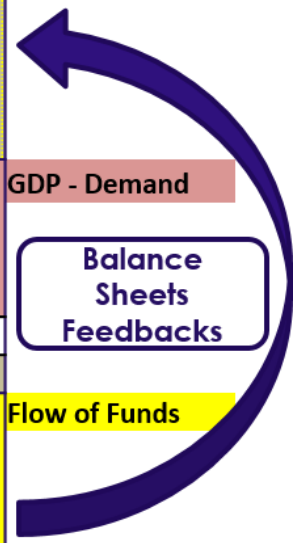
- Importance of representing inter-relations between balance sheets of economic agents

- Feedback mechanisms between stock accumulation emerging out of flow dynamics, and flow responses to stock accumulation

- Accounting framework is directly constructed on the complete set of national income, including secondary income distribution, flow of funds and balance sheets, warranting the coherence and consistency of the behavioural rules included in the model

STOCK-FLOW CONSISTENT DYNAMICS

	Non Financial Corporations	Financial Corporations	Government	Households	Rest of World	
Value Added	GDP_PRD_NVA_NFC	GDP_PRD_VA_FC	GDP_PRD_VA_G	GDP_PRD_VA_H		GDP - Production
Taxes on Value Added	-GDP_PRD_NT		GDP_PRD_NT			
Wages	-GDP_INC_W_NFC	-GDP_INC_W_FC	-GDP_INC_W_G	GDP_INC_NW_H	GDP_INC_NW_W	GDP - Income
Taxes on Production	-GDP_INC_NT_NFC	-GDP_INC_NT_FC	GDP_INC_NT_G	-GDP_INC_NT_H		
Interest	-RED_INT_NFC	RED_INT_FC	-RED_INT_G	RED_INT_H	RED_INT_W	Redistribution of Income
Dividends	-RED_DIV_NFC	RED_DIV_FC	RED_DIV_G	RED_DIV_H	RED_DIV_W	
Factor Payments	-RED_FFP_NFC	-RED_FFP_FC			RED_FFP_W	
Rents	-RED_REN_NFC	-RED_REN_FC	RED_REN_G	RED_REN_H	RED_REN_W	
Income Tax	-RED_TAX_NFC	-RED_TAX_FC	RED_TAX_G	-RED_TAX_H		
Net Contributions	RED_CON_NFC	RED_CON_FC	RED_CON_G	RED_CON_H		
Others	-RED_OTH_NFC	-RED_OTH_FC	RED_OTH_G	RED_OTH_H	-RED_OTH_W	
Adjustments	RED_ADJ_NFC	RED_ADJ_FC		RED_ADJ_H		
Consumption	GDP_DMD_C		-GDP_DMD_C_G	-GDP_DMD_C_H		GDP - Demand
Investment	GDP_DMD_NI_NFC	-GDP_DMD_I_FC	-GDP_DMD_I_G	-GDP_DMD_I_H		
Exports	GDP_DMD_X				-GDP_DMD_X	
Imports	-GDP_DMD_M				GDP_DMD_M	
Depreciation	-DEP_CAP_NFC	-DEP_CAP_FC	-DEP_CAP_G	-DEP_CAP_H		
Capital redistribution	RED_CAP_NFC	RED_CAP_FC	RED_CAP_G	RED_CAP_H		
Change in SDR	FOF_SDR_NFC	FOF_SDR_FC	FOF_SDR_G	FOF_SDR_H	FOF_SDR_W	Flow of Funds
Change in Deposits	FOF_DEP_NFC	FOF_DEP_FC	FOF_DEP_G	FOF_DEP_H	FOF_DEP_W	
Change in Debt	FOF_DEBT_NFC	FOF_DEBT_FC	FOF_DEBT_G	FOF_DEBT_H	FOF_DEBT_W	
Change in Equity	FOF_EQU_NFC	FOF_EQU_FC	FOF_EQU_G	FOF_EQU_H	FOF_EQU_W	
Change in Insurance and Technical Reserves	FOF_ITS_NFC	FOF_ITS_FC	FOF_ITS_G	FOF_ITS_H	FOF_ITS_W	
Change in Others	FOF_OTH_NFC	FOF_OTH_FC	FOF_OTH_G	FOF_OTH_H	FOF_OTH_W	



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STRUCTURE OF A COUNTRY CASE MODEL

Variable	Non Financial Corporations		Households	Financial Corporations		Central Bank		Government	RoW	Σ
	Current	Capital		Current	Capital	Current	Capital			
Consumption of NFC Products	$+C$		$-C_H$					$-C_G$		0
Public Services								$+PS_G$ $-PS_G$		0
Consumption of FC Services			$-(INS_H + COM_H)$	$INS_H + COM_H$						0
Interm. Cons. of NFC Products	$+IC$			$-IC_B$				$-IC_G$		0
Interm. Cons. of FC Services	$-(INS_F + COM_F)$			$INS_F + COM_F$						0
Gross Fixed Capital Formation	$+I_F^K$	$-I_F^K$	$-I_H^K$		$-I_B^K$			$-I_G^K$		0
Change in inventories	$+I^V$	$-I^V$								0
Imports	$-IM$								$+IM$	0
Exports	$+EX$								$-EX$	0
Taxes on Imports	$-T^{IM}$							$+T^{IM}$		0
Value Added Tax	$-T^V$							$+T^V$		0
Other Taxes on Products	$-T^P$							$+T^P$		0
Wages	$-W_F$		$+W$	$-W_B$				$-W_G$		0
Employers Social Contributions	$-SC_F$		$+SC$	$-SC_B$				$-SC_G$		0
Mixed Income Distribution	$-MI_H$		$+MI_H$							0
G.O.S. Redistribution	$-GOS_F$		$+GOS_F^H$					$+GOS_F^G$		0
Net Other Taxes on Production	$-T_F^Y$			$-T_B^Y$				$-T^Y$		0
Int. on Deposits	$+IntD_F$		$+IntD_H$	$-IntD$				$+IntD_G$		0
Int. on Domestic Loans	$-IntL_F$		$-IntL_H$	$+IntL$						0
Int. on Domestic FX Loans	$-IntL_F^{FX,B}$			$+IntL_F^{FX,B}$						0
Int. on RoW FX Loans	$-IntL_F^{FX,W}$			$-IntL_B^{FX,W}$					$+IntL^{FX,W}$	0
Int. on Domestic public Bonds				$+IntBg_B$				$-IntBg$	$+IntBg_W$	0
Int. on FX public Bonds								$-IntBg^{FX}$	$+IntBg^{FX}$	0
Int. on FX public Loans								$-IntLg^{FX}$	$+IntLg^{FX}$	0
Int. on Advances				$-IntA$		$+IntA$				0
Int. on FX Reserves				$+IntR_B^{FX}$		$+IntR_{CB}^{FX}$			$-IntR^{FX}$	0
Firms Dividends	$-Div_F$		$+Div_F^H$					$+Div_F^G$	$+Div_F^W$	0
Banks Dividends			$+Div_B^H$	$-Div_B$					$+Div_B^W$	0
Royalties	$-Roy$							$+Roy$		0
Taxes on Income	$-T_F^I$		$-T_H^I$	$-T_B^I$				$-T^I$		0
Workers Social Contributions			$-WSC$	$+WSC_B$				$+WSC_G$		0
Social Transfers			$+ST$	$-ST_B$				$-ST_G$		0
Remittances			$+Rem$						$-Rem$	0
Central Bank Profits						$-F_{CB}$		$+F_{CB}$		0
Other Transfers	$-O_F$		$+O_H$	$-O_B$				$-O_G$	$-O_W$	0
Retained Earnings	$-RE_F$	$+RE_F$		$-RE_B$	$+RE_B$					0
[Capital]		$[K_F]$	$[K_H]$		$[K_B]$			$[K_G]$		$[K]$
[Inventories]		$[V]$								$[\dot{V}]$
Foreign Direct Investment		$+FDI_F$			$+FDI_B$				$-FDI$	0
Cash and Deposits		$-\dot{D}_F$	$-\dot{D}_H$		$+\dot{D}$			$-\dot{D}_G$		0
Government Deposits at the CB							$+\dot{D}_{CB}$	$-\dot{D}_{CB}$		0
FX Deposits		$-\dot{D}_F^{FX}$			$-\dot{D}_B^{FX}$			$-\dot{D}_G^{FX}$	$+\dot{D}^{FX}$	0
Domestic Currency Loans		$+\dot{L}_F$	$+\dot{L}_H$		$-\dot{L}$					0
Domestic FX Loans		$+\dot{L}_F^{FX,B}$			$-\dot{L}_F^{FX,B}$					0
RoW FX Loans		$+\dot{L}_F^{FX,W}$			$+\dot{L}_B^{FX,W}$				$-\dot{L}^{FX,W}$	0
Domestic Government Bonds					$-\dot{Bg}_B$			$+\dot{Bg}$	$-\dot{Bg}_W$	0
FX Government Bonds								$+\dot{Bg}^{FX}$	$-\dot{Bg}^{FX}$	0
FX Government Loans								$+\dot{Lg}^{FX}$	$-\dot{Lg}^{FX}$	0
Technical insurance Reserves			$-\dot{TIR}_H$		$+\dot{TIR}_H$					0
Domestic Currency Reserves					$-\dot{Rd}$		$+\dot{Rd}$			0
FX Reserves					$-\dot{R}_B^{FX}$		$-\dot{R}_{CB}^{FX}$		$+\dot{R}^{FX}$	0
Advances					$+\dot{A}$		$-\dot{A}$			0
Σ	0	0	0	0	0	0	0	0	0	0

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IN A TYPICAL GENERAL EQUILIBRIUM FRAMEWORK

Variable	Non Financial Corporations		Households	Government	RoW	Σ
	Current	Capital				
Consumption of NFC Products	$+C$		$-C_H$	$-C_G$		0
Public Services				$+PS_G$	$-PS_G$	0
Consumption of FC Services			$-(INS_H + COM_H)$			0
Interm. Cons. of NFC Products	$+IC$			$-IC_G$		0
Interm. Cons. of FC Services	$-(INS_F + COM_F)$					0
Gross Fixed Capital Formation	$+I_K$	$-I_F^K$	$-I_H^K$	$-I_G^K$		0
Change in inventories	$+I^V$	$-I^V$				0
Imports	$-IM$				$+IM$	0
Exports	$+EX$				$-EX$	0
Taxes on Imports	$-T^{IM}$			$+T^{IM}$		0
Value Added Tax	$-T^V$			$+T^V$		0
Other Taxes on Products	$-T^P$			$+T^P$		0
Wages	$-W_F$		$+W$	$-W_G$		0
Employers Social Contributions	$-SC_F$		$+SC$	$-SC_G$		0
Mixed Income Distribution	$-MI_H$		$+MI_H$			0
C.O.S. Redistribution	$-COS_F$		$+COS_F^H$	$+COS_F^G$		0
Net Other Taxes on Production	$-T_F^Y$			$-T^Y$		0
Taxes on Income	$-T_F^I$		$-T_H^I$	$-T^I$		0
Workers Social Contributions			$-WSC$	$+WSC_G$		0
Social Transfers			$+ST$	$-ST_G$		0
Remittances			$+Rem$		$-Rem$	0
						0
Other Transfers	$-O_F$		$+O_H$	$-O_G$	$-O_W$	0
Retained Earnings	$-RE_F$	$+RE_F$				0
[Capital]		$[K_F]$	$[K_H]$	$[K_G]$		$[K]$
[Inventories]		$[V]$				$[V]$

A MONETARY ECONOMY WITH BANKING AND FINANCE

- We model the financial system in detail, with its complete relation to the rest of the domestic economy and the world.
- There is no automatic equalization of investment to savings as in real CGE models but rather investment decision is seperate from the saving decision and follows expected profit rate
- As in contemporary monetary theory, banks are not intermediaries between savers and borrowers. Rather, they lend to domestic firms to finance investment in excess of retained earnings (with rationing) and finance this lending (and other net asset purchases) by household/firm bank deposits, their own capital and borrowing from the central bank.
- The central bank conducts an interest rate policy to target inflation rate and thus provides the necessary domestic currency liquidity to the banking system while setting its price.
- In this particular sense, our models resemble financial CGEs constructed for developing economies in Agenor et al. (2007).
- Saving-investment equality emerges as a result of accounting identity in this set-up.

A MONETARY ECONOMY WITH BANKING AND FINANCE

- Banks set the interest rate on lending and deposits
- They also determine the amount of loans to borrowers, depending on their liquidity and riskiness of the loans. They can ration lending, both in domestic and FX.
- They decide how much government bonds to purchase depending on the return on bonds.
- They obey a capital adequacy ratio and distribute dividends depending on their capital needs.
- GEMMES models incorporate the central bank in the country models. Inflation-targeting central bank, which may intervene in the FX markets
- Central Bank: Lender of last resort to the financial sector.

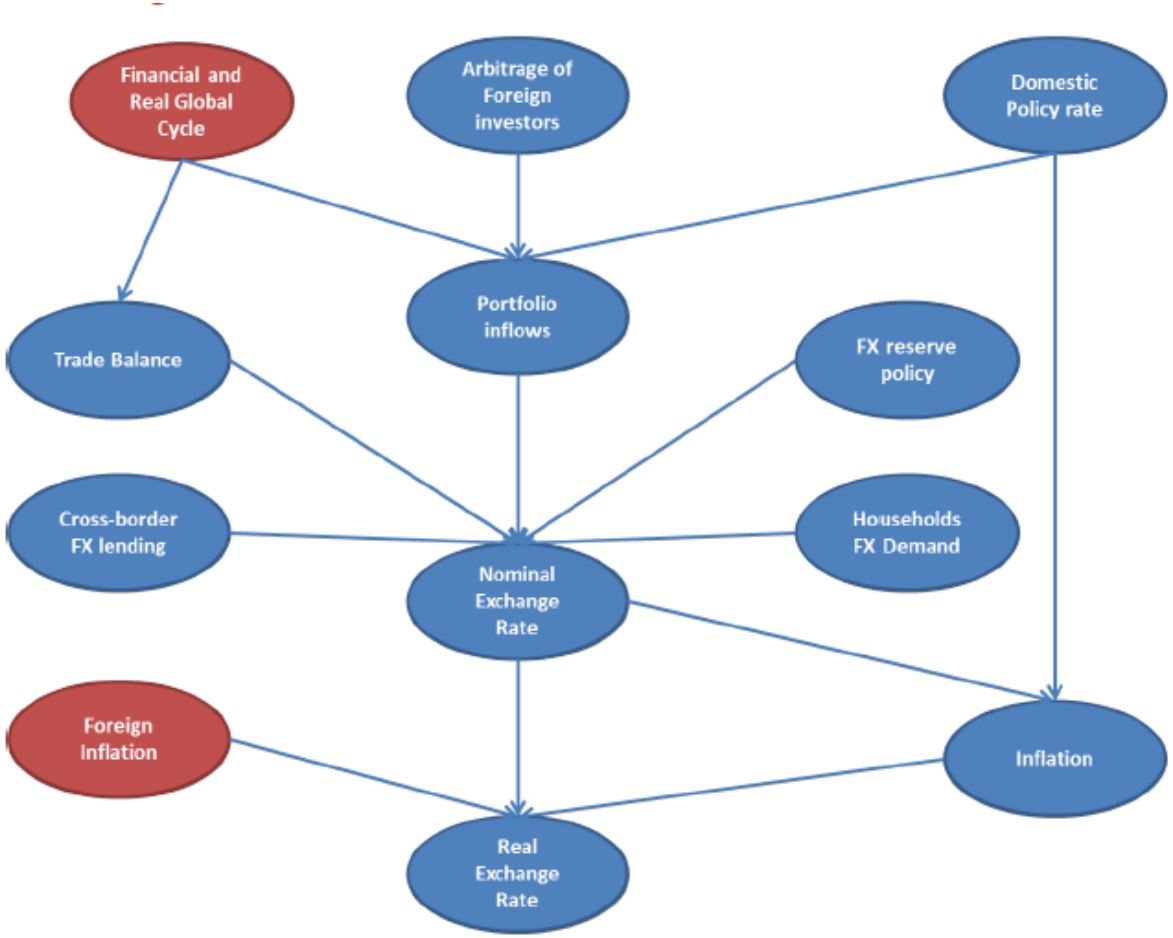
INFLATION AND UNEMPLOYMENT

- GEMMES models are truly monetary: Explicit modelling of inflation
- Domestic producers set prices as a variable mark-up over unit costs
- Markup depends on demand conditions
- Imported intermediate goods directly affect domestic production costs
- Thus both demand-pull and cost-push inflation is modelled.
- Similarly, GEMMES models generate involuntary unemployment.

A MONETARY ECONOMY WITH BANKING AND FINANCE

- Importance to distinguish between the resource constraint, i.e current account, and financing, i.e lending for investment/consumption.
- While trade flows involves the actual *exchange of real resources*, payments are in currency and require *money financing*.
- Hence although current account and capital account are mirror-images(accounting identity), they are the outcome of decisions taken by different agents separately.
- Our monetary structure overcomes the problems of canonical open economy models where real resources are borrowed and therefore the real constraint becomes synonymous with financing constraints Borio and Disyatat (2015).
- Thus explicit modelling of the nominal exchange rate -> Determined by demand and supply for FX.
- Real exchange rate -> Determined endogenously by the separate dynamics of nominal exchange rate, domestic inflation and foreign inflation

EXCHANGE RATE DYNAMICS IN AN OPEN EMERGING ECONOMY.



THE ACCOUNTING EQUILIBRIUM OF DISEQUILIBRIUM

- Markets are characterised by continuous disequilbria and imbalances leading to the infamous debate between Marshall and Walras on the equilibrating force: Price & Quantity.

- We argue that both quantity adjustment and price adjustment processes operate at the same time with different adjustment speeds

- Essential to explicitly model both adjustment processes since the existence of a long-run attractor of the model and the dynamics of convergence to this attractor will strongly depend on these.

GOODS MARKET DISEQUILIBRIUM

- In models with price as the equilibrating mechanism:

$$\dot{p} = \beta_P.[AD(p) - AS(p)]$$

$$\lim_{B_P -> \infty} p = p^E,\ p^E \mid AD(p^E) = AS(p^E)$$

- In models with quantity as the equilibrating mechanism

$$Y^p = Y^e$$

$$\dot{Y}^e = \beta_y.[AD(p) - Y^e]$$

$$\lim_{B_y -> \infty} Y^e = Y^{eE},\ Y^{eE} \mid AD(p) = Y^p)$$

IN GEMMES

$$\dot{V} = AS(p) - AD(p)$$

DEMAND IS NOT EQUAL TO SUPPLY, THE DISEQUILIBRIUM IS ABSORBED BY INVENTORIES

$$\dot{p} = \beta_P.[p^d - p]$$

PRICES ARE STICKY, THEY MOVE SLOWLY TOWARDS DESIRED PRICE

$$p^d = (1 + \mu) \cdot HUC,$$

DESIRED PRICE IS A MARK-UP OVER HISTORICAL UNIT COSTS

$$\mu = \mu_0 - \mu_1 \cdot \left(\frac{V}{Y^e} - \alpha_v \right)$$

MARK-UP IS VARIABLE, DEPENDS ON INVENTORY TO EXPECTED SALES RATIO

$$\dot{Y}^e = \beta_y.(AD(p) - Y^e)$$

IF DEMAND IS ABOVE EXPECTED SALES, SALES EXPECTATIONS ADJUST UPWARDS

$$Y^p = Y^e + I^V$$

PRODUCTION IS EQUAL TO EXPECTED SALES + PRODUCTION TO REPLACE INVENTORIES

$$I^V = \beta_v.(V^d - V)$$

PRODUCTION TO REPLACE INVENTORIES DEPENDS ON DESIRED INVENTORY LEVELS

$$V^d = \alpha.Y^e$$

DESIRED INVENTORIES ARE A FRACTION OF EXPECTED SALES

FOREIGN CURRENCY MARKET DISEQUILIBRIUM

- Aggregate demand (D^{FX}) determined from imports, current transfers, banks demand
- Aggregate supply (S^{FX}) determined from exports, financial account, central bank intervention
- Nominal exchange rate (e^{N}) depends on excess demand (or supply)
- Reserves (R^{FX}) clear the market

$$D^{FX} = IM \cdot p_W + \frac{IA}{e_N} + \dot{R}^{B,FX,NOP},$$

$$S^{FX} = \frac{X}{e_N} + WFF_D + \dot{L}_B^{FX} - \dot{R}^{CB,FX,I}.$$

$$\dot{e}_N = e_N \cdot \beta_{en} \cdot \left(\frac{D^{FX} - S^{FX}}{S^{FX}} \right)$$

$$\dot{R}^{FX} = \frac{X}{e_N} - IM \cdot p_W + \frac{\dot{B}_G^W}{e_N} + \dot{L}_B^{FX} + \frac{IA}{e_N}$$

DISCRETE VS. CONTINUOUS TIME

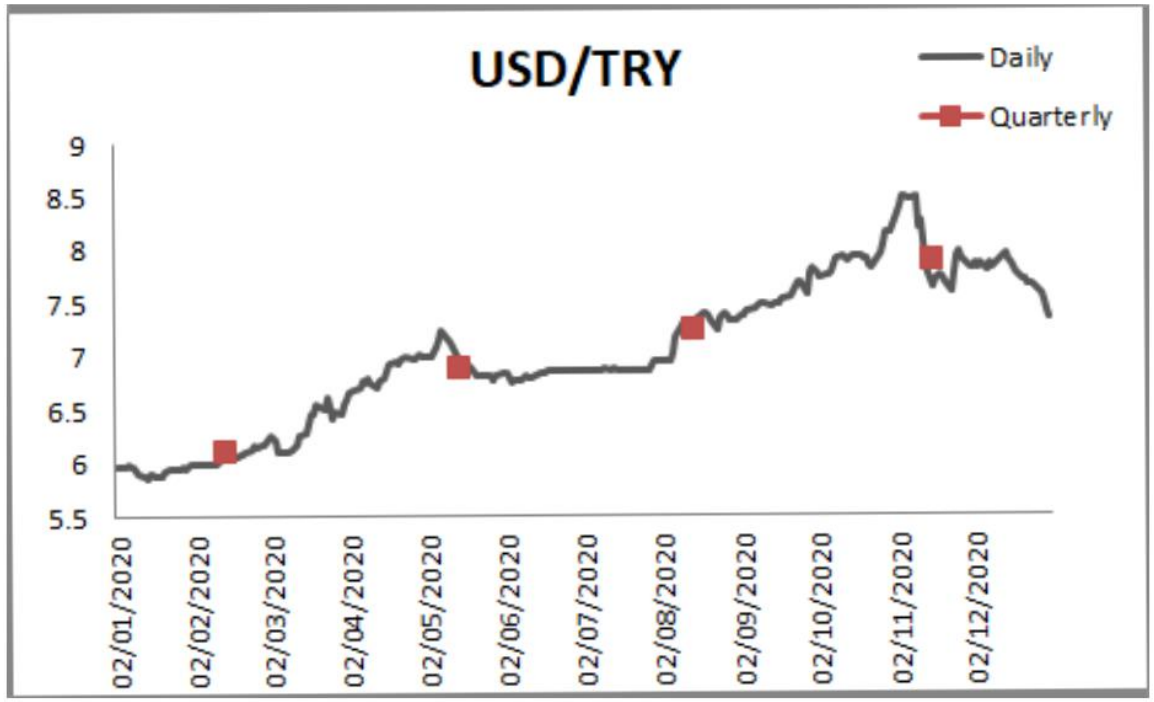
- Modelling excess demand adjustment processes in discrete time poses several problems (Gandolfo 2012), particularly if excess demand function involves both stock variables and variables which are sums of flows over the observation period (such as gross domestic product or aggregate demand), it is difficult to derive a plausible (exact or approximate) discrete time representation for an adjustment process.

$$\dot{x} = \beta_x.(x^T - x)$$
$$x_{t+1} = \beta_x.(x_t^T - x_t)$$

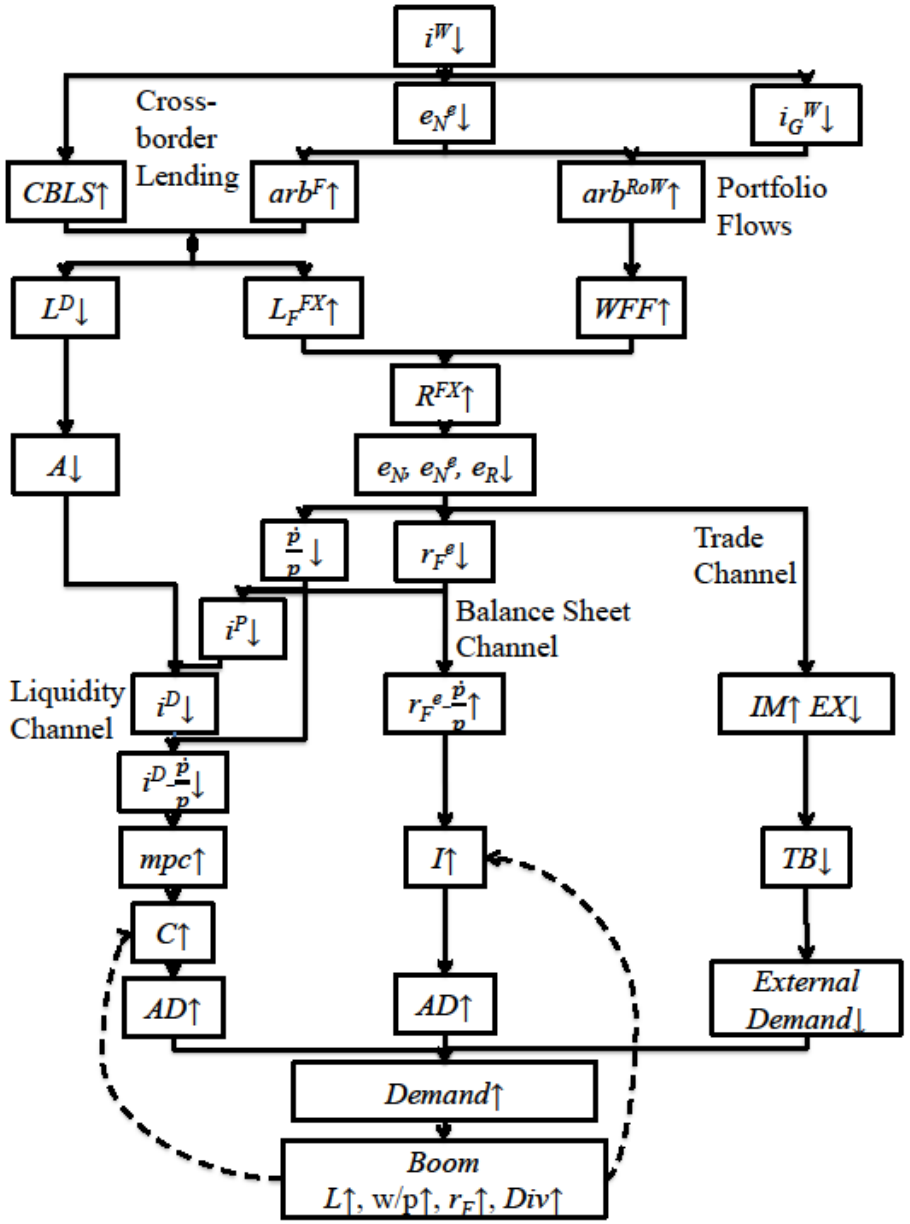
- β_x is not an adjustment speed in discrete time and does not have the same interpretation.
- Discrete time processes written as above are very unstable unless the time unit in the model is very small and adjustments to disequilibrium take place on a very frequent basis.

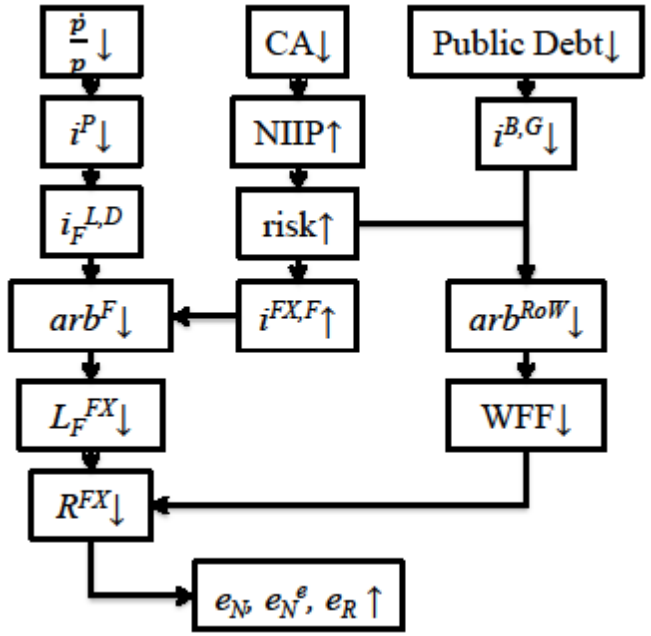
DISCRETE VS. CONTINUOUS TIME

- In monetary models with financial markets that adjust much more rapidly than goods markets, an appropriate discrete time model may require very small time units in order to capture the behaviour of the variable correctly (such as exchange rates)
- Without such small time units, several market adjustments may take place within the employed time unit in the model (a quarter for instance),thus making the calibration of the model impossible. Such market adjustment speeds are directly given by the value of the parameter (β_x) in Continuous Time.

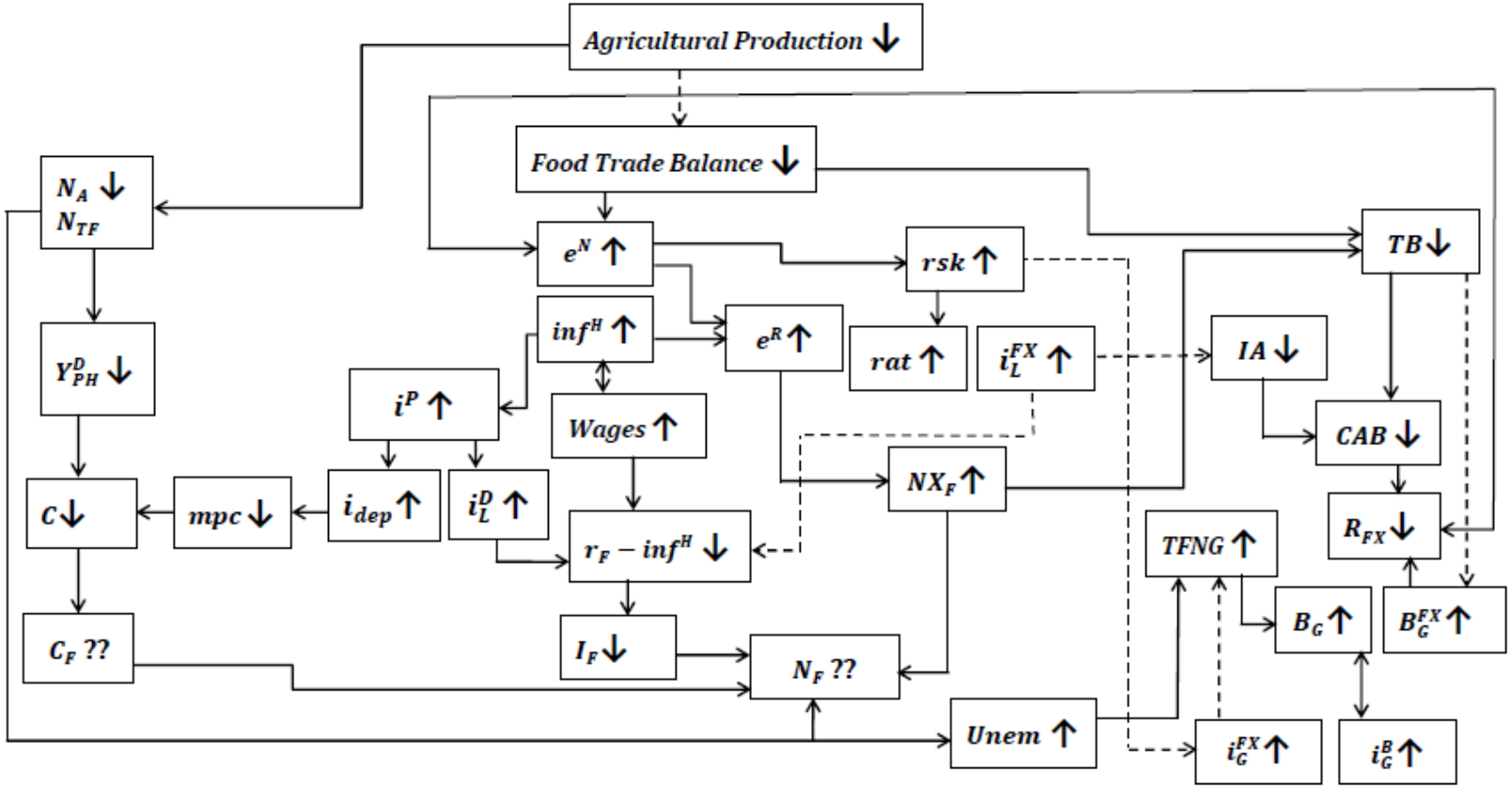


GEMMES IS INTRINSICALLY DYNAMIC



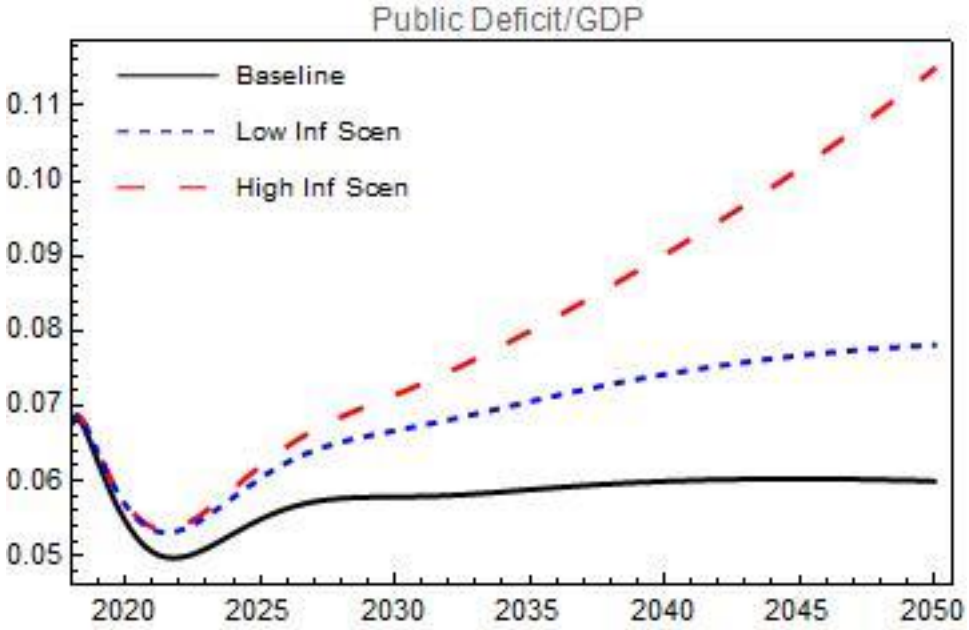


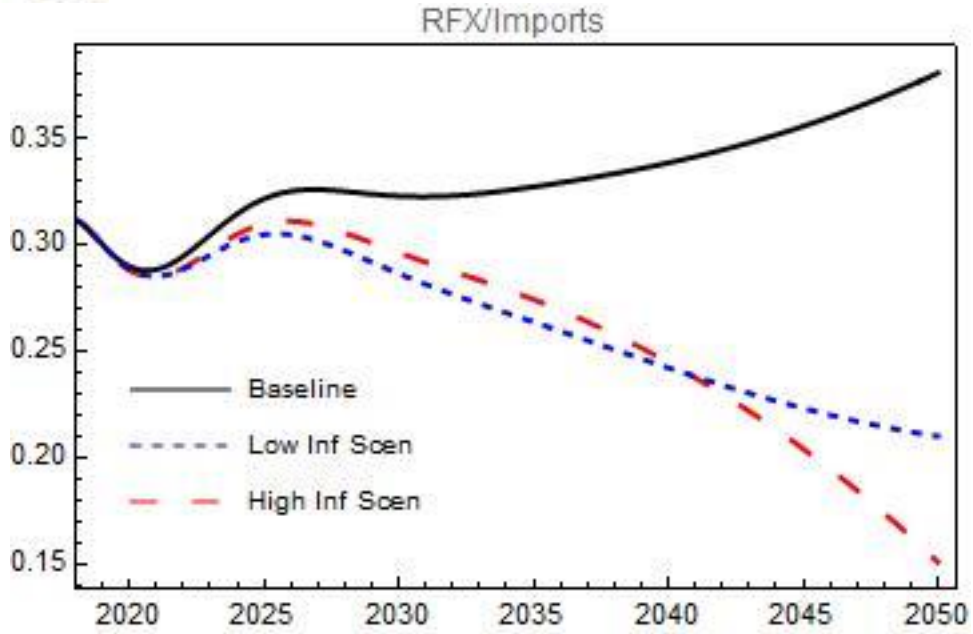
GEMMES IS INTRINSICALLY DYNAMIC



GEMMES does not use steady-states

- GEMMES models do not assume that the country starts from a steady state (a state where the economy is stably growing, with macrovariables growing at constant equal rates)
- We use the economic data for the initial point of our simulations and we do not force that this point is a steady state.
- Therefore, our baseline scenarios (with no climate change or energy transition for instance) still display different dynamics for the variables in the model, as the economy responds to the initial disequilibrium that we start from.
- CGEs impose a steady state at the initial point of simulation and solve the parameter values that give a steady state equilibrium at this point.

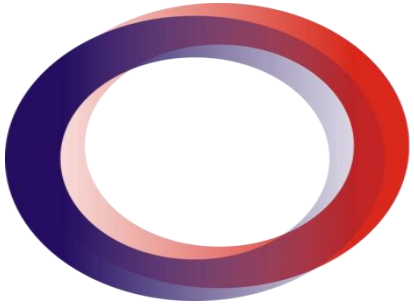

Public Deficit/GDP
Baseline
Low Inf Scen
High Inf Scen
0.11
0.10
0.09
0.08
0.07
0.06
0.05
2020
2025
2030
2035
2040
2045
2050


RFX/Imports
0.35
0.30
0.25
0.20
0.15
Baseline
Low Inf Scen
High Inf Scen
2020
2025
2030
2035
2040
2045
2050

What is GEMMES in a nutshell?

- GEMMES is a ***truly dynamic,*** system dynamics model, with a ***coherent and complete modelling of the financial system***.
- It does not rely on unrealistic optimization procedures to formulate economic behaviour.
- It is a ***disequilibrium model*** (with equilibrating price-quantity dynamics), written in ***continuous time***, semi-estimated/semi calibrated using available data on the country
- It does ***not impose steady states at initial point/ it does not set the long run equilibrium*** but rather simulates the country's economy beginning from its current structure.
- We write down behavioral equations, estimate/calibrate them with data, start the model from the initial datapoints and simulate.
- ***GEMMES stands in the middle of pure theory & data***. That's why its so tedious and artisanal to construct. It incorporates all macro-financial channels, dynamic feedbacks, etc. and at the same time it is estimated/calibrated to fit national accounts, financial sector data, balance of payments, external debt statistics and balance sheets. It is thus similar to theory-driven structural econometrics, brought to 21st century with ***state-of-the-art dynamic simulation and calibration/estimation methods***.

GEMMES



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Climate Change, Loss of Agricultural Output and the Macro-Economy: The Case of Tunisia

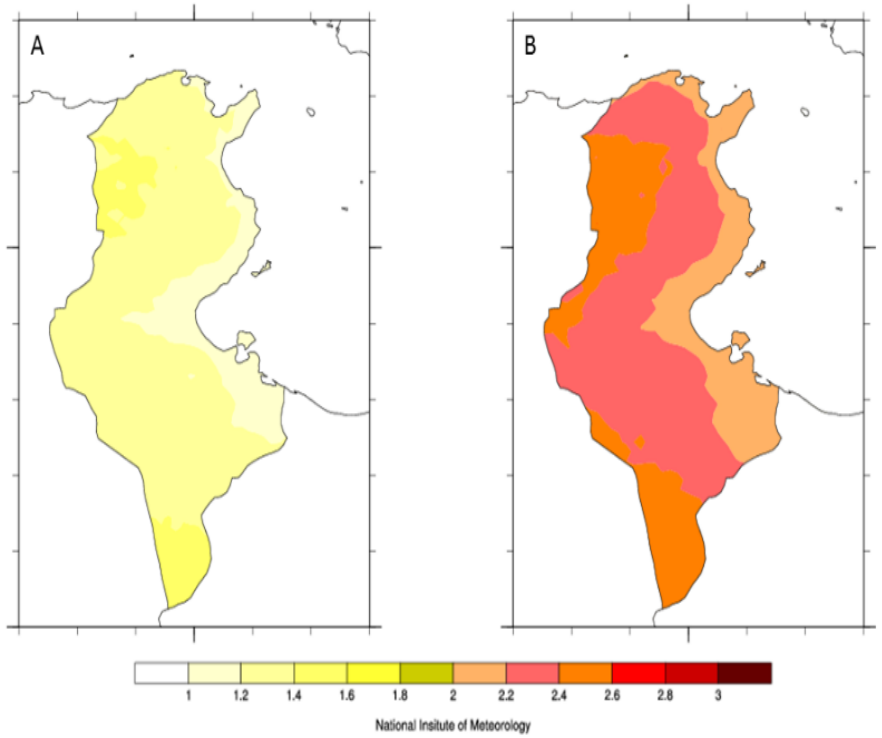
02 MAJOR ECONOMIC PROBLEMS

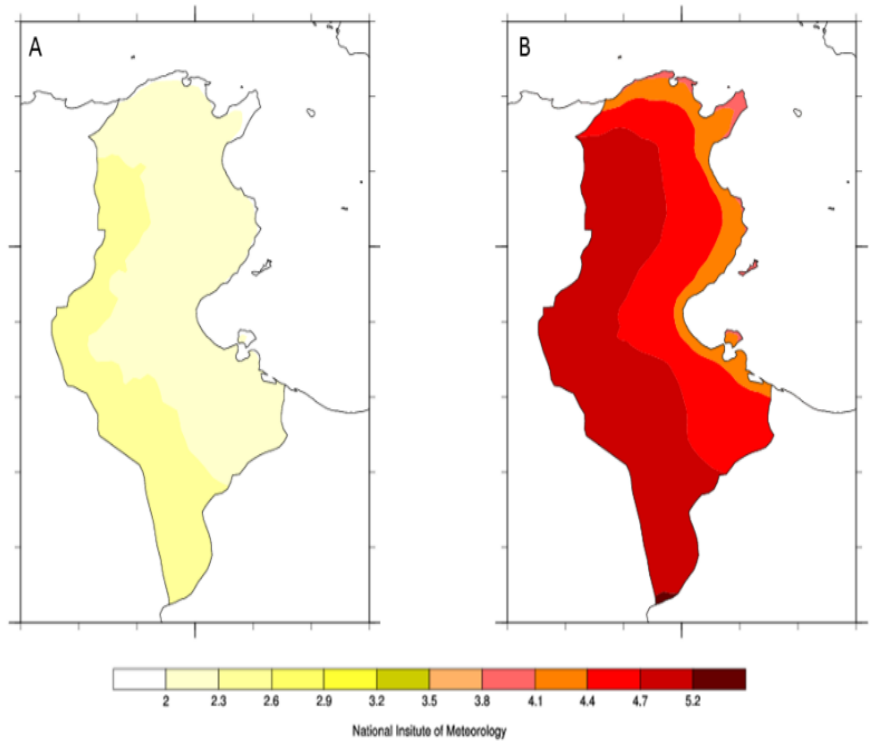
INCREASINGLY ALARMING IMBALANCES IN THE TRADE BALANCE, THE CURRENT ACCOUNT AND THE FOREIGN EXCHANGE MARKET

Indicator	2001-2010	2011-2019	2020	2021
Average annual growth rate				
GDP	4.6	1.6	−8.6	4.3
Agriculture sector	1.9	4.6	0.2	−2.5
Processed Food sector	2.7	2.4	0.7	−3.5
Sector's contribution to GDP				
Agriculture sector	8.7	8.8	9.4	10.3
Processed Food sector	3.5	3.3	3.4	3.7
Trade Balance(% of GDP)	10.9	15.6	16.9	11.5
Food Balance(% of Trade Balance)	7.5	7.3	12.9	12
Investment (% of GDP)	24.1	21.1	19.4	15.8
Total External Debt (% of GDP)	39.5	46.2	61.9	56.3
FX reserves (months of imports)	6.2	3.7	5.4	4.4
Inflation rate(%)	4.1	5	5.6	5.7
Food inflation(%)	4	5.6	4.3	7.6
Unemployment rate(%)	13	15.1	18	17.9
Budget deficit(% of GDP)	2.5	5.1	9.7	6.6
Public Debt(% of GDP)	49.1	56.2	78.0	79.5
NIIP(% of GDP)	−93.6	−153.2	−163.9	−160.6

Potential impacts of climate change on the agricultural sector

Climate scenarios: Temperature evolution





Scenario RCP 4.5 (Source : INM)

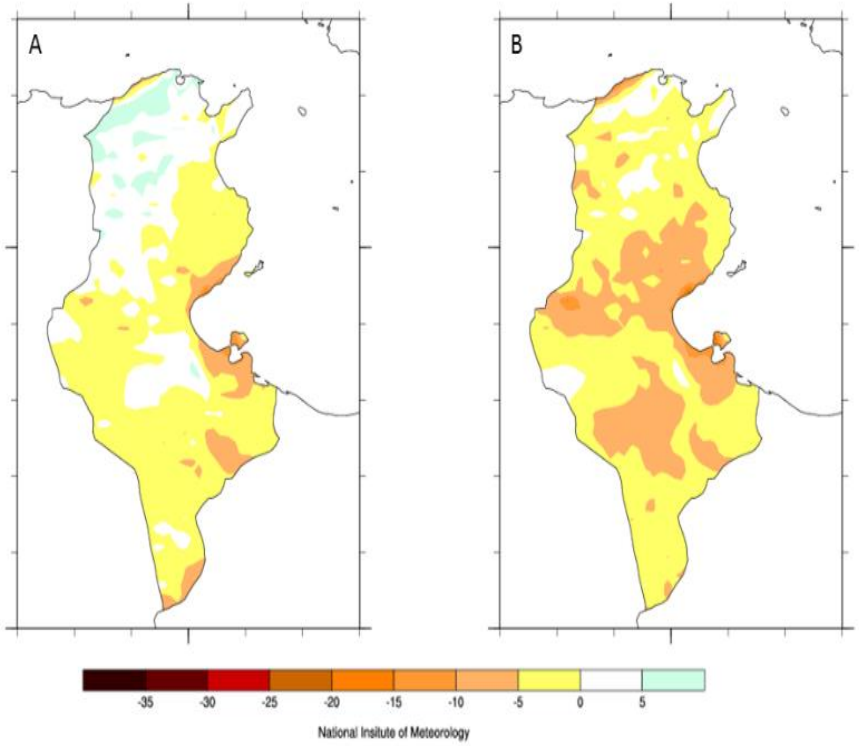
- 1°C to 1,8°C until 2050
- 2°C to 3°C until 2100

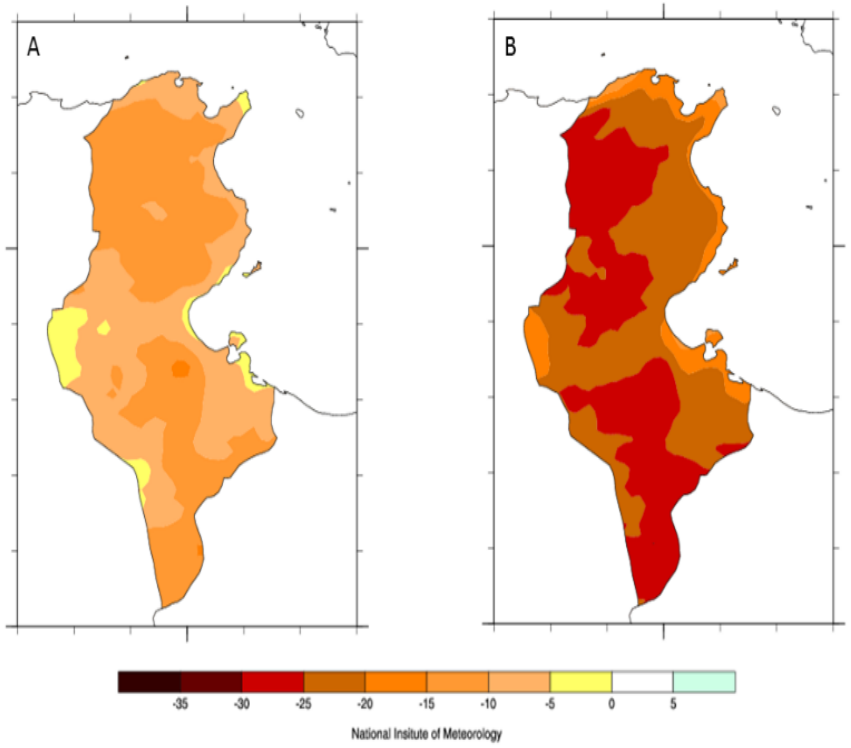
Scenario RCP 8.5 (Source : INM)

- 2°C to 2,3°C until 2050
- 4,1°C to 5,2°C until 2100

Potential impacts of climate change on the agricultural sector

Climate scenarios: Evolution of precipitation





Scenario RCP 4.5 (Source : INM)

- 5 % to 10 % until I 2050
- 5 % to 20 % until 2100

Scenario RCP 8.5 (Source : INM)

- 1 % to 14 % until 2050
- 18 % to 27 % until 2100

03

Potential impacts of climate change on the agricultural sector

Agricultural production losses

THE MAIN CLIMATE RISKS THAT AFFECT AGRICULTURAL PRODUCTION IN TUNISIA ARE:

- The increase in droughts will lead to a reduction in the area of arable land as well as its yield caused by the loss of soil fertility and humidity and desertification.
- The most affected lands are located in perennial areas prone to droughts such as the arid regions of the south or to flooding in the humid north.
- In addition, rising sea levels caused a loss of coastal aquifer resources of nearly 50% due to increased salinization due to marine intrusion. Thus, agricultural land located in the coastal zone would decrease according to experts by more than 38,000 hectares by 2050
- Water resources would decrease by 30% (40% of groundwater with a drop of 39% in groundwater tables and 24% for deep water tables. As for surface water, their volume would be reduced by 32%. (Source: water strategy 2050)

03 Potential impacts of climate change on the agricultural sector

Agricultural production losses

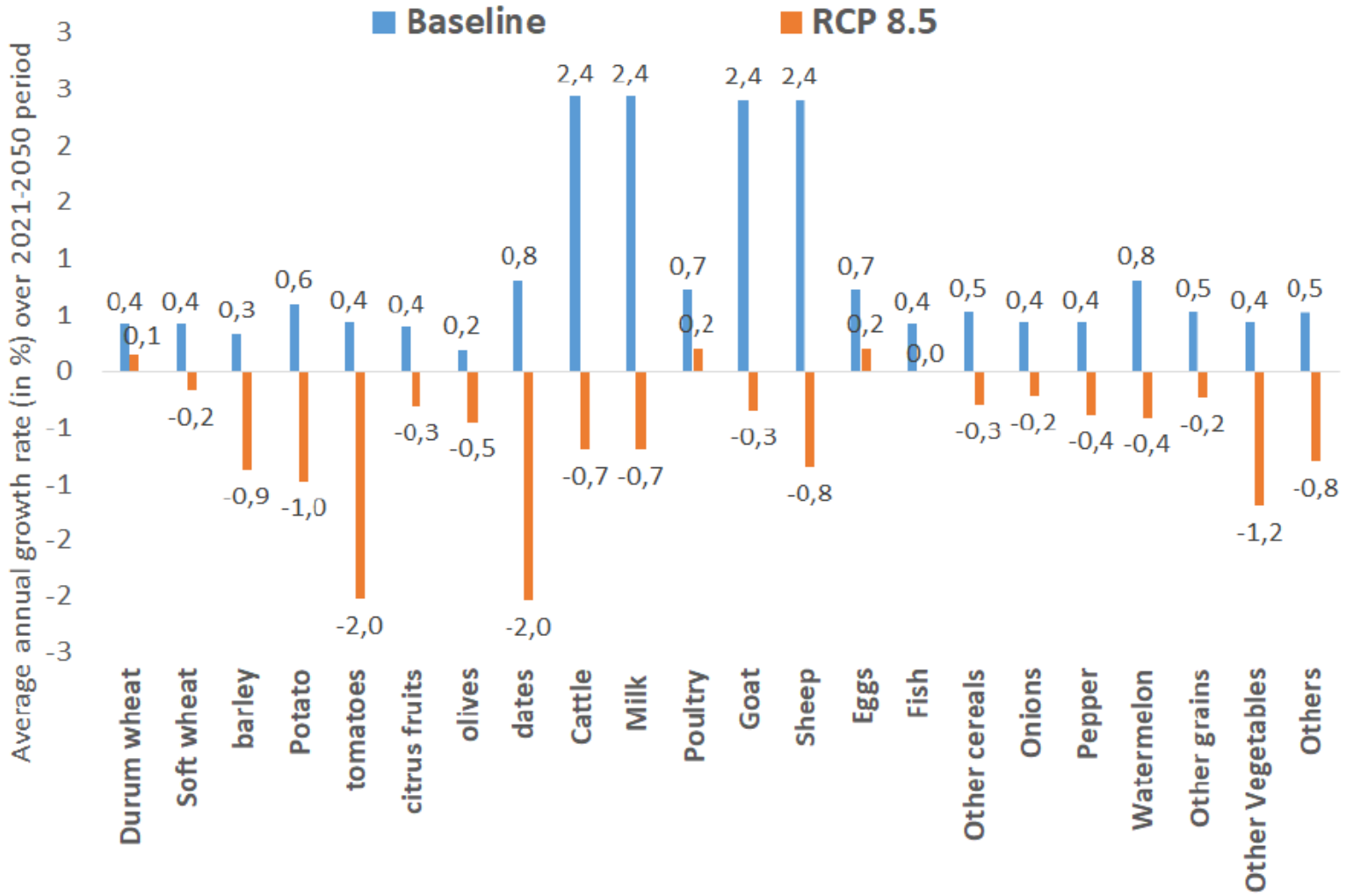
- The impacts of climate change on areas and yields were quantified through projections developed as part of the adaptaction project (adaptaction, 2020) for cereal crops, olives and the fishing sector.

- FAO projections (model: "global agro-ecological zones were used for several agricultural products which are not studied within the framework of the adapt-action project, namely dates, citrus fruits, tomatoes, potatoes, production animal (bovine, sheep and caprine), other cereals, other plant products and other fruits.

03.

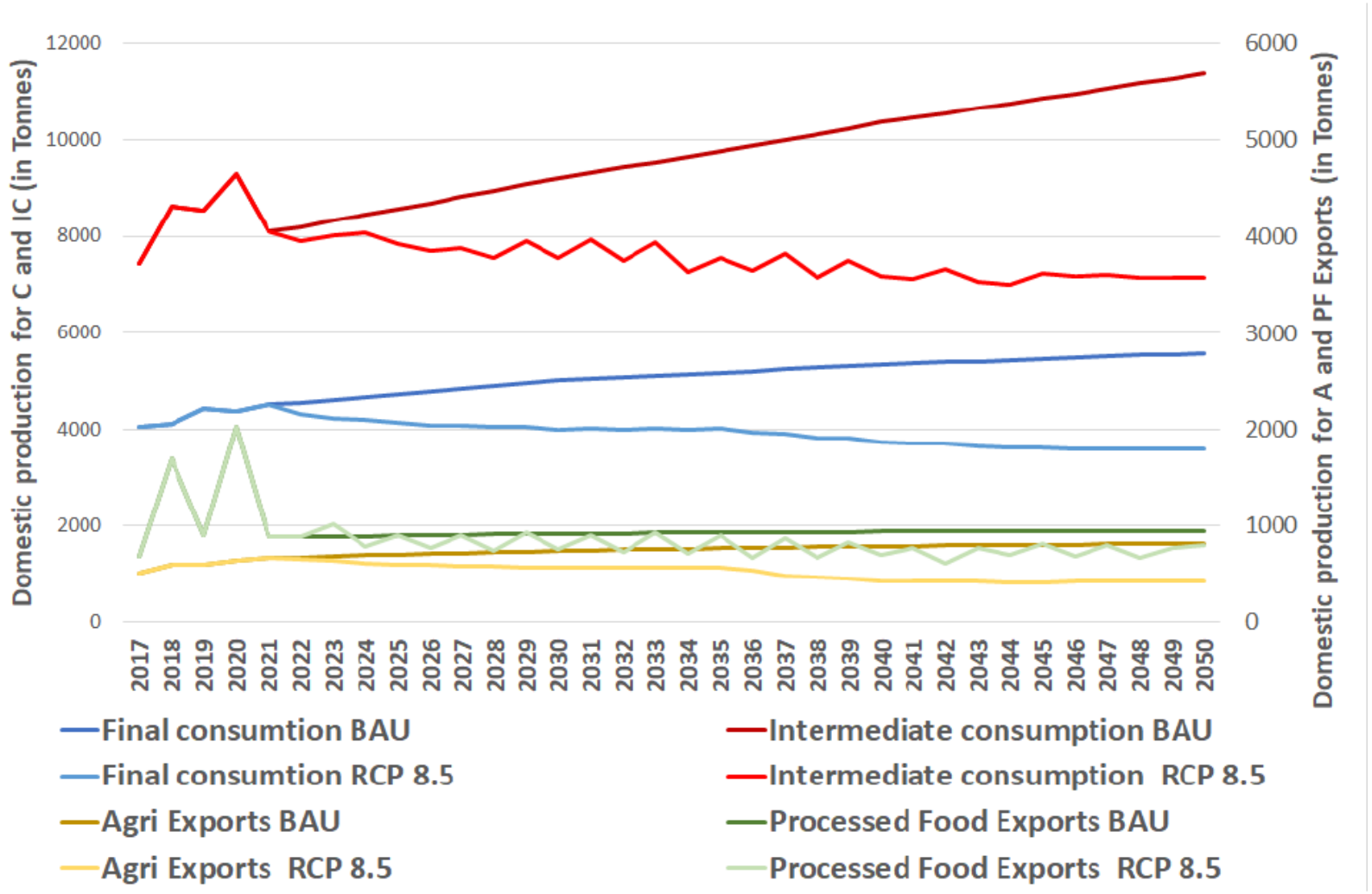
Potential Impact of climate change on Tunisian crops

Agricultural production projections: BAU and RCP 8.5



Potential Impact of climate change on Tunisian crops

Agricultural production projections: BAU and RCP 8.5



Impacts économiques du changement climatique

Le modèle GEMMES-Tunisie

- The GEMMES-Tunisia model: General Monetary Macro-dynamics for the Ecological Shift
- It is a modified version of the prototype model of Yilmaz & Godin (2020) for developing countries, adapted and calibrated to the specificities of the Tunisian economy.
- Other applications of the GEMMES model are being studied for: Morocco, Mexico, Colombia, Turkey and India.
- The model represents a continuous-time dynamic system for a small open economy and consists of more than 220 equations, with an 81-dimensional system of differential equations.
- A coherent stock-flow accounting framework with an explicit modelling of financial sector and flow of funds.
- Continuing disequilibrium in markets leading to price-quantity adjustments.

Impacts économiques du changement climatique

Le modèle GEMMES-Tunisie: Cadre comptable du modèle

	Agriculture		Non-Agricultural NFC		Household	Banks	C. Bank	Government	RoW	Σ
	Current	Capital	Current	Capital						
Agricultural Cons.	$+C^A$				$-C^A_{HH}$					0
Agricultural Margins	$-MA^F_A - MA^{X,F}_A$		$+MA^F_A + MA^{X,F}_A$							0
Transformed food Cons.			$+C^{TF}$		$-C^{TF}_{HH}$					0
NFC Consumption			$+C^F + G^F_C$		$-C^F_{HH}$					0
Public Services					$-C^G_{HH}$			$+C^G - G^G_C$		0
Investment, capital.		$-I^A_{Cap}$	$+I^T_{Cap}$	$-I^F_{Cap}$	$-I^{HH}_{Cap}$			$-I^G_{Cap}$		0
Investment, Irrigation.		$-I^A_{Irrig}$	$+I^T_{Irrig}$					$-I^G_{Irrig}$		0
Imports			$-IM^{TF} - IM^F - IM^A$						$+IM^W$	0
Exports	$+X^A$		$+X^F + X^{TF}$						$-X_W$	0
Agr. Inter. Cons.	$+IC^A - IC^A_A$		$-IC^A_F$					$-IC^A_G$		0
Tr. Food Inter. Cons.	$-IC^{TF}_A$		$+IC^{TF} - IC^{TF}_F$					$-IC^{TF}_G$		0
NFC Inter. Cons.	$-IC^F_A$		$+IC^F - IC^F_F$			$-IC^F_B$		$-IC^F_G$		0
Wages	$-WB_A$		$-WB_F$		$+WB^T$	$-WB_B$		$-WB_G$		0
Indirect Taxes less Sub.	$-TBP_A$		$-TBP_F$			$-TBP_B$		$+TBP^G - TBP_G$		0
Employers' Social Con.	$-BSC_A$		$-BSC_F$			$-BSC_B$		$+BSC^G - BSC_G$		0
VAT and other Taxes	$-VAT_A$		$-VAT_F$					$+VAT^G - VAT_G$		0
Subsidies	$+G^A_S$		$+G^F_S$					$-G^T_S$		0
GOS distribution	$-MI_A$	$+RE_A$	$-GOS_{HH}$		$+MI_A + GOS_{HH}$					0
Int. Deposits			$+IntD^D_F$		$+IntD^{HH}$	$-IntD^D_B$				0
Int. FX Deposits			$+IntD^{F,X}_F$				$-IntD^{F,X}_F$			0
Int. Domestic Loans	$-IntL^D_A$		$-IntL^D_F$		$-IntL^D_H$	$+IntL^D$				0
Int. NFC Inter. FX L.			$-IntL^{B,FX}_F$			$+IntL^{B,FX}_F$				0
Int. NFC Direct FX L.			$-IntL^{D,FX}_F$						$+IntL^{D,FX}_F$	0
Int. Banks FX Loans						$-IntL^{B,X}_B$			$+IntL^{B,X}_B$	0
Int. Bonds						$+IntB^B$	$+IntB^{CB}$	$-IntB$	$+IntB^W$	0
Int. Advances						$-IntA$	$+IntA$			0
Dividends			$-Div_F$		$+Div^{HH}_F$	$+Div^B_F - Div_B$		$-Div^G_F$	$+Div^W$	0
Remittances					$+Rem$				$-Rem$	0
Central Bank Profits							$-F_{CB}$	$+F_{CB}$		0
Taxes on Inc. and Prof.			$-T^F_F$		$-T^I_{HH}$	$-T^F_B$		$+T^T$		0
Social Contributions					$-SC_{HH}$			$+SC^G$	$+SC^W$	0
Social Benefits					$+SB^{HH}$	$-SB_B$		$-SB_G$		0
Others			O^F		O^{HH}	O^B		O^G	O^W	0
Savings	$-RE_A$	$+RE_A$	$-RE_F$	$+RE_F$	$[S_H]$	$[RE_B]$	0	$[S_G]$	$[S_W]$	0
[Capital]		$[K_A]$		$[K_F]$	$[K_H]$			$[K_G]$		$[K_T]$
[Inventories]		$[V^A]$		$[V^F + V^{TF}]$						$[\dot{V}]$
Deposits				$-\dot{D}^D_F$	$-\dot{D}^{HH}$	$+\dot{D}$				0
Reserves						$-\dot{R}^D$	$+\dot{R}^D$			0
Domestic Loans		$+\dot{L}^D_A$		$+\dot{L}^D_F$	$+\dot{L}^D_H$	$-\dot{L}^D_B$				0
Bonds						$-\dot{B}^B_G$	$-\dot{B}^{CB}_G$	$+\dot{B}_G$		0
Advances						$+\dot{A}$	$-\dot{A}$			0
Firms Equity				$+\dot{EQ}_F$		$-\dot{EQ}^B_F$			$-\dot{EQ}^W_F$	0
Banks Equity						$+\dot{E}^B$			$-\dot{E}^B_W$	0
FX deposits				$-\dot{D}^{FX}_F$		$+\dot{D}^{FX}$			$-\dot{D}^{FX}_W$	0
FX Reserves						$-\dot{R}^{FX,B}$	$-\dot{R}^{FX,CB}$		$+\dot{R}^{FX}$	0
Intermediate FX Loans				$+\dot{L}^{B,FX}_F$		$-\dot{L}^{B,FX}_F$				0
Direct FX Loans				$+\dot{L}^{D,FX}_F$				$+\dot{L}^{G,FX}_G$	$-\dot{L}^{G,FX}_W$	0
Other				$+\dot{O}_F$	$+\dot{O}_{HH}$	$+\dot{O}_B$		$+\dot{O}_G$	$+\dot{O}_W$	0
Σ	0	0	0	0	0	0	0	0	0	0

04 Economic Impacts of Climate Change

GEMMES-Tunisia Model

- We construct a macroeconomic model with three productive sectors explicitly modeled: **Agriculture**, the **processed-food** industry and a NFC sector which produces all other **non-food goods and services.**

Production

- The productive sectors use inputs from the three sectors for intermediate consumption, employ households and use their capital stock to produce.
- **Agricultural production is exogenous to the model** and is determined by climate conditions. We **smooth and interpolate** the previously presented agricultural production for consumption, intermediate consumption and exports.
- Excess demand in the agriculture sector is met by food imports. We assume no rationing in food import markets.
- For processed food and non-food sector , we utilize the **disequilibrium adjustment structure** extensively developed in Franke (1996); Chiarella and Flaschel (2000); Charpe et al. (2011); Chen et al. (2006); Flaschel and Proaño (2007), such that aggregate demand less of imports is not necessarily equal to total production.
- Excess supply and demand in these markets are met by stock (dis)accumulation.

04 ECONOMIC IMPACTS OF CLIMATE CHANGE

GEMMES-TUNISIA MODEL

- FIRMS FORM **ADAPTIVE EXPECTATIONS** ON AGGREGATE DEMAND, WITH A TREND DETERMINED BY CAPITAL ACCUMULATION RATE FOR NON-FOOD GODOS/SERVICES AND POPULATION GROWTH RATE FOR PROCESSED FOOD.
- EXCESS DEMAND (SUPPLY) INDUCES FIRMS TO INCREASE (DECREASE) PRODUCTION. (AS WELL AS MARK-UPS OVER UNIT COSTS)
- FIRMS ALSO PRODUCE TO ENSURE A **DESIRED LEVEL OF INVENTORIES** IS ALWAYS MAINTAINED AS BUFFER IN CASE SALES EXPECTATIONS ARE WRONG.
- IMPORTS OF NON-AGRICULTURAL GOODS FOR CONSUMPTION, INTERMEDIATE CONSUMPTION AND INVESTMENT DEPEND **ARMINGTON-TYPE IMPORT PROPENSITIES** THAT VARY OVER TIME.
- IMPORT PROPENSITIES ARE SLOW-MOVING AND THEY ADJUST TO TARGET IMPORT PROPENSITIES, WHICH ARE NEGATIVE FUNCTIONS OF THE **REAL EXCHANGE RATE, IMPORT TAXES** AND OF THE TUNISIA'S **RELATIVE LABOUR PRODUCTIVITY** WITH RESPECT TO ITS BUSINESS PARTNERS.

04 Economic Impacts of Climate Change

GEMMES-Tunisia Model

Pricing

- Desired prices of all domestically produced goods are set as mark-up over historical unit costs.
- We assume constant mark-up in the agriculture sector. In non-food NFC sector, mark-ups increase (decrease) if firms observe that inventory accumulation exceeds (falls short of) desired level.
- Due to sticky prices, actual prices move towards desired prices slowly over time as also argued by Calvo (1983).
- Final consumer prices are composite functions of domestic and import prices.

Investment and Financing

- For the Processed Food Industry and NFCs, real investment depends on the profit rate net of inflation.
- For the Agro-Food Industry and non-food NFC sector, part of the profits is retained to finance the investment. The rest of the investment financing is provided by borrowing from the banking sector, either in national currency or in FX.

Economic Impacts of Climate Change

GEMMES-Tunisia Model

Financial Sector

- Banks remunerate household and business deposits and interest on these deposits is set as a mark-down from the policy rate set by the central bank. The mark-down depends on the liquidity position of the banking sector.
- Banks also set the lending rates in domestic and FX to households and productive sectors. Lending rates are a variable mark-up on the average funding cost of banks, and depend on the riskiness of the loans
- In order to lend to domestic businesses in foreign currencies, banks borrow from abroad in foreign currencies. The quantity and interest rate of these loans depend on country risk.
- Country risk depends on the ratio of FX debt of Tunisia to GDP and effects cross-border lending rate.
- When country risk increases, banks also face higher rationing from the rest of the world and foreign currency loans to NFCs are therefore subject to a supply constraint.
- Banks hold all government bonds in national currency.
- We incorporate into the model the central bank which sets the key rate according to a purely **inflation-targeting Taylor** rule. In the simulations below, the central bank does not intervene in the foreign exchange markets and lets the currency float.

Economic Impacts of Climate Change

GEMMES-Tunisia Model

Government

- The government collects taxes on income and products (such as import taxes, value-added tax, etc.), employs workers to provide public goods, invests in public capital, and uses intermediate consumption from different sectors to provide public services in addition to expenditure on social transfers.
- The government invests in public capital. It also subsidizes agricultural products to keep their consumer prices low.
- It finances its deficit by borrowing through domestic currency bonds and borrowing from abroad in FX.
- For the government, the amount borrowed in foreign currency is a fraction of the trade deficit, to ensure that the government provides the foreign currency requirement needed to finance the current account deficit.
- In the simulations, we assume that foreign currency government borrowing is not rationed by the rest of the world, but interest rates on foreign currency government borrowing depend on country risk, which depends on the country's total foreign currency debt by relative to GDP.

04 Economic Impacts of Climate Change

GEMMES-Tunisia Model

Households

- Households work for the three productive sectors and the government and receive wage income and any mixed income from the agricultural sector, on which they pay income taxes.
- They receive interest on their savings deposits, dividends from companies and banks, social transfers from the government and they pay interest on household loans (which are just mortgages).
- They also receive transfers from Tunisians living abroad.
- Regarding consumption, they consume three types of products from the three productive sectors considered and only keep their savings in the form of deposits in national currency.
- The decision to consume agricultural, agro-industrial and other goods follows a function of the **linear expenditure system (LES)**, with minimum consumption necessary in the three sectors and variable consumption that depends on relative prices.
- We impose that the share of income spent on food decreases as income increases, in accordance with **Engel's law**.

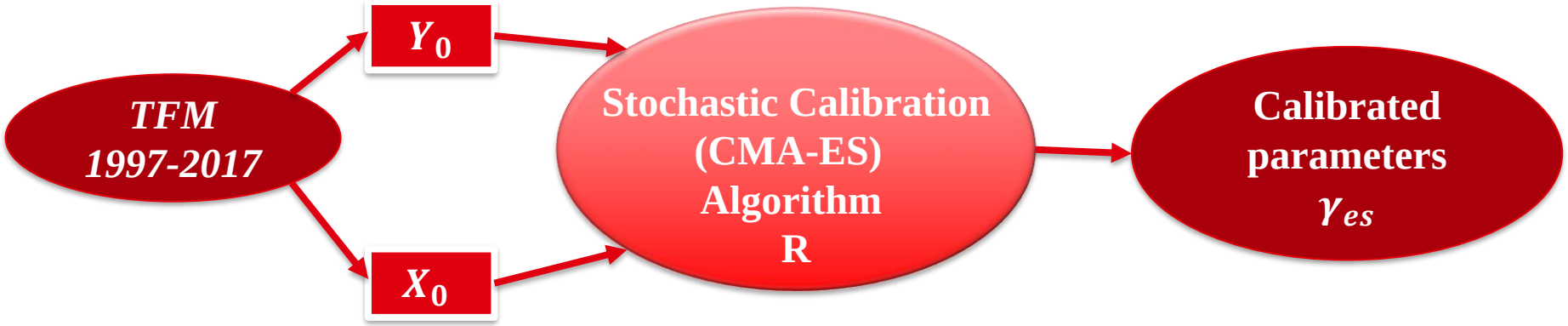
04 Economic Impacts of Climate Change

GEMMES-Tunisia Model

Rest of the World

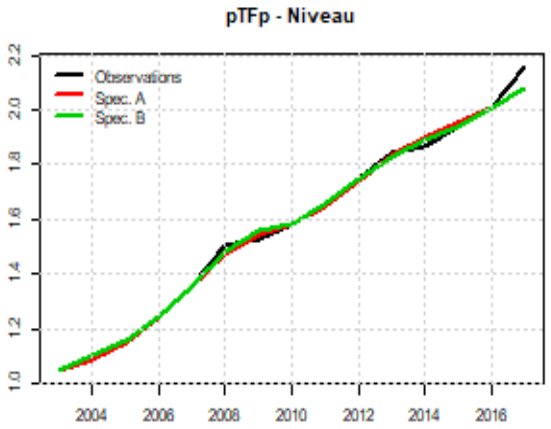
- The country receives remittances from the rest of the world.
- We assume an exogenous growth rate for Tunisia's trading partners, exogenous risk-free global interest rate and exogenous inflation on food and non-food goods.
- The nominal exchange rate is flexible in the model and depends on the interplay between demand and supply.
- As in the goods market, FX reserves of the country falls if FX financing from abroad falls short of current account deficit.
- Excess demand in the FX market depreciates the Dinar.

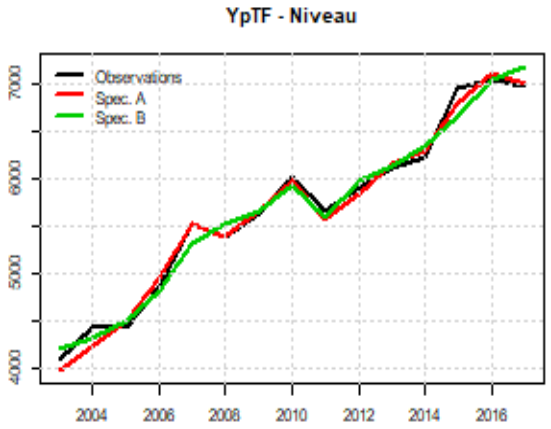
GEMMES Tunisia model: Parameter calibration/estimation

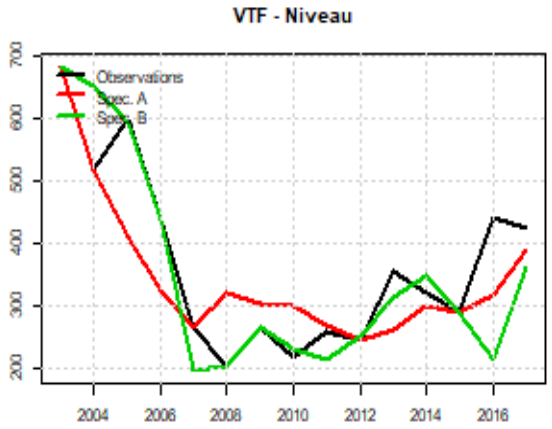


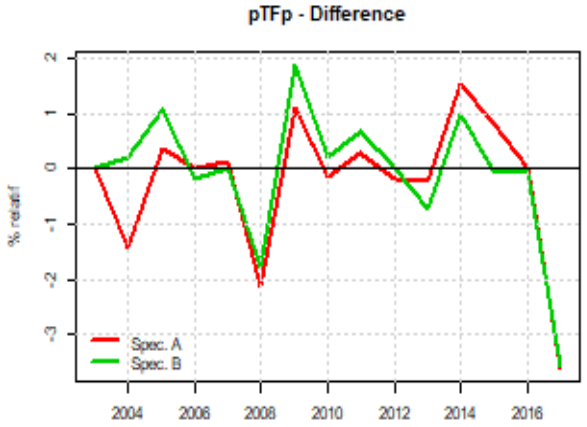
04 Economic mpacts of Climate Change

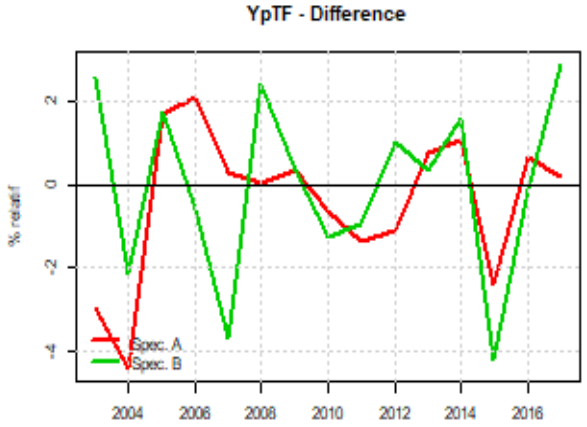
GEMMES Tunisia model: Parameter calibration/estimation

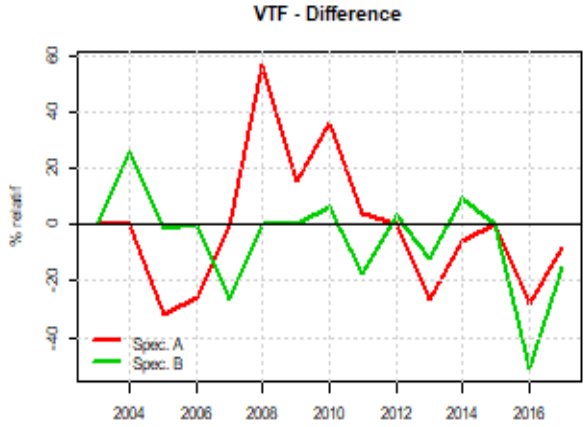






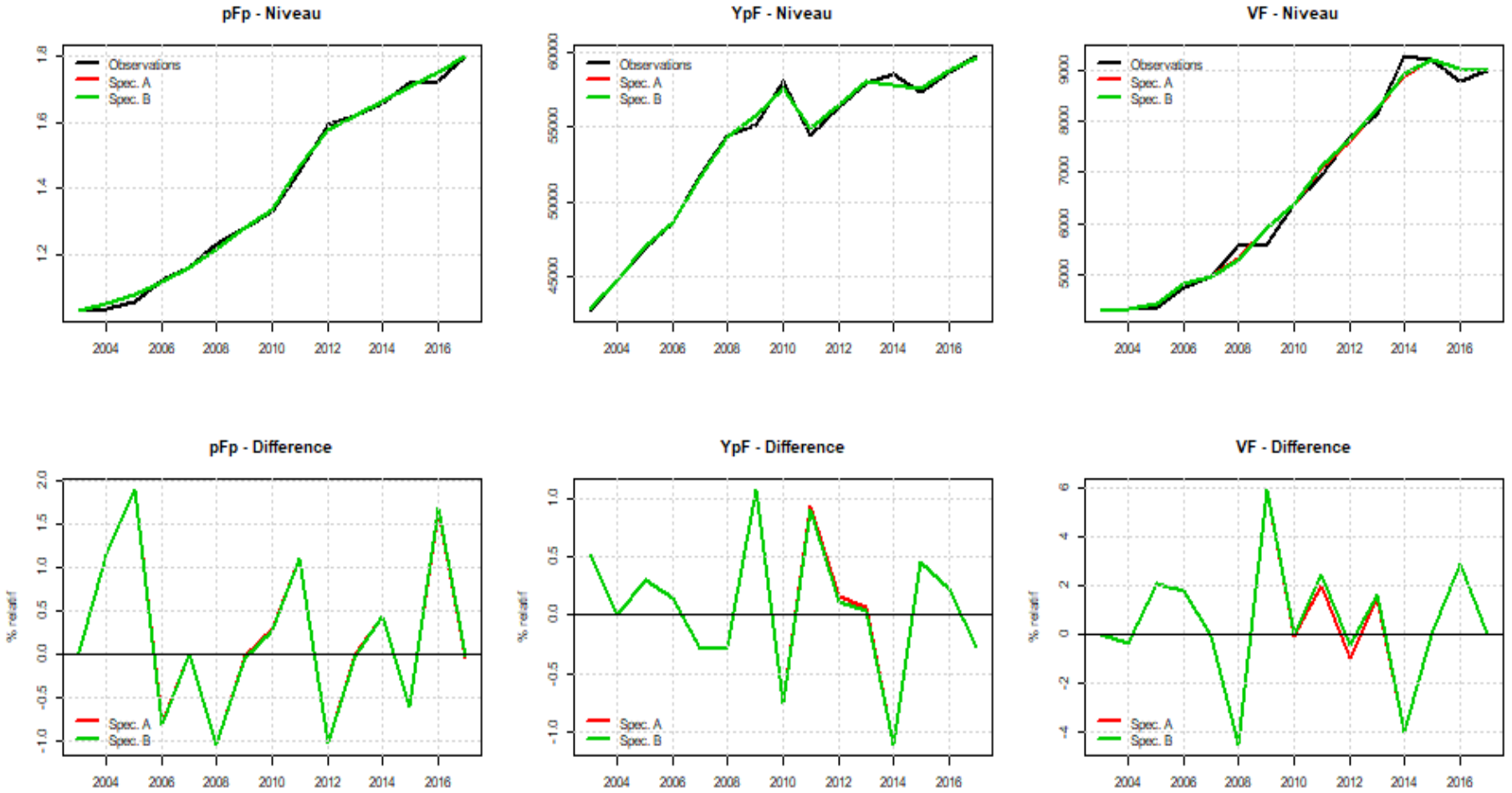






Impacts économiques du changement climatique

GEMMES Tunisia model: Parameter calibration/estimation



Hypothèses des scénarios

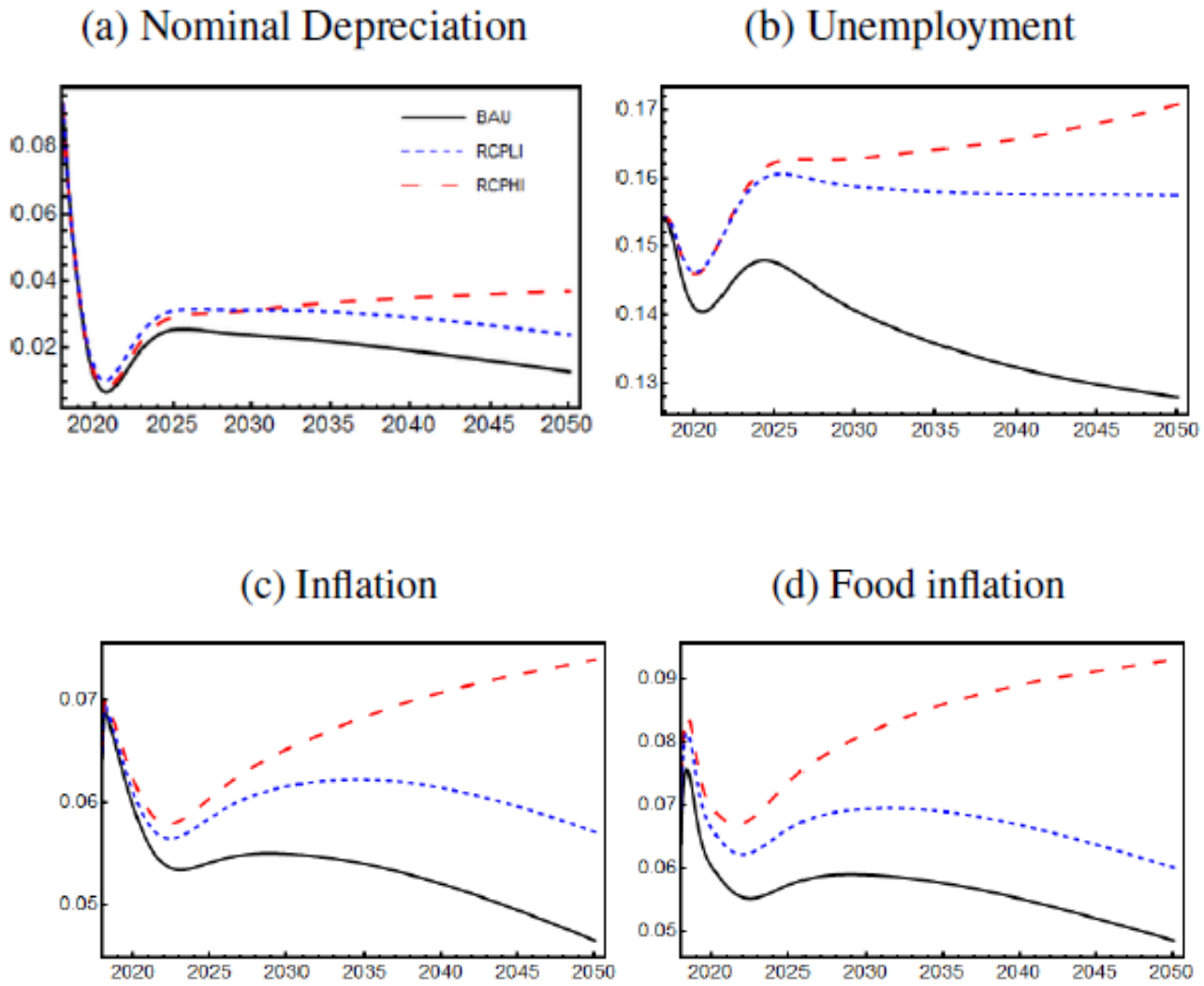
Variable	*BAU*	*RCP8.5 Low Inf (RCPLI)*	*RCP8.5 High Inf (RCPHI)*
gr_{ypac}	0.97%	-0.36%	-0.36%
gr_{ypaic}	1.3%	-0.13%	-0.13%
gr_{ypaw}	1.45%	-0.53%	-0.53%
gr_X^{PF}	1%	-0.37%	-0.37%
$Inf^{NF,w}$	3%	3%	3%
$Inf_C^{A,w}$	3%	3%	5.5%
$Inf_{IC}^{A,w}$	3%	3%	5.5%
$inf^{PF,w}$	3%	3%	5.5%
Inf_X^{NF}	3%	3%	3%
Inf_X^{PF}	3%	3%	5.5%
Inf_X^{A}	3%	3%	5.5%
gr_a	1.5%	1.5%	1.5%
gr_{aw}	1.5%	1.5%	1.5%
gr_w	3%	3%	3%
α_{pop}	0.7%	0.7%	0.7%

Table 4: Exogenous Variables for all scenarios.

Table 5: Projections of Key Economic Indicators Under Climate Change scenarios

Indicators	BAU Scenario			RCPLI Scenario			RCPHI Scenario		
	Mean 2018-2050	2050	StDev	Mean 2018-2050	2050	StDev	Mean 2018-2050	2050	StDev
Unemployment Rate (in%)	13.7	12.8	0.67	15.5	15.70	0.32	16.28	17.1	0.6
Inflation (in%)	5.34	4.66	0.39	6.5	5.7	0.22	6.72	7.4	0.49
Food Inflation (in%)	5.6	4.86	0.43	6.66	6	0.35	8.3	9.29	0.8
Processed Food Inflation (in%)	5.61	4.68	0.95	6.43	5.82	0.74	8.25	9.04	0.75
Real Growth Rate (in%)	2.39	2.27	0.24	2.26	2.23	0.2	2.03	1.85	0.24
Trade Deficit (in % of GDP)	9.45	8.6	0.47	10.33	10.35	0.25	11.58	13.67	1.03
Food Imports (in% of GDP)	3.32	4.39	0.65	5.2	7.52	1.52	6.12	10.1	2.24
Current Account Deficit (in%of GDP)	7.23	6.9	0.32	8.09	8.54	0.45	8.85	11.14	1.12
FX Reserves/Imports (in days)	121.13	125.65	2.92	97.6	64.12	18.67	98.5	45.7	22.5
Domestic Bond Rate (in%)	6.59	6.2	0.18	7.19	8.06	0.55	8.41	10.57	1.21
FX Bond Rate (in%)	3.08	3.36	0.29	3.4	3.97	0.47	3.59	4.78	0.68
Public FX Debt (in% of GDP)	59.79	66.45	6.27	64.04	74.86	8.7	66.64	85.35	11.48
Total Public Debt (in% of GDP)	85.98	93.9	8.65	96.6	117.57	15.53	102.32	140.93	21.68
Public Deficit (in% of GDP)	6.25	5.40	0.33	7.79	8.14	0.58	9.18	12.52	1.75
Real Exchange Rate (in%)	1.37	1.31	0.03	1.41	1.38	0.02	1.38	1.32	0.03
Investment (in% of GDP)	17.32	16.7	0.48	16.89	16.31	0.52	16.61	15.68	0.69
Country Risk	8.51	9.44	0.98	9.58	11.45	1.57	10.19	14.14	2.27
Per capita income (in in EUR)	4613	6157	807	4412	5765	696	3964	4580	361

For RCPLI and RCPHI Scenarios, red values imply more than 2 StDev increase/decrease compared to BAU Scenario values, orange values imply between 1 and 2 StDev increase/decrease compared to BAU Scenario values, and yellow values imply less than 1 StDev increase/decrease compared to BAU Scenario values.

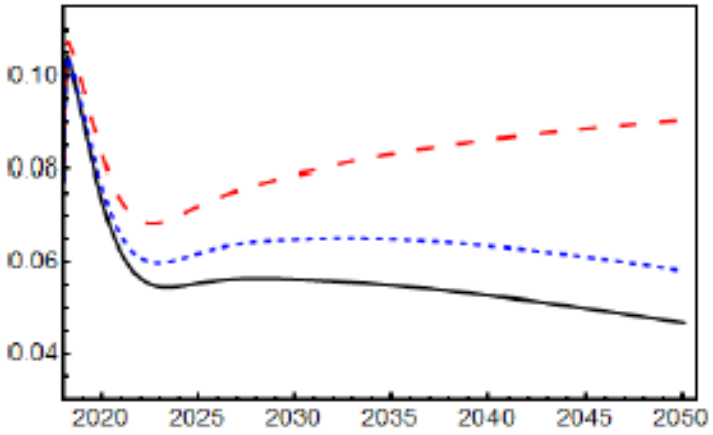


-- Baseline

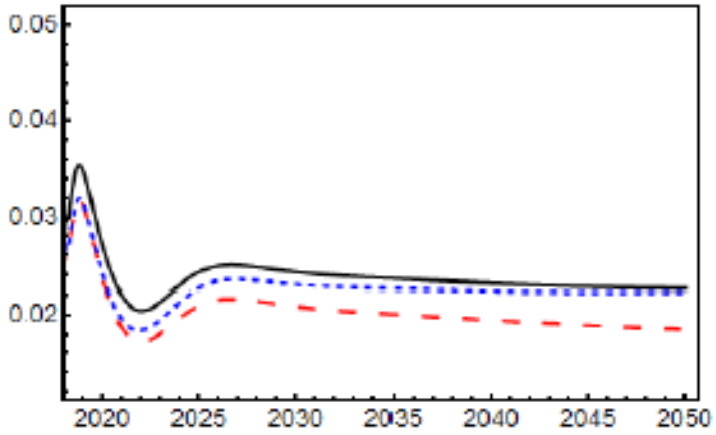
-- RCP 8.5 with low global food inflation

-- RCP 8.5 with high global food inflation

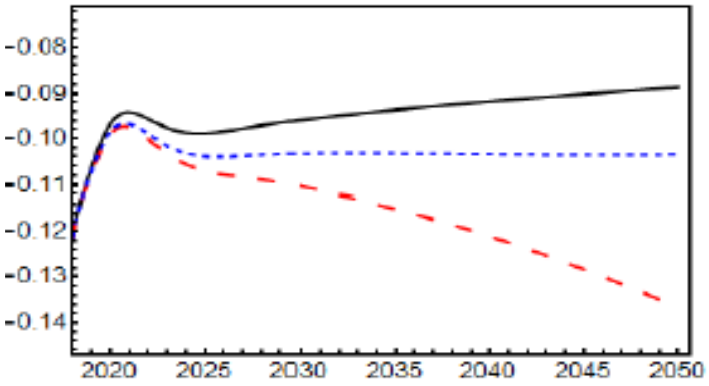
(e) Processed Food Inflation



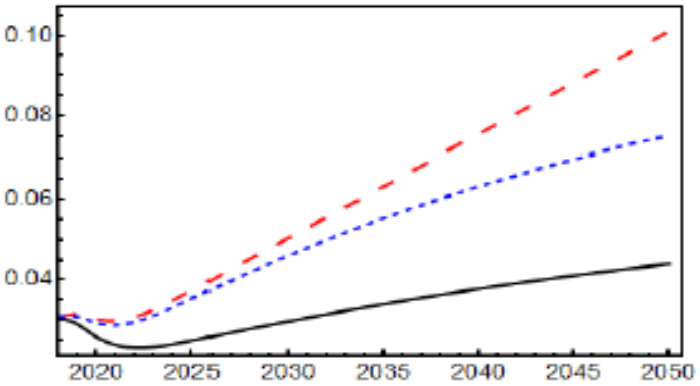
(f) Real Growth Rate



(g) Trade Balance (% GDP)



(h) Food Imports(% GDP)

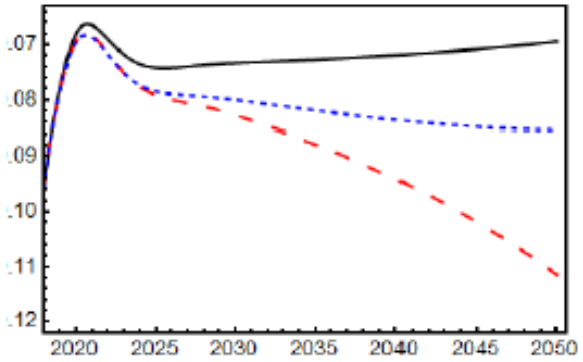


-- Baseline

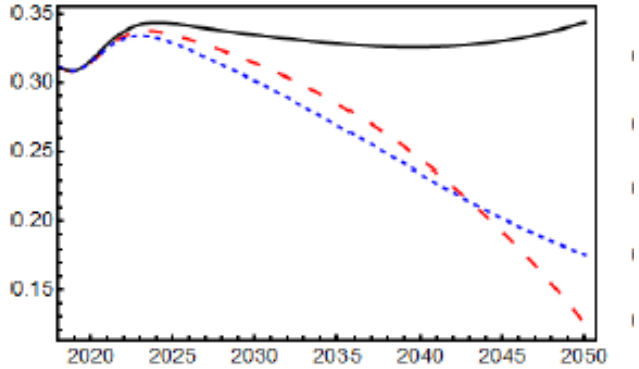
-- RCP 8.5 with low global food inflation

-- RCP 8.5 with high global food inflation

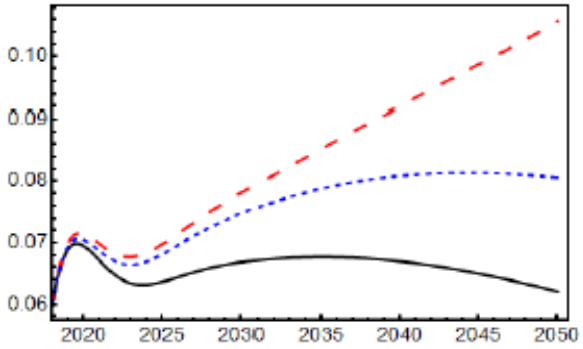
(i) Current Account(% GDP)



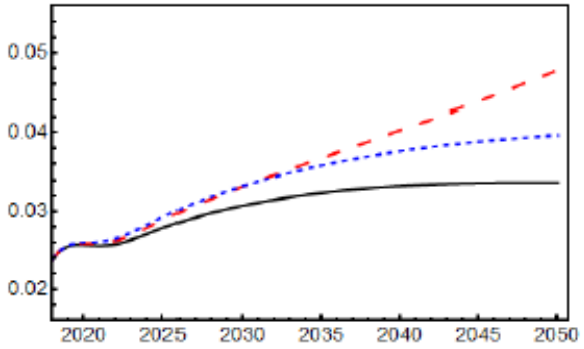
(j) FX Reserves/Imports



(k) Domestic Bond Rate



(l) FX Bond Rate

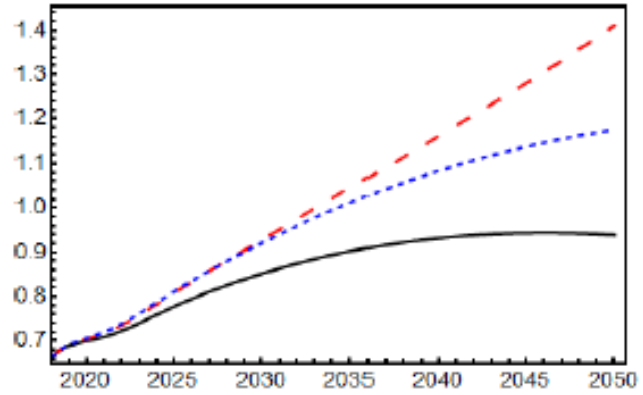


-- Baseline

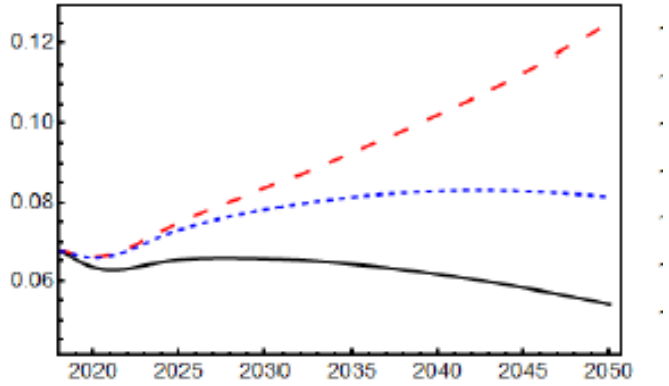
-- RCP 8.5 with low global food inflation

-- RCP 8.5 with high global food inflation

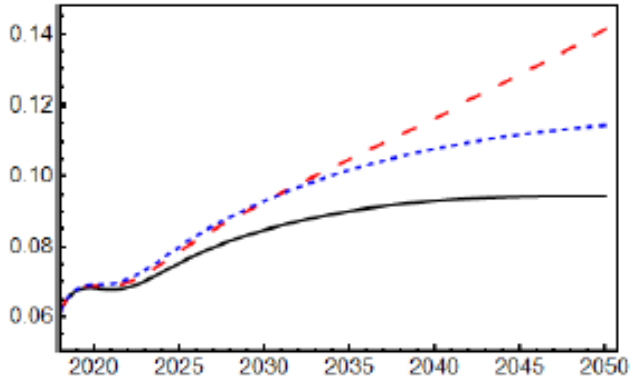
(n) Public Total Debt/GDP



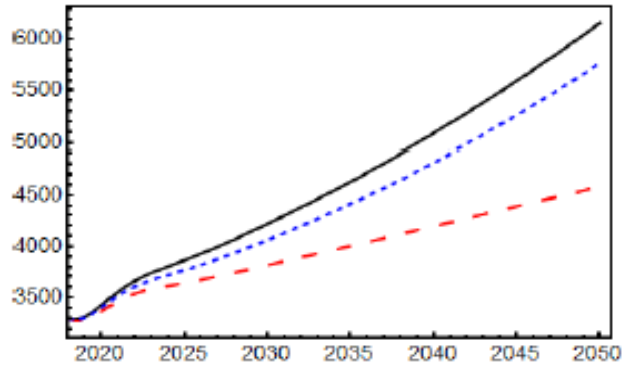
(o) Public Deficit



(r) Country Risk



(t) Per capita Income



-- Baseline

-- RCP 8.5 with low global food inflation

-- RCP 8.5 with high global food inflation

06 Adaptation Policy

WE SIMULATE TWO ADAPTATION SCENARIOS OUTLINED IN THE «WATER 2050 PLAN» BY THE TUNISIAN GOVERNMENT. IN BOTH PLANS, THE PUBLIC AND PRIVATE SECTOR INVEST 1.1% GDP EACH YEAR UNTIL 2050 ON ADAPTATION.

Variable	*Reference (2020)*	*Reinforced Tendency*	*Water and Development*
GDP growth (2021-2050)	2.5%	2.5%	4.3%
Agriculture	1.8%	1%	3.5%
Industry	1.1%	2%	4%
Tourism	3.4%	2%	4%
Services	3.2%	3%	4.5%
Water Elasticity of GDP	0.52	0.5	0.1
Agriculture	0.42	0.2	0.15
Industry	0.6	0.6	0.1
Services	0.5	0.5	0.1
Water Resources (Mm3)	4985	4622	4594
Conventional	4929	3745	3968
Non-Conventional	66	877	626
Desalination	39	752	376
Waste Water Management	27	125	250

Table 6: Adaptation Scenarios

06 Adaptation Policy

- **CONCESSIONAL LOANS**

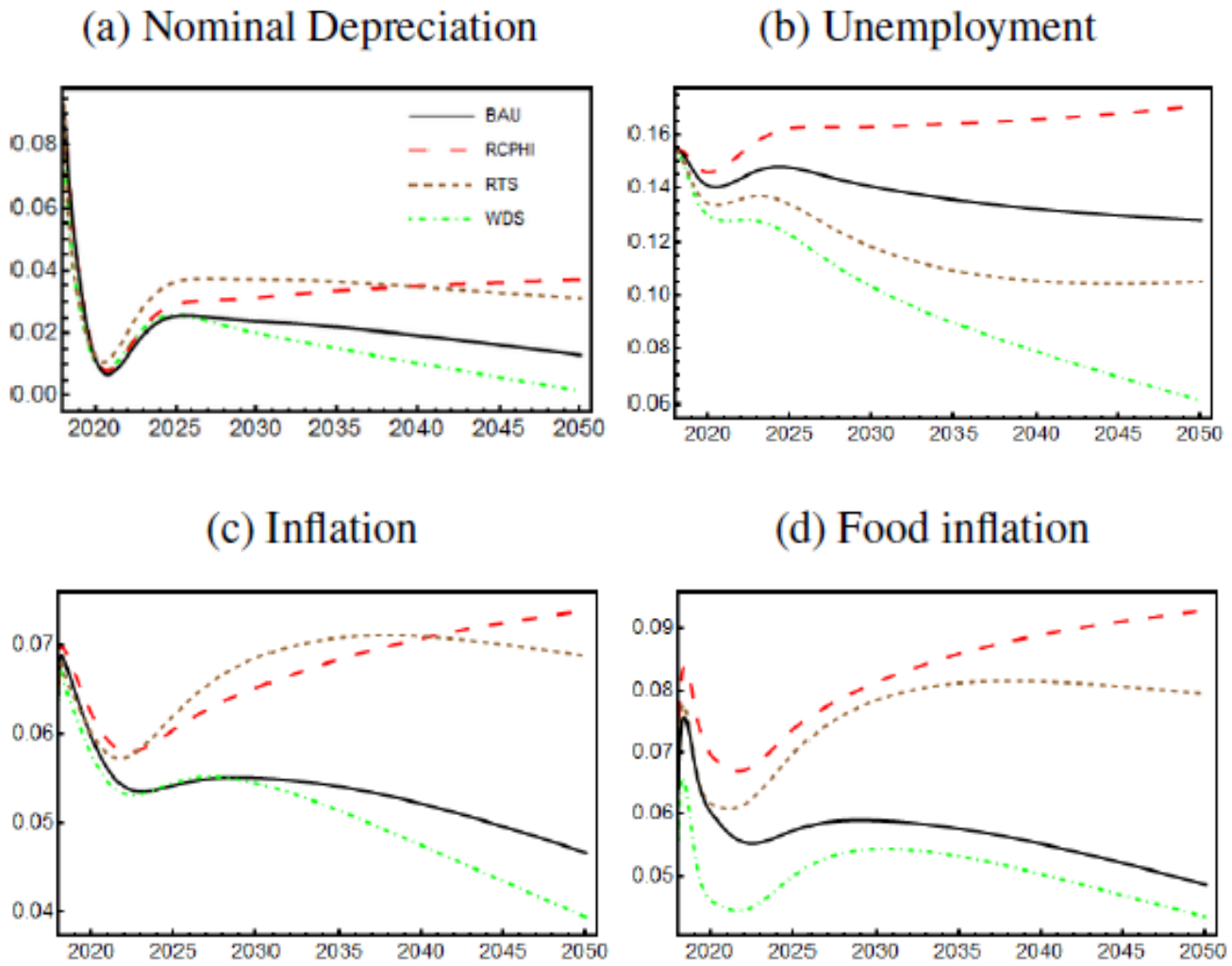
WE ASSUME THAT PUBLIC PART OF THE ADAPTATION POLICY IS FINANCED BY LOW-INTEREST FOREIGN CURRENCY LOANS FROM INTERNATIONAL INSTITUTIONS, DEVELOPMENT BANKS OR THE INTERNATIONAL FINANCIAL SYSTEM VIA GREEN BONDS.

WE SET THE FINANCING RATE ON THIS PUBLIC ADAPTATION INVESTMENT AT 1.7%, WHICH IS EQUAL TO THE FINANCING RATE ON THE SFAX DESALINATION PLANT CURRENTLY UNDER CONSTRUCTION

Table 7: Projections of Key Economic Indicators Under Adaptation Scenarios

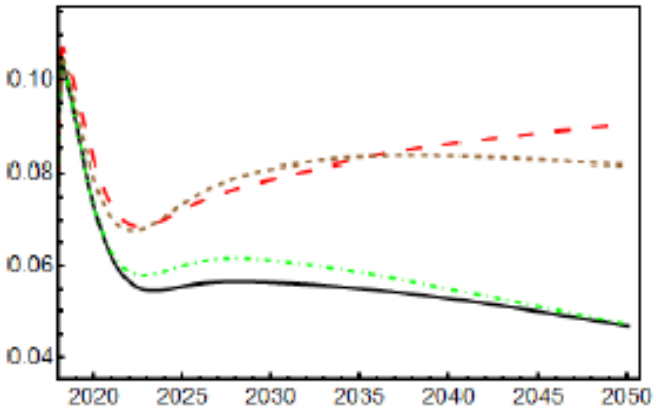
Indicators	RCPHI Scenario			RTS Scenario			WDS Scenario		
	Mean 2018-2050	2050	StDev	Mean 2018-2050	2050	StDev	Mean 2018-2050	2050	StDev
Unemployment Rate (in%)	16.28	17.1	0.6	11.68	10.51	1.35	9.61	6.07	2.41
Inflation (in%)	6.72	7.4	0.49	6.74	6.88	0.44	5.05	3.93	0.58
Food Inflation (in%)	8.3	9.29	0.8	7.64	7.95	0.67	5	4.33	0.41
Processed Food Inflation (in%)	8.25	9.04	0.75	8.07	8.18	0.6	5.88	4.72	0.94
Real Growth Rate (in%)	2.03	1.85	0.24	2.38	2.07	0.35	4.1	4.23	0.26
Trade Deficit (in % of GDP)	11.58	13.67	1.03	11.61	12.08	0.26	9.62	7.68	1.28
Food Imports (in% of GDP)	6.12	10.1	2.24	4.38	6.47	1.22	1.87	2.04	0.27
Current Account Deficit (in%of GDP)	8.85	11.14	1.12	9.98	11.04	0.53	8.09	6.91	0.71
FX Reserves/Imports (in days)	98.5	45.7	22.5	82.73	31.53	27.7	113.5	121.3	3.44
Domestic Bond Rate (in%)	8.41	10.57	1.21	8.51	9.84	0.12	6.10	4.89	0.52
FX Bond Rate (in%)	3.59	4.78	0.68	4.45	5.64	0.95	3.09	2.82	0.24
Public FX Debt (in% of GDP)	66.64	85.35	11.48	77.45	95.57	14.4	61.4	60.76	5.17
Total Public Debt (in% of GDP)	102.32	140.93	21.68	104.5	133.88	20.08	78.07	70.98	4.66
Public Deficit (in% of GDP)	9.18	12.52	1.75	7.97	9.28	0.88	5.30	3.42	0.94
Real Exchange Rate (in%)	1.38	1.32	0.03	1.41	1.34	0.03	1.33	1.20	0.06
Investment (in% of GDP)	16.61	15.68	0.69	18.73	17.69	0.76	20.32	19.91	0.38
Country Risk	10.19	14.14	2.27	13.07	16.99	3.15	8.53	7.67	0.8
Per capita income (in EUR)	3964	4580	361	4118	4946	453	5581	9048	1645

For RTS and WDS Scenarios, yellow, orange and red colours imply a worsening of the key economic indicator, while green colour implies an improvement, compared to the RCPHI Scenario values. Red values imply more than 2 StDev increase/decrease compared to RCPHI Scenario values, orange values imply between 1 and 2 StDev increase/decrease compared to RCPHI Scenario values, and yellow values imply less than 1 StDev increase/decrease compared to RCPHI Scenario values.

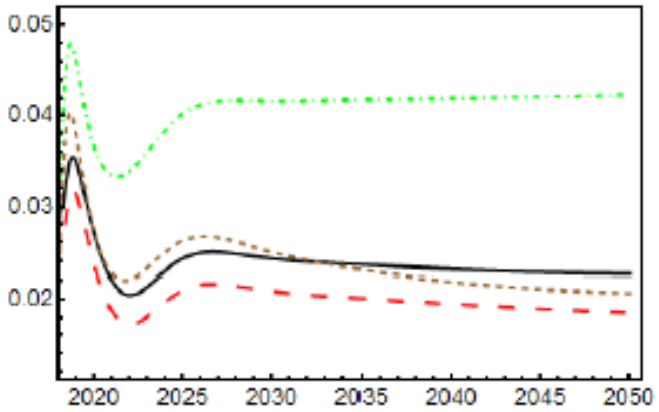


-- Baseline
-- RCP 8.5 High Global Food Inflation
-- Reinforced tendency
-- Water and Development

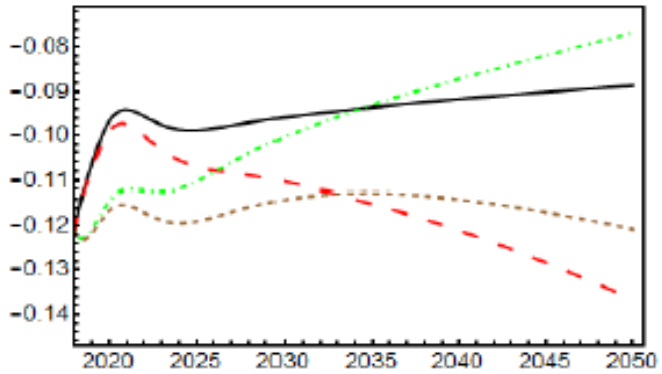
(e) Processed Food Inflation



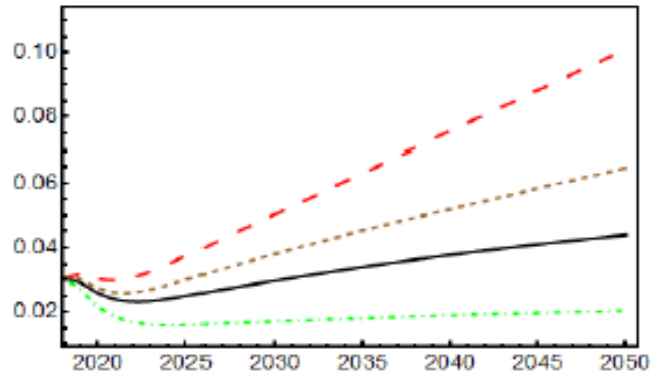
(f) Real Growth Rate



(g) Trade Balance (% GDP)

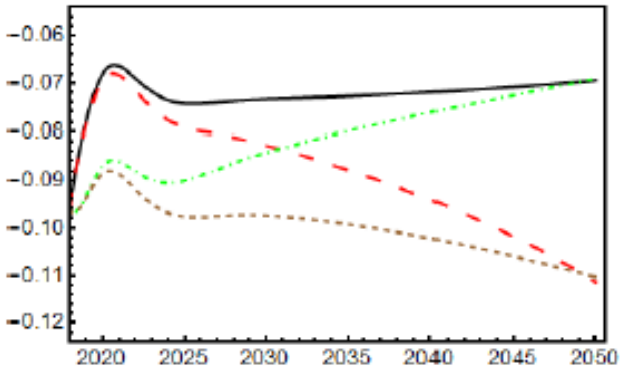


(h) Food Imports(% GDP)

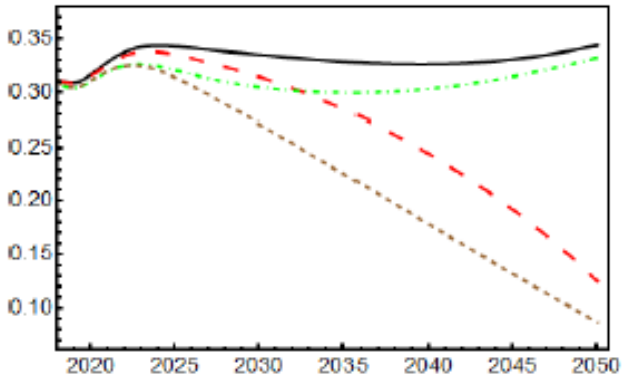


-- Baseline
-- RCP 8.5 High Global Food Inflation
-- Reinforced tendency
-- Water and Development

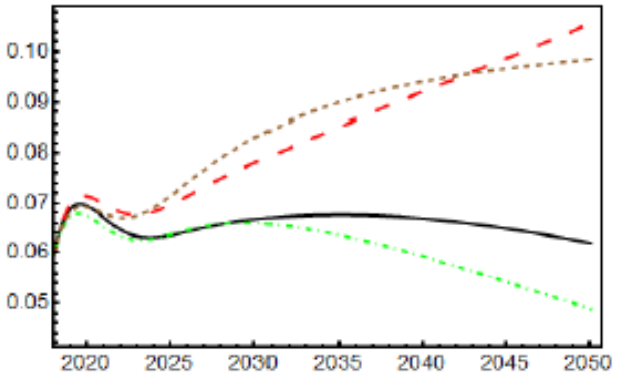
(i) Current Account(% GDP)



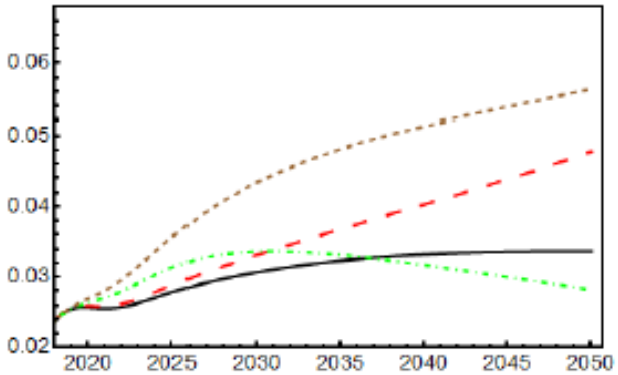
(j) FX Reserves/Imports



(k) Domestic Bond Rate

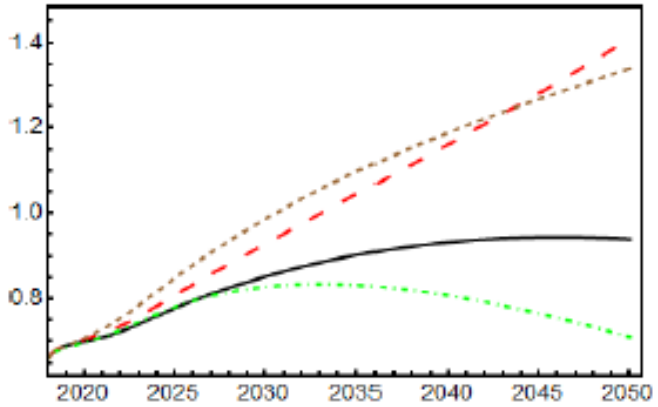


(l) FX Bond Rate

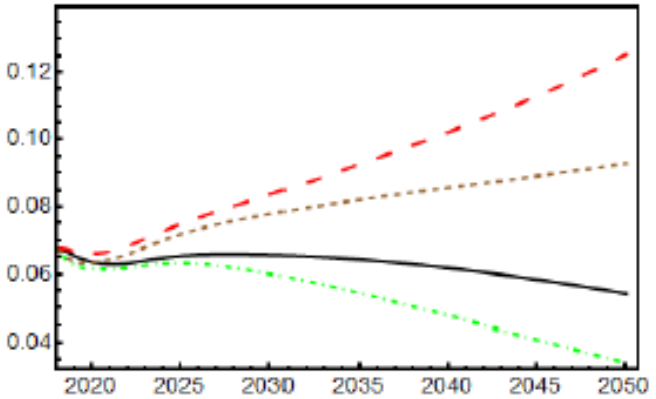


-- **Baseline**
-- **RCP 8.5 High Global Food Inflation**
-- **Reinforced tendency**
-- **Water and Development**

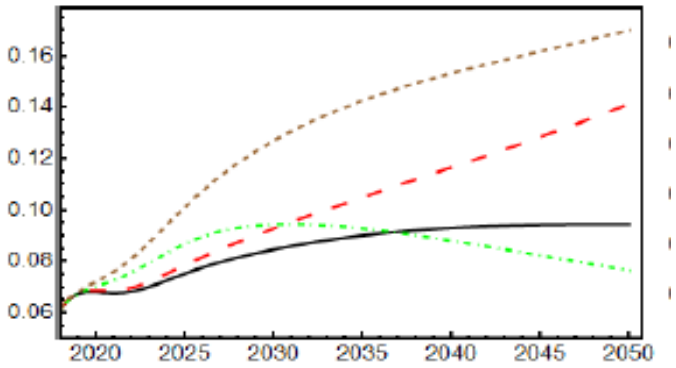
(n) Public Total Debt/GDP



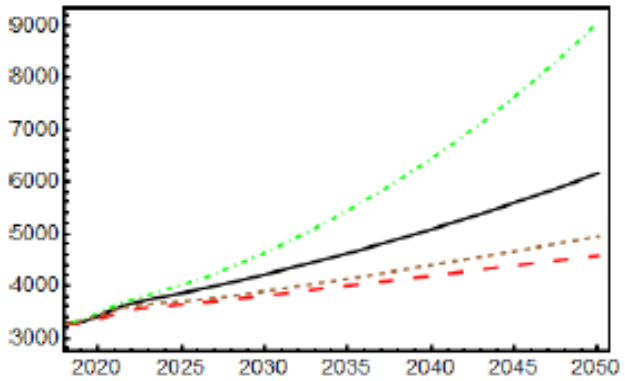
(o) Public Deficit



(r) Country Risk



(t) Per capita Income



-- BAU
-- RCP 8.5 High Global Food Inflation
-- Reinforced tendency
-- Water and Development

CONCLUSION

- THE IMPACT OF CLIMATE CHANGE ON TUNISIAN AGRICULTURE HAS SIGNIFICANT NEGATIVE REPERCUSSIONS ON THE ECONOMY, PARTICULARLY ON FOOD INFLATION, UNEMPLOYMENT, THE CURRENT ACCOUNT AND THE SUSTAINABILITY OF PUBLIC DEBT.

- THESE IMPACTS WILL BE AMPLIFIED IF CLIMATE DAMAGE LEADS TO HIGHER FOOD PRICES GLOBALLY.

- **SUCCESSFUL ADAPTATION POLICY REQUIRES REDUCING THE WATER ELASTICITY OF PRODUCTION IN AGRICULTURE, INDUSTRY AND SERVICES SIGNIFICANTLY**

- NEW POLICIES AIMED AT INCREASING THE PRODUCTIVITY OF AGRICULTURAL PRODUCTION AND THE ECONOMY IN GENERAL ARE ALSO ESSENTIAL TO ENSURE FOOD SECURITY AND AVOID A LONG-TERM BALANCE OF PAYMENTS CRISIS.

CAN COLOMBIA COPE WITH A GLOBAL LOW CARBON TRANSITION?

ANTOINE GODIN (AGENCE FRANÇAISE DE DÉVELOPPEMENT)

BASED ON A STUDY WITH AFD, DNP AND UNAL

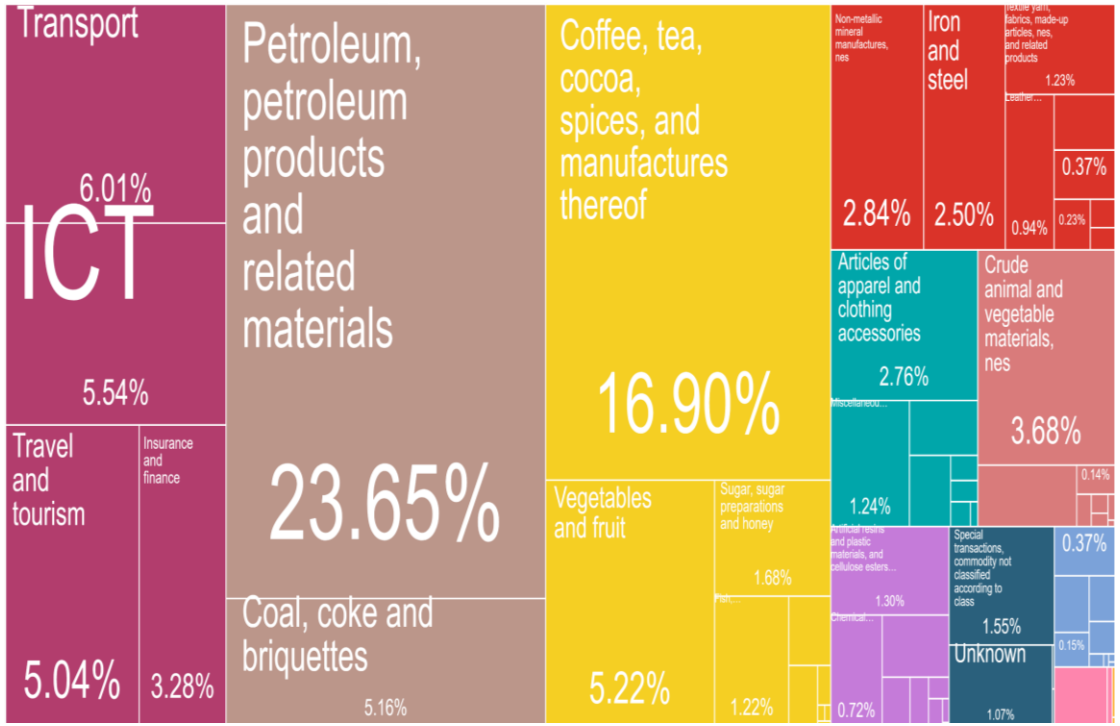
CONTEXT

CLIMATE RISKS, COLOMBIA AND MOTIVATION

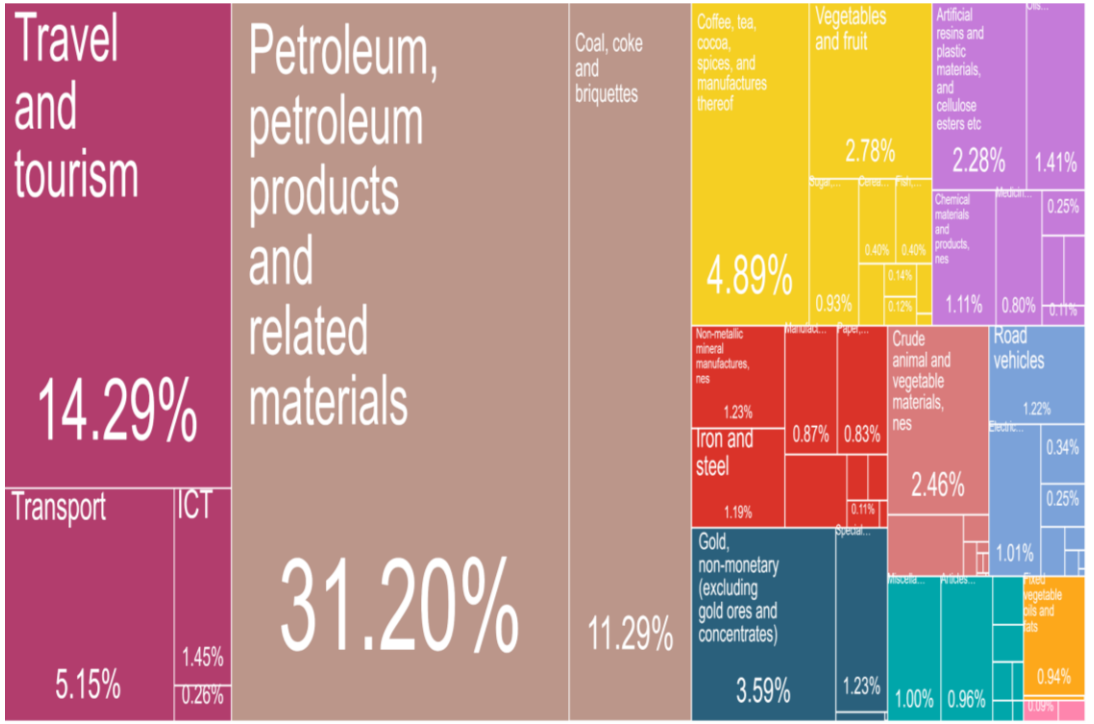
EXPORT BASKET

- **Colombian exports** are dominated by products of **low complexity** and **technological intensity**
- This is a sign of the **lack of diversification** and **capabilities** of its productive structure

1990



2019

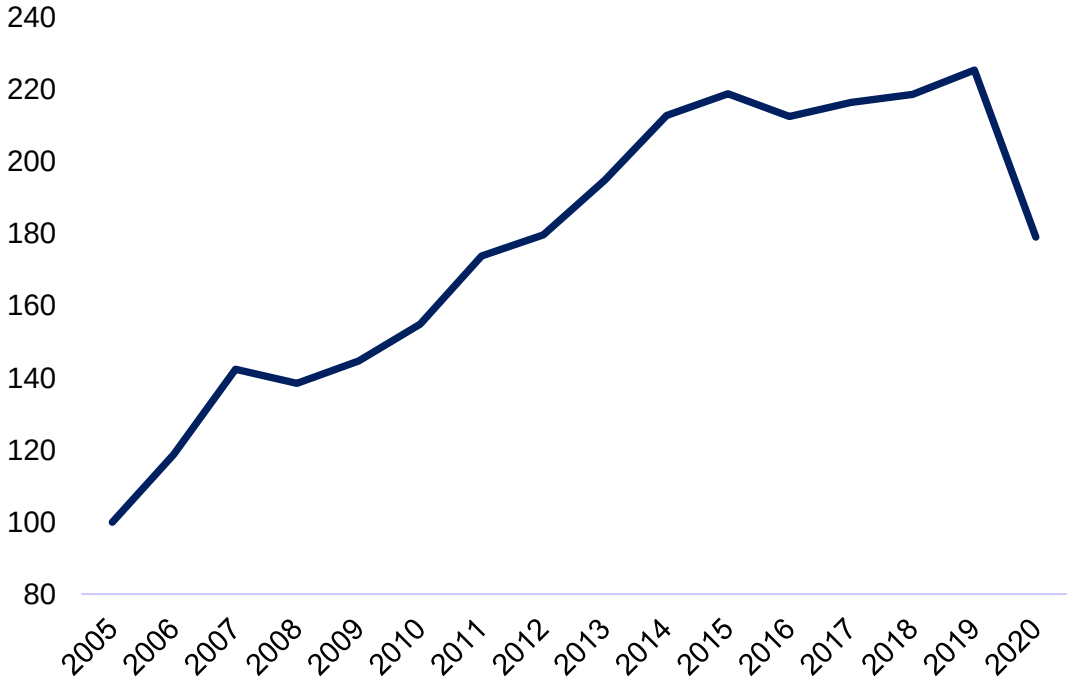


Source: Atlas of Economic Complexity

DEMAND TRENDS

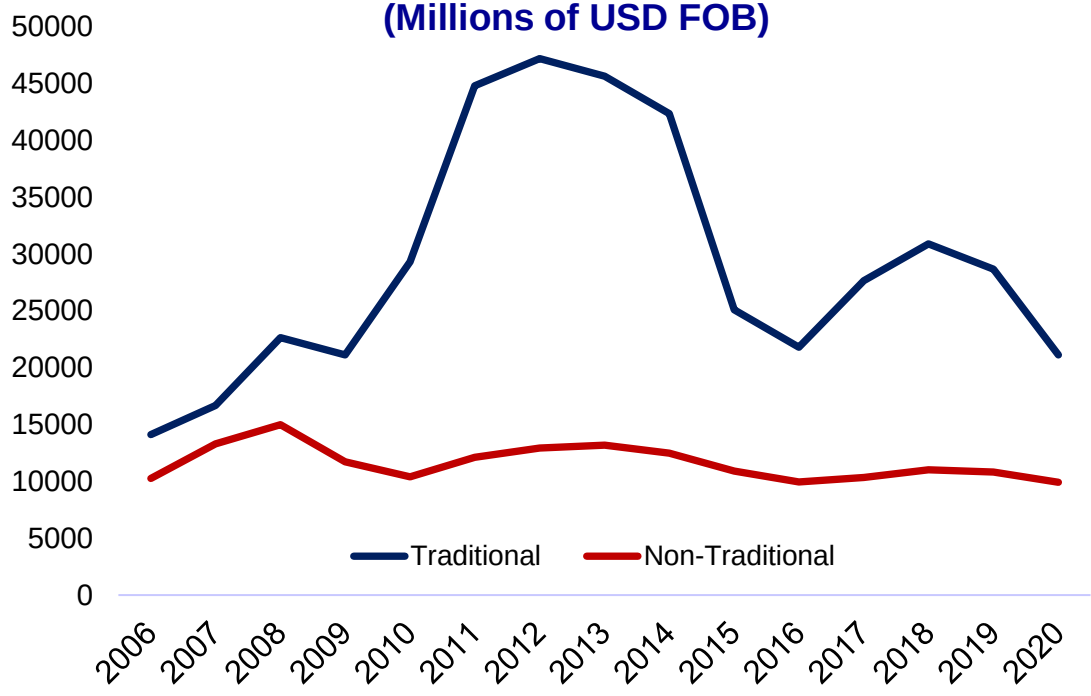
- After the **terms-of-trade shock** in 2014, **gross capital formation** has grown very little in real terms.
- Looking at **non-traditional exports**, the possibility of **premature deindustrialization** and **Dutch disease** becomes apparent (Botta et al. 2016).

Gross fixed capital formation (2005 = 100)



Source: DANE. Authors' calculations

Traditional* and non - traditional exports (Millions of USD FOB)

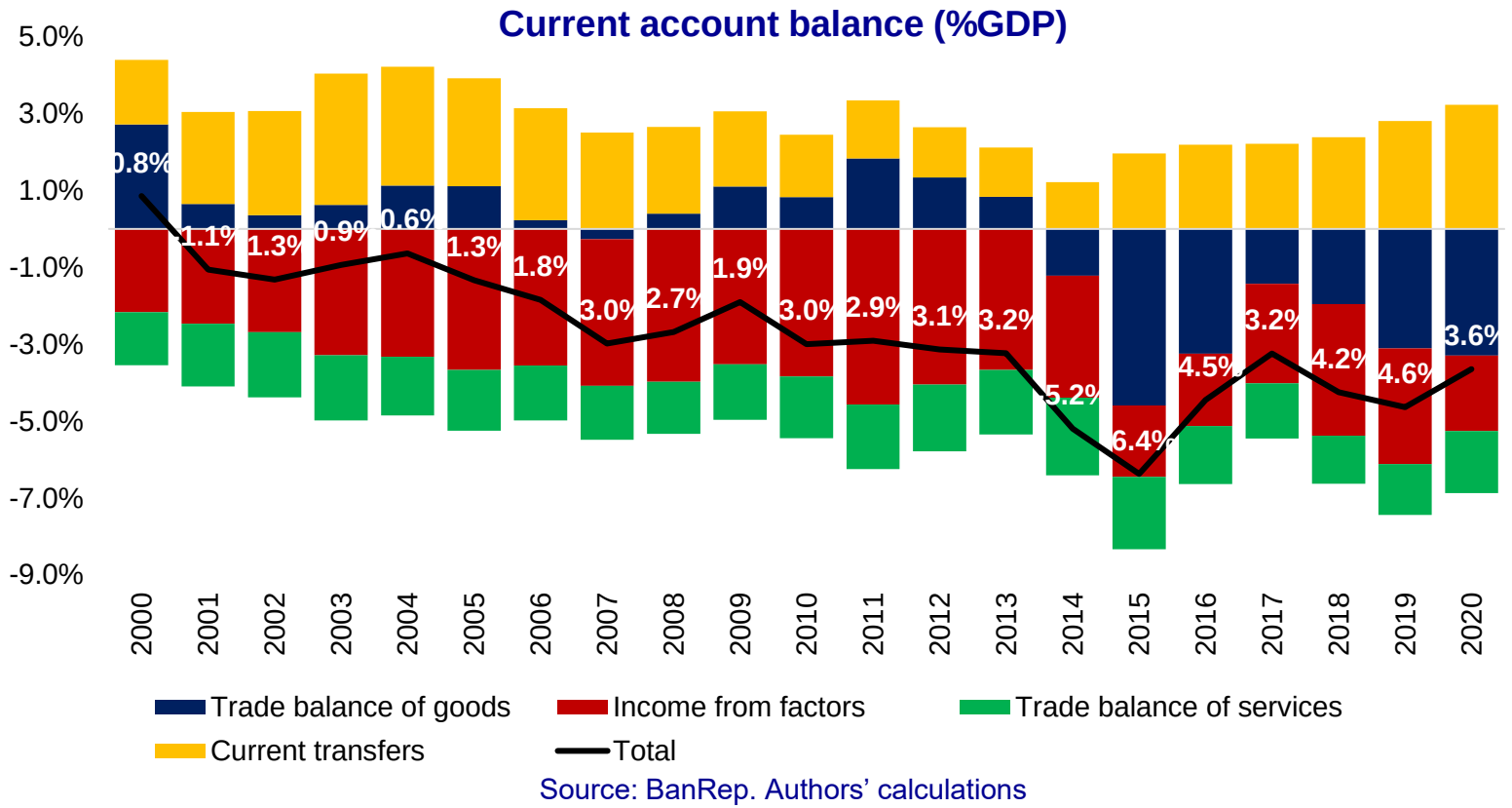


Source: DANE. Authors' calculations

* Traditional exports include coffee, bananas, gold, flowers, ferronickel, coal, oil and petroleum products,

CURRENT ACCOUNT

- Colombia's **pattern of international insertion** poses difficulties in generating, in **a sustainable manner** and through the development of exports, the **foreign currency necessary** to sustain its growth process.

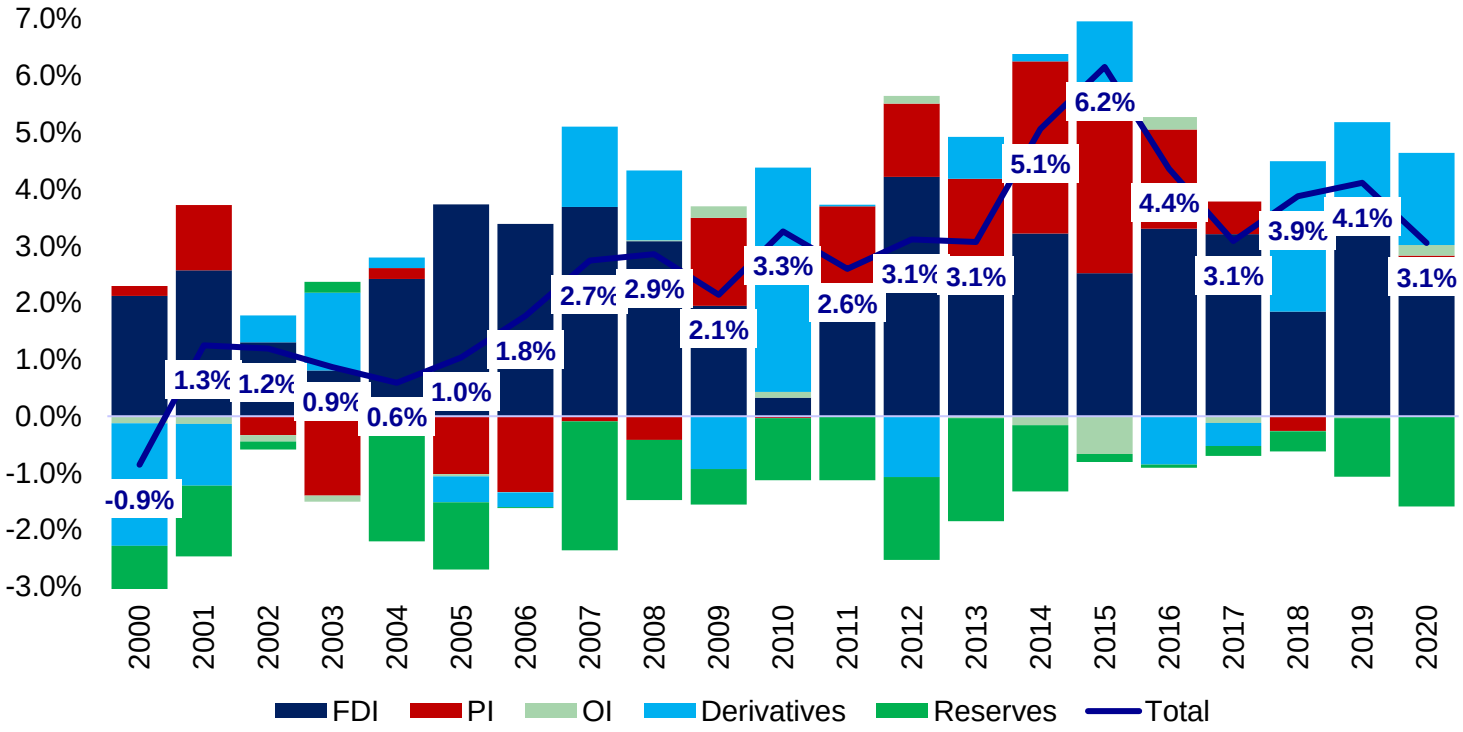


Source: BanRep. Authors' calculations

CAPITAL INFLOW RELIANCE

- As a result, Colombia shows **foreign capital inflows dependency** to finance its **external deficit**.
- This creates **additional pressures** on the current account and **exposure** to changes in **international trade and financial cycles**.

Net inflows in financial account (%GDP)



Source: BanRep. Authors' calculations

METHOD

APPROACH, MODEL, CALIBRATION AND SCENARIOS

MODEL STRUCTURE – TRANSACTION FLOW MATRIX

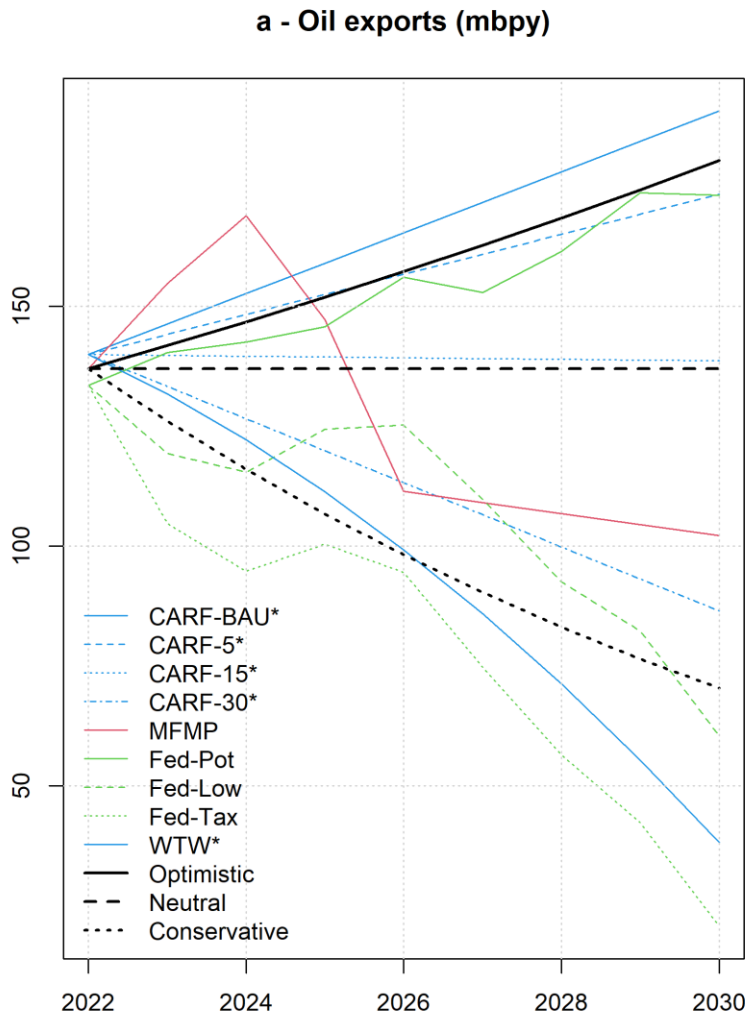
Variable	Non Financial Corporations		Households	Financial Corporations		Central Bank		Government	RoW	Σ
	Current	Capital		Current	Capital	Current	Capital			
Consumption of NFC Products	$+C$		$-C_H$					$-C_G$		0
Public Services								$+PS_G$	$-PS_G$	0
Consumption of FC Services			$-(INS_H + COM_H)$	$INS_H + COM_H$						0
Interm. Cons. of NFC Products	$+IC$			$-IC_B$				$-IC_G$		0
Interm. Cons. of FC Services	$-(INS_F + COM_F)$			$INS_F + COM_F$						0
Gross Fixed Capital Formation	$+I^K$	$-I^K_F$	$-I^K_H$		$-I^K_B$			$-I^K_G$		0
Change in inventories	$+I^V$	$-I^V$								0
Imports	$-IM$								$+IM$	0
Exports	$+EX$								$-EX$	0
Taxes on Imports	$-T^{IM}$							$+T^{IM}$		0
Value Added Tax	$-T^V$							$+T^V$		0
Other Taxes on Products	$-T^P$							$+T^P$		0
Wages	$-W_F$		$+W$	$-W_B$				$-W_G$		0
Employers Social Contributions	$-SC_F$		$+SC$	$-SC_B$				$-SC_G$		0
Mixed Income Distribution	$-MI_H$		$+MI_H$							0
G.O.S. Redistribution	$-GOS_F$		$+GOS^H_F$					$+GOS^G_F$		0
Net Other Taxes on Production	$-T^Y_F$			$-T^Y_B$				$-T^Y$		0
Int. on Deposits	$+IntD_F$		$+IntD_H$	$-IntD$				$+IntD_G$		0
Int. on Domestic Loans	$-IntL_F$		$-IntL_H$	$+IntL$						0
Int. on Domestic FX Loans	$-IntL^{FX,B}_F$			$+IntL^{FX,B}_F$						0
Int. on RoW FX Loans	$-IntL^{FX,W}_F$			$-IntL^{FX,W}_B$					$+IntL^{FX,W}$	0
Int. on Domestic public Bonds				$+IntBg_B$				$-IntBg$	$+IntBg_W$	0
Int. on FX public Bonds								$-IntBg^{FX}$	$+IntBg^{FX}$	0
Int. on FX public Loans								$-IntLg^{FX}$	$+IntLg^{FX}$	0
Int. on Advances				$-IntA$		$+IntA$				0
Int. on FX Reserves				$+IntR^{FX}_B$		$+IntR^{FX}_{CB}$			$-IntR^{FX}$	0
Firms Dividends	$-Div_F$		$+Div^H_F$					$+Div^G_F$	$+Div^W_F$	0
Banks Dividends			$+Div^H_B$	$-Div_B$					$+Div^W_B$	0
Royalties	$-Roy$							$+Roy$		0
Taxes on Income	$-T^I_F$		$-T^I_H$	$-T^I_B$				$-T^I$		0
Workers Social Contributions			$-WSC$	$+WSC_B$				$+WSC_G$		0
Social Transfers			$+ST$	$-ST_B$				$-ST_G$		0
Remittances			$+Rem$						$-Rem$	0
Central Bank Profits						$-F_{CB}$		$+F_{CB}$		0
Other Transfers	$-O_F$		$+O_H$	$-O_B$				$-O_G$	$-O_W$	0
Retained Earnings	$-RE_F$	$+RE_F$		$-RE_B$	$+RE_B$					0
[Capital]		$[K_F]$	$[K_H]$		$[K_B]$			$[K_G]$		$[K]$
[Inventories]		$[V]$								$[V]$
Foreign Direct Investment		$+FDI_F$			$+FDI_B$				$-FDI$	0
Cash and Deposits		$-D_F$	$-D_H$		$+D$			$-D_G$		0
Government Deposits at the CB							$+D_{CB}$	$-D_{CB}$		0
FX Deposits		$-D^{FX}$			$-D^{FX}$			$-D^{FX}$	$+D^{FX}$	0

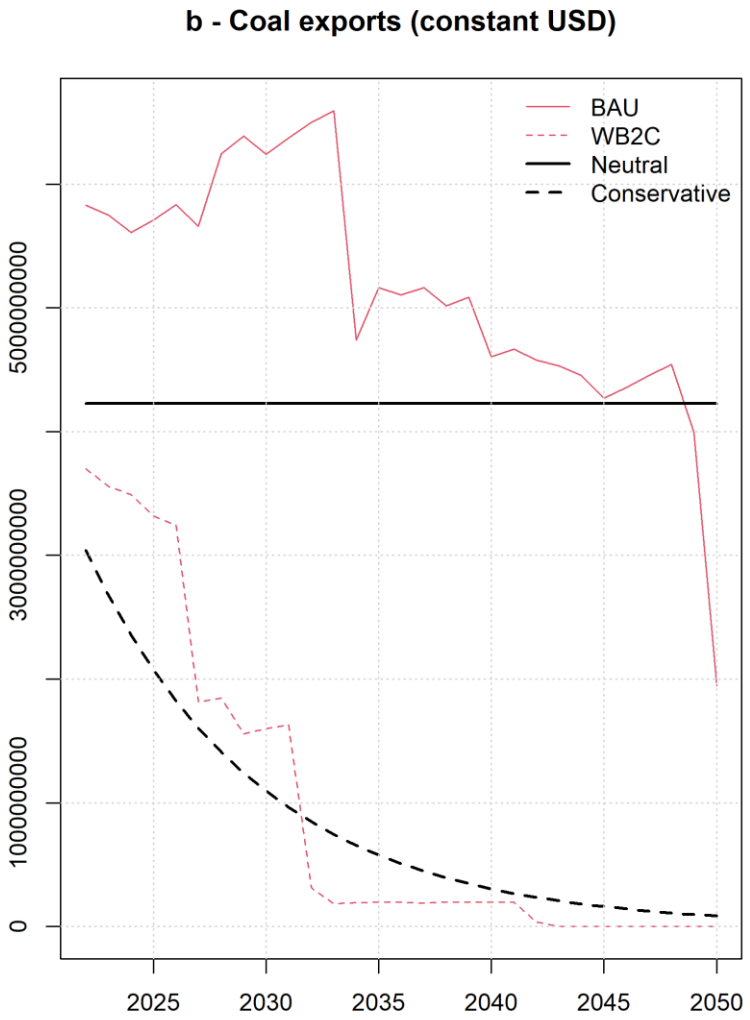
MODEL STRUCTURE – BALANCE SHEET

Variable	NFC	Households	FC	CB	Government	RoW	$+\sum$
Capital stock	$+K_F$	$+K_H$	$+K_B$		$+K_G$		K
Inventories	$+V_F$						V
[Non-Financial Assets]	$+NFA_F$	$+NFA_H$	$+NFA_B$	$+NFA_{CB}$	$+NFA_G$	$+NFA_W$	NFA
Foreign Direct Investment	$-FDI_F$		$-FDI_B$			$+FDI$	0
Cash and Deposits	$+D_F$	$+D_H$	$-D$		$+D_G$		0
Government Deposits at the CB				$-D_{CB}$	$+D_{CB}$		0
FX Deposits	$+D_F^{FX}$		$+D_B^{FX}$		$+D_G^{FX}$	$-D^{FX}$	0
Domestic Currency Loans	$-L_F$	$-L_H$	$+L$				0
Domestic FX Loans	$-L_F^{FX,B}$		$+L_F^{FX,B}$				0
RoW FX Loans	$-L_F^{FX,W}$		$-L_B^{FX,W}$			$+L^{FX,W}$	0
Domestic Government Bonds			$+Bg_B$		$-Bg$	$+Bg_W$	0
FX Government Bonds					$-Bg^{FX}$	$+Bg^{FX}$	0
FX Government Loans					$-Lg^{FX}$	$+Lg^{FX}$	0
Technical Insurance Reserves		$+TIR_H$	$-TIR_H$				0
Domestic Currency Reserves			$+Rd$	$-Rd$			0
FX Reserves			$+R_B^{FX}$	$+R_{CB}^{FX}$		$-R^{FX}$	0
Advances			$-A$	$+A$			0
[Financial Assets]	$+FA_F$	$+FA_H$	$+FA_B$	$+FA_{CB}$	$+FA_G$	$+FA_W$	0

SCENARIO BUILDING

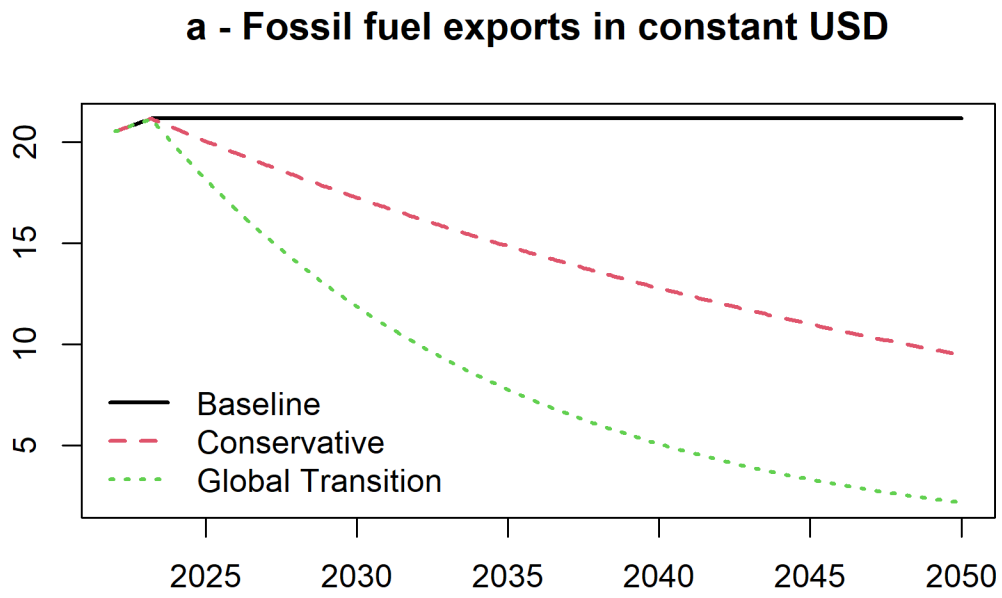
- Oil and coal exports at a glance

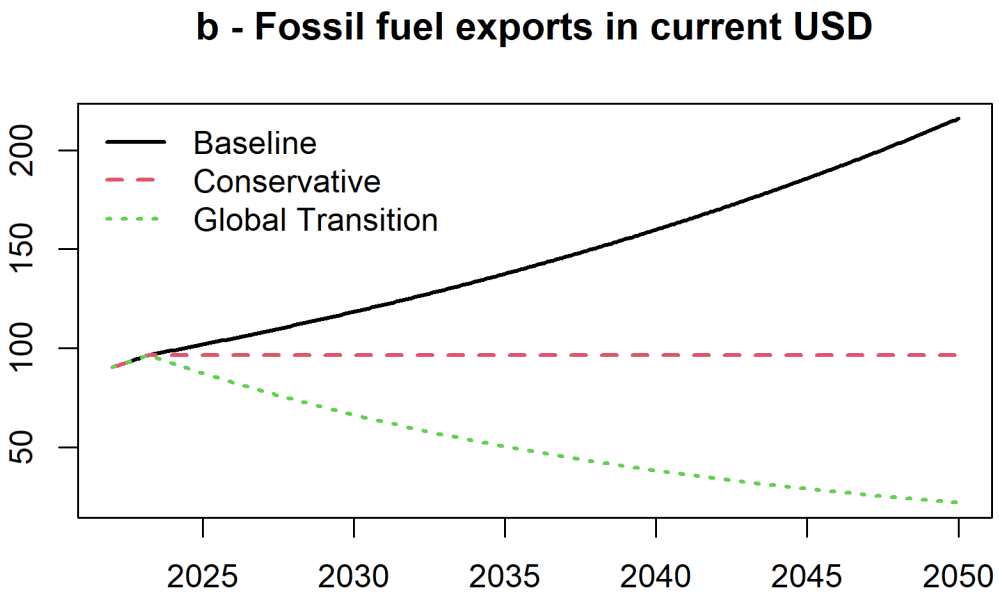




SCENARIO BUILDING

- Resulting scenarios for fossil fuels





Source: BanRep. Authors' calculations

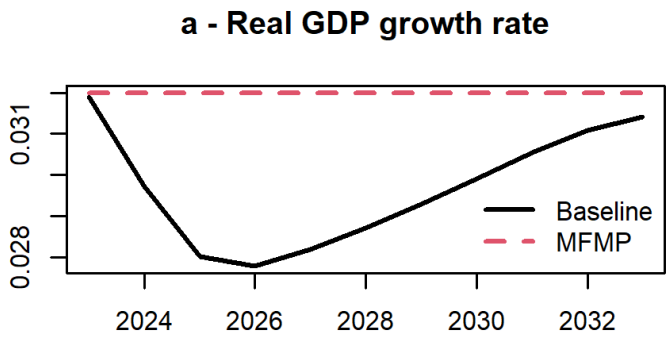
SCENARIO BUILDING

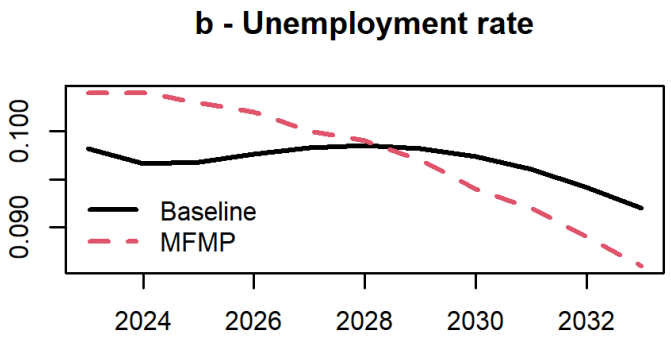
We assume

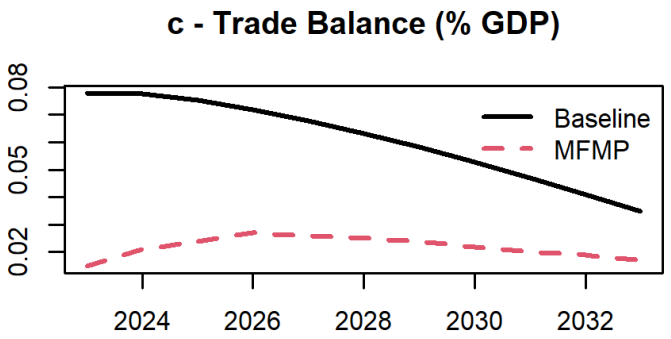
- Population to grow at a constant rate of 1%,
- Domestic and world productivity to grow at a constant rate of 2% (hence assuming away any catching-up),
- World GDP in real terms to grow at constant rate of 3%
- World inflation is set at 3%.
- FDI inflows as a share of NFCs investment slow down from their peak value in 2019, falling from 38% of investment (i.e. 4.5% of GDP) to 26% (3% of GDP) by 2050
- A reversal in observed trends of propensity to export non-fossil fuel goods and services and revert it to its average over the last fifteen years.

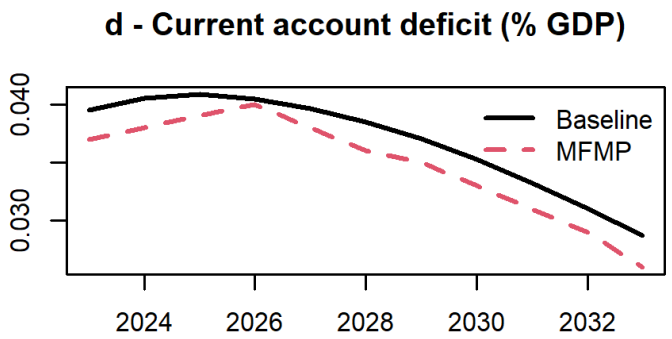
COMPARISON WITH MHCP (2022)

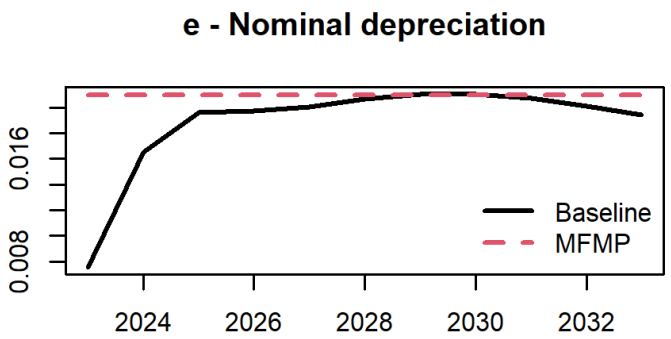
- Similar levels and trends, slightly more conservative on our baseline.

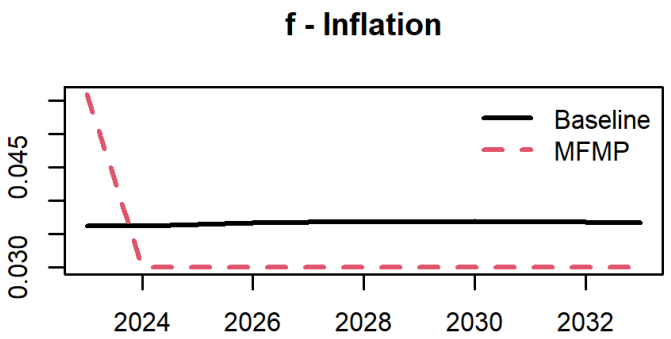






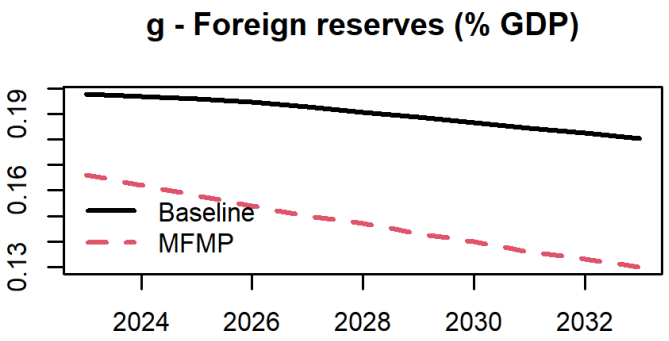


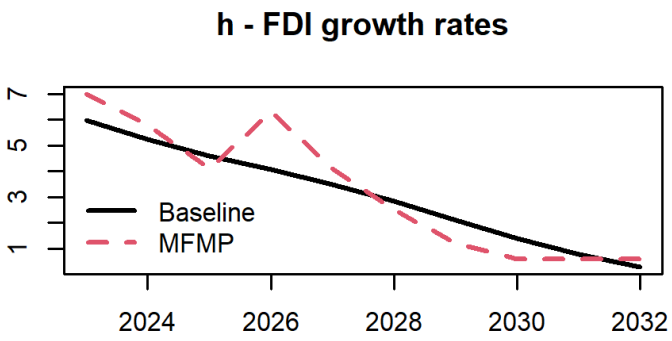


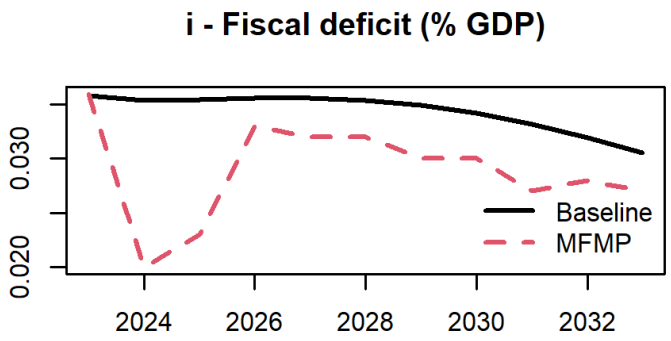


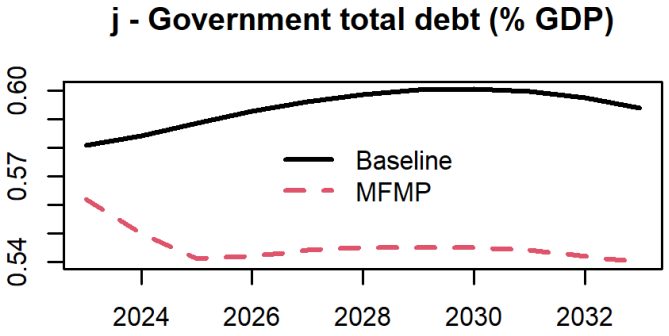
COMPARISON WITH MHCP (2022)

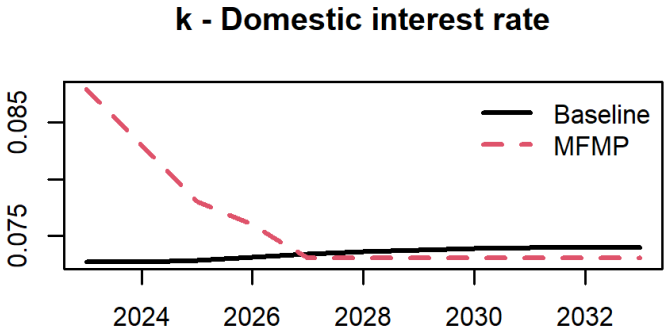
- Similar levels and trends, slightly more conservative on our baseline.

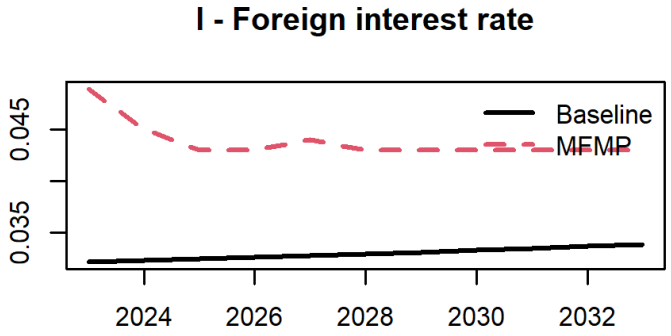






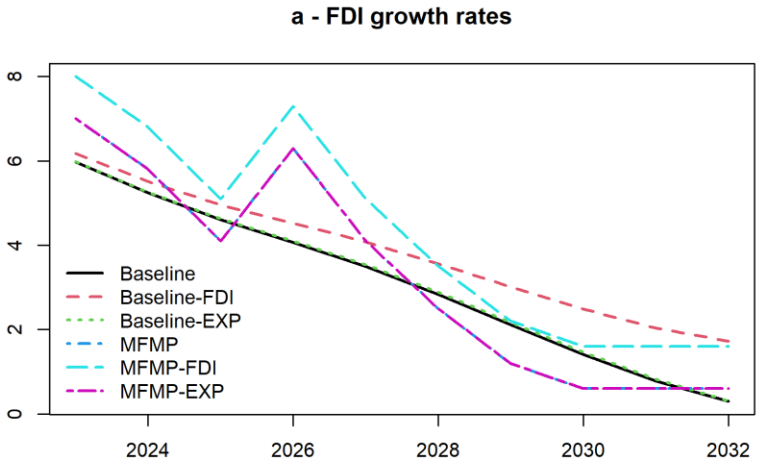


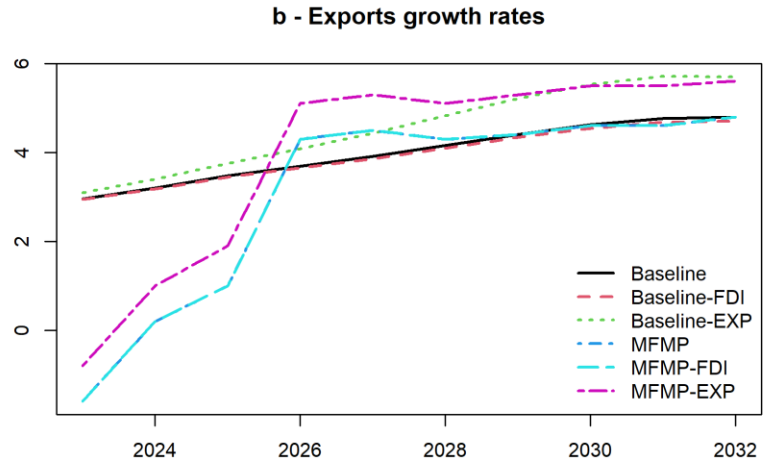


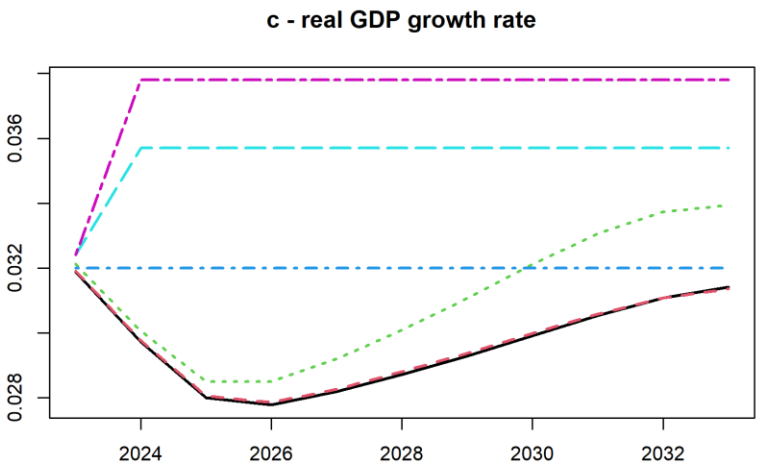


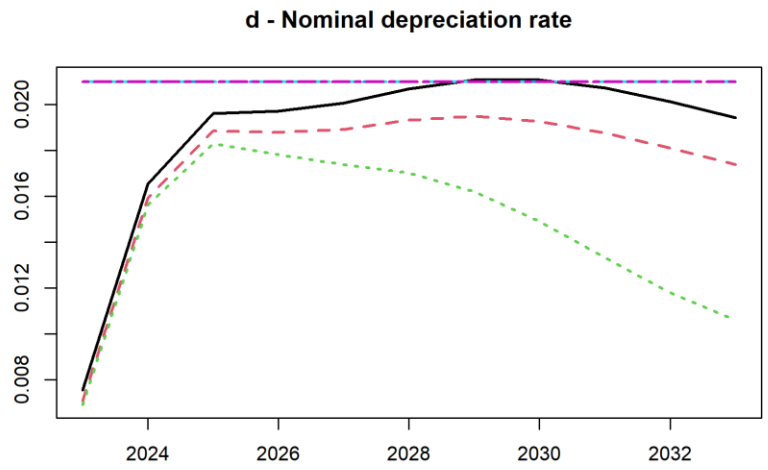
COMPARISON WITH MHCP (2022)

- Testing two external scenarios shows difference in response from our model









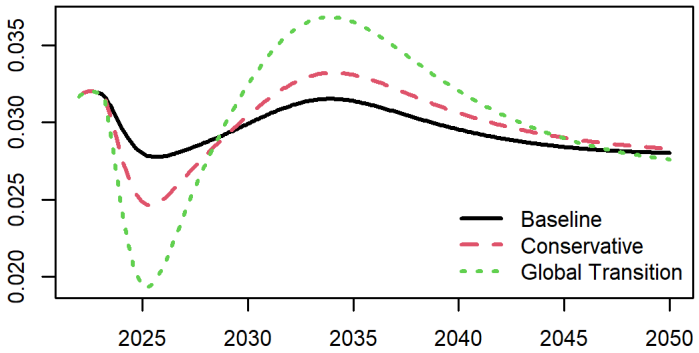
RESULTS

TRANSITION AND POLICY RESPONSE

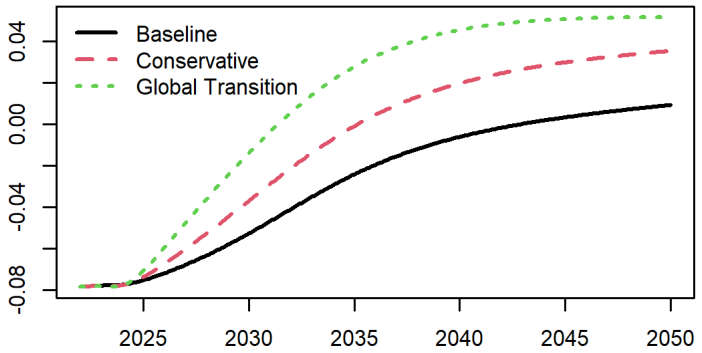
https://www.afd.fr/en/ressources/modelling-low-carbon-transitions-colombia-macrofinancial-opportunities-and-risks

GLOBAL TRANSITION DYNAMICS

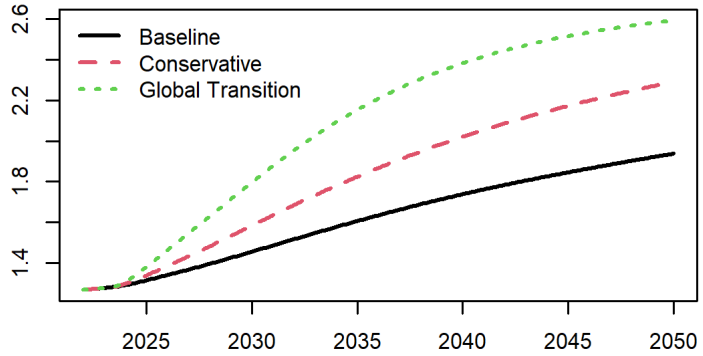
a - Real GDP growth rate



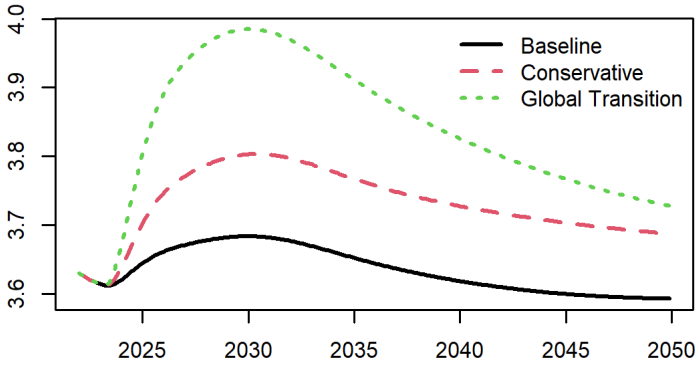
b - Trade balance % of real GDP



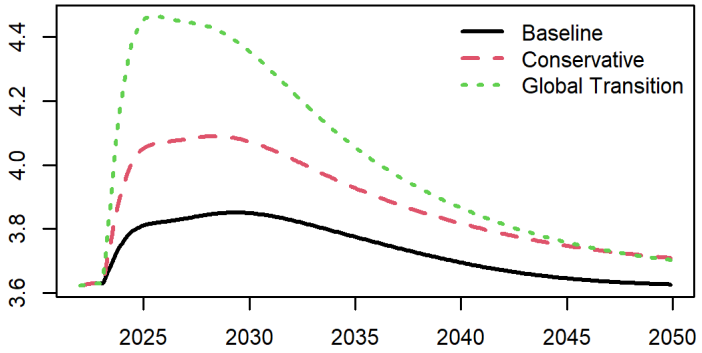
c - Nominal Exchange rate



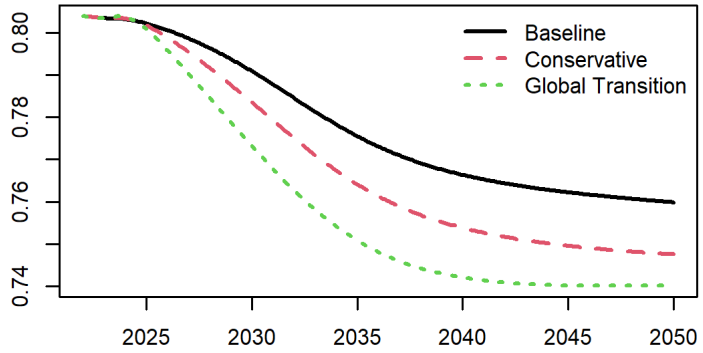
d - Producer inflation rate (%)



e - Consumer inflation rate (%)

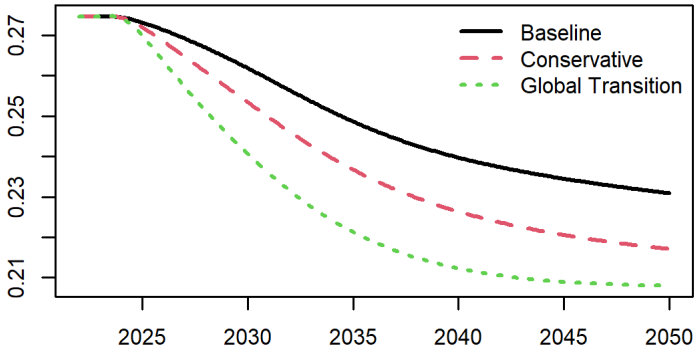


f - Consumption as a share of real GDP

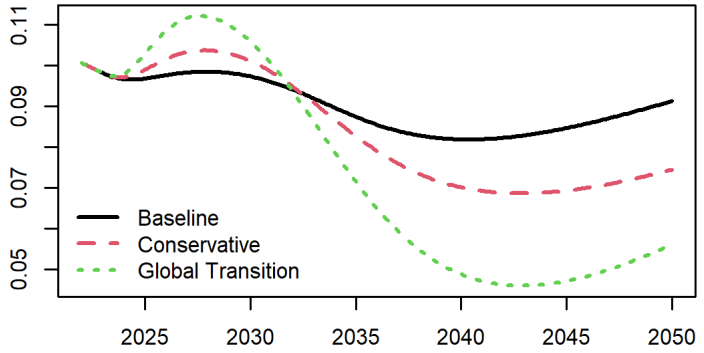


GLOBAL TRANSITION DYNAMICS

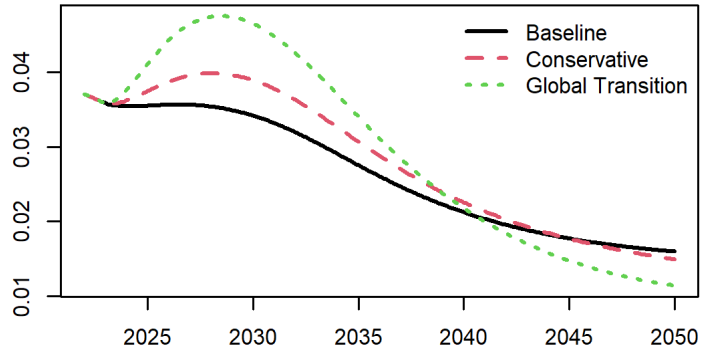
g - Investment as a share of real GDP



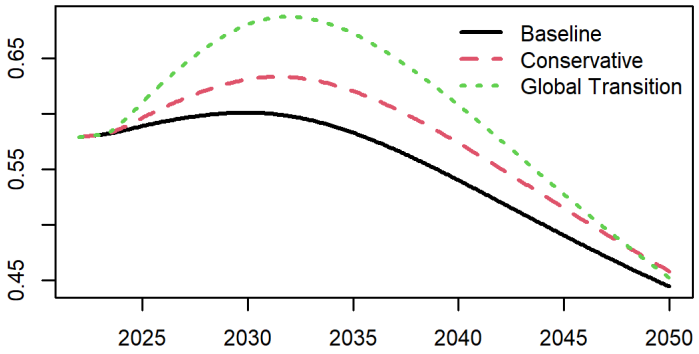
h - Unemployment rate(%)



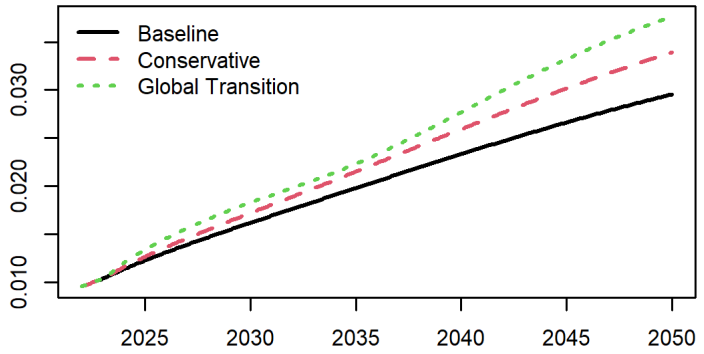
i - Fiscal deficit (%GDP)



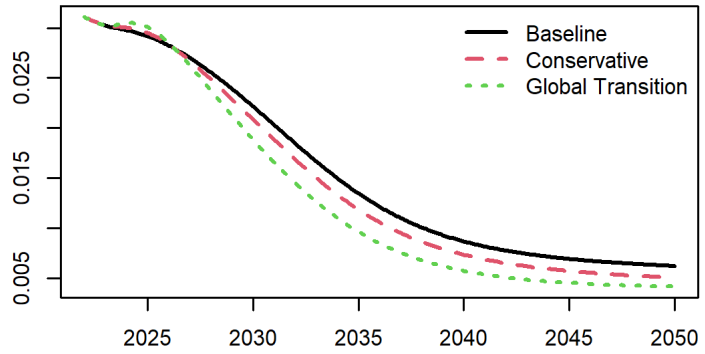
j - Government total debt (%GDP)



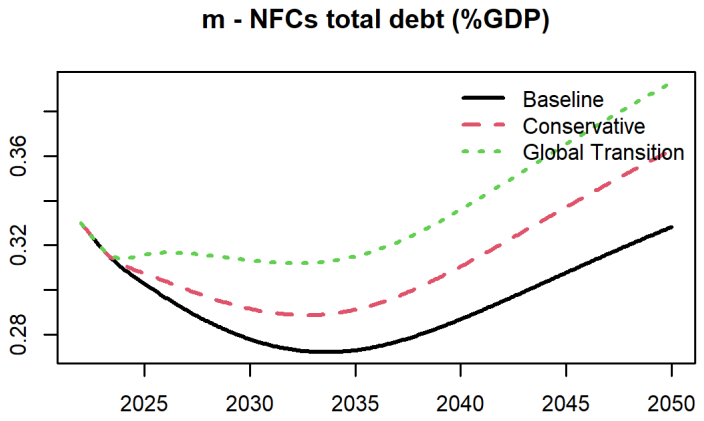
k - Current Account (%GDP)

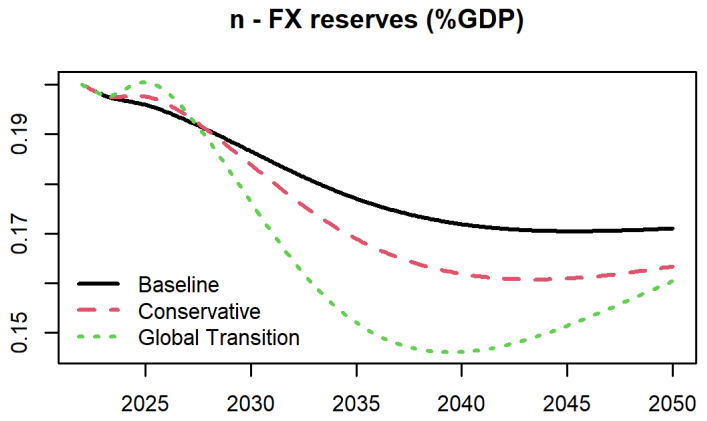


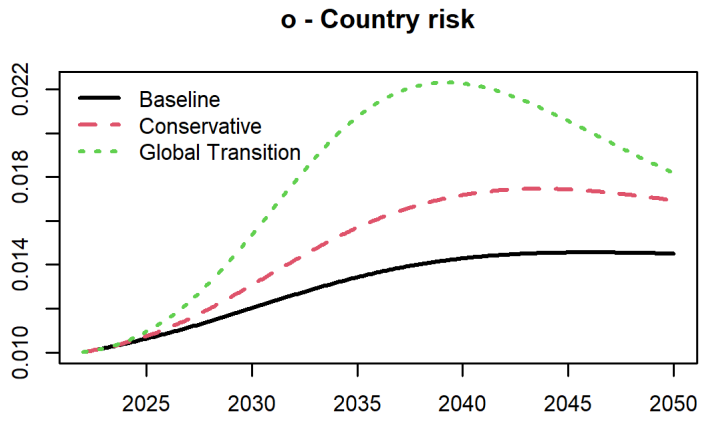
l - Financial Account (%GDP)

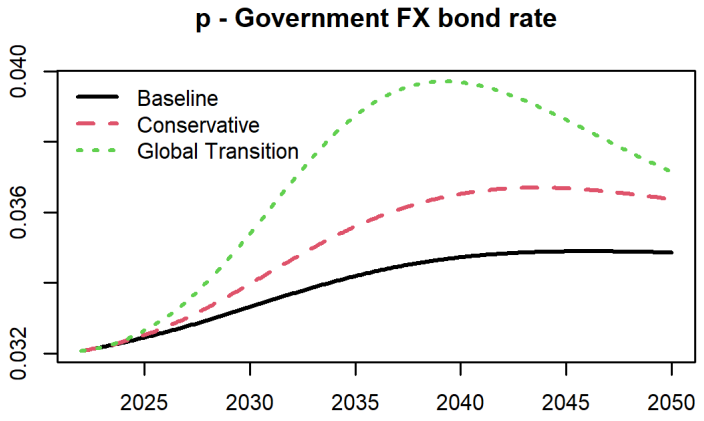


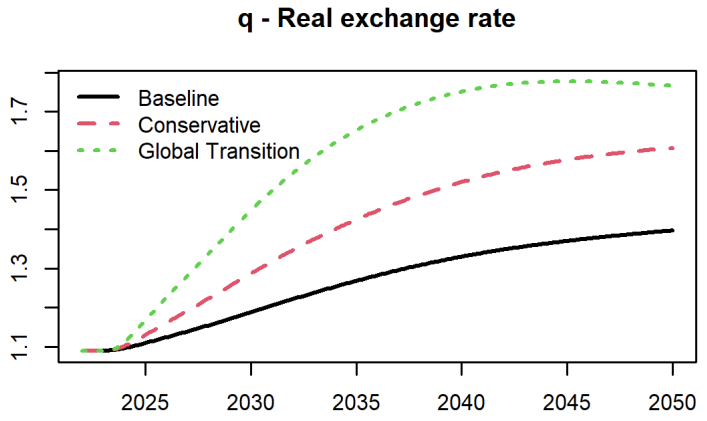
GLOBAL TRANSITION DYNAMICS

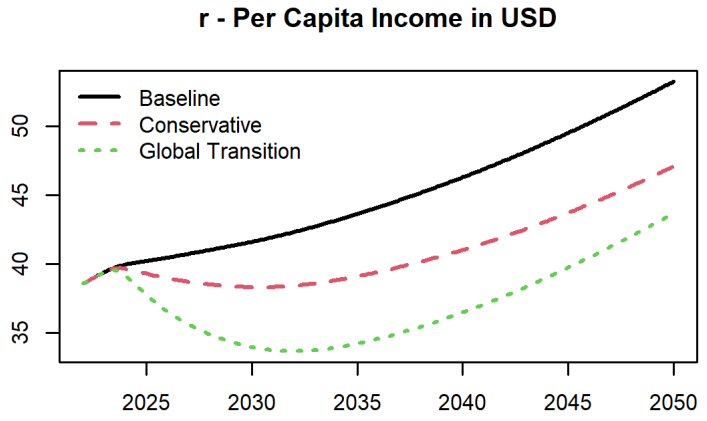








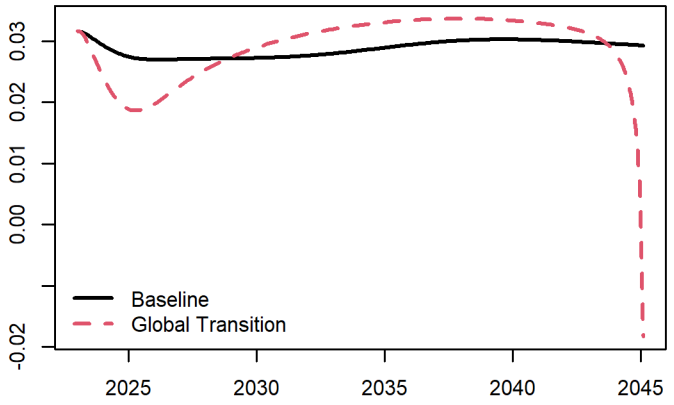




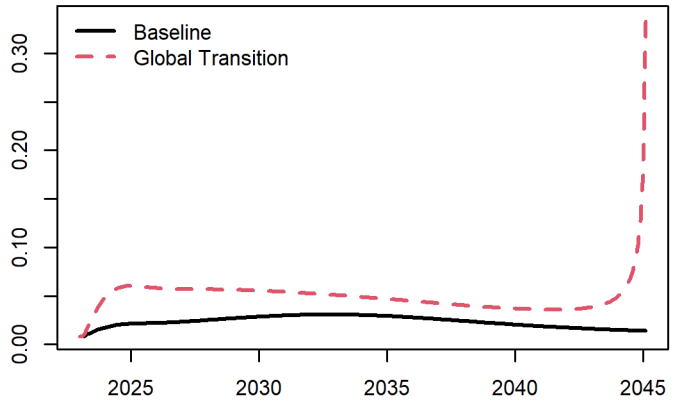
THE POSSIBILITY OF A CURRENCY CRISIS

- If exports keep on losing market share, as observed over the last decade, currency crisis could emerge.

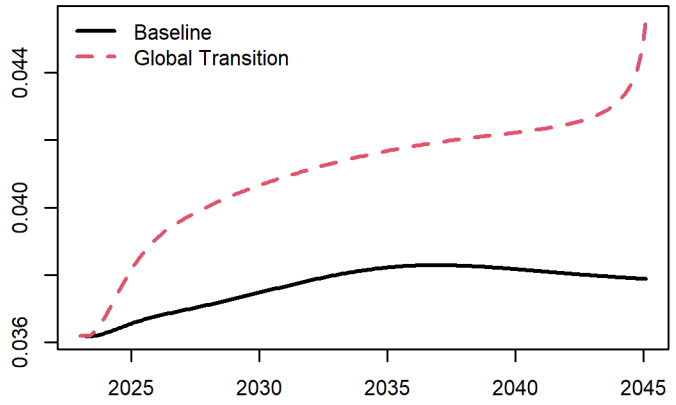
a - real GDP growth rate



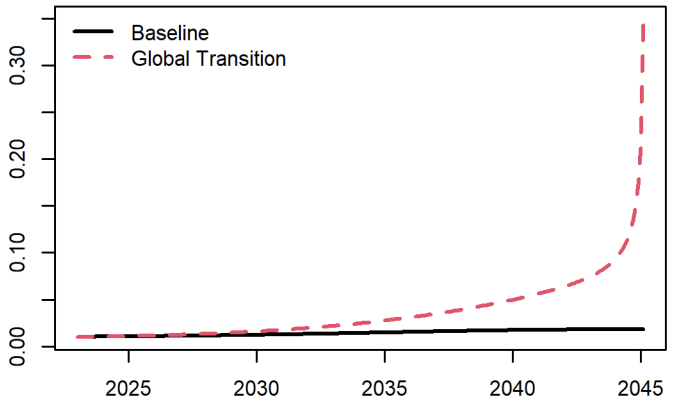
b - Nominal depreciation



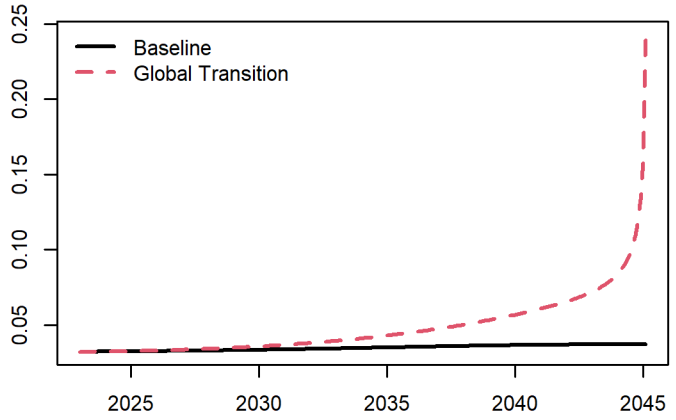
c - Inflation



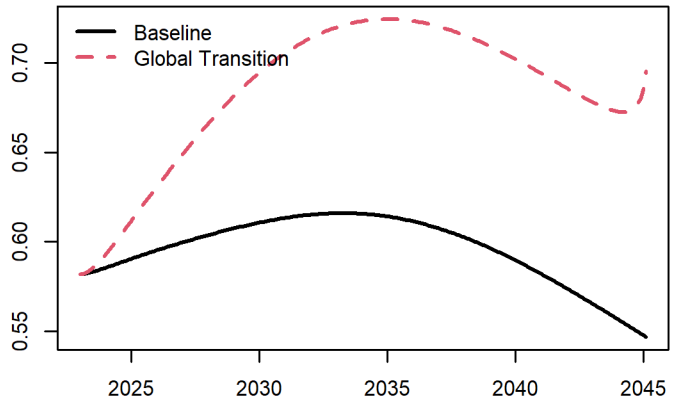
d - Country risk



e - Foreign interest rate



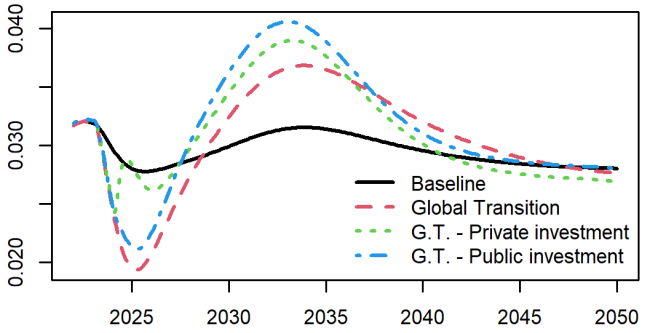
f - Government total debt (% GDP)



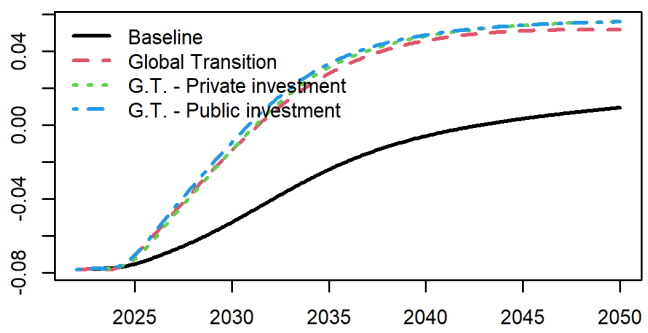
POLICY RESPONSES – EXPORTS DIVERSIFICATION

- Assuming export diversification via public or private investment

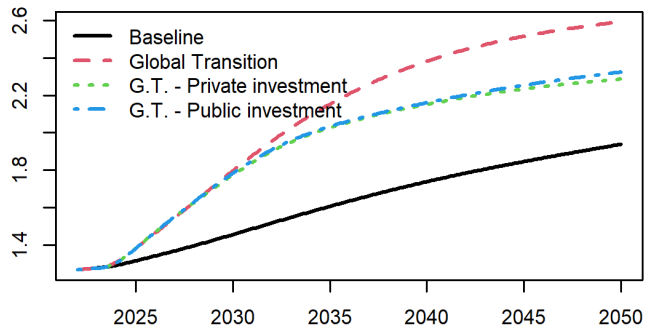
a - Real GDP growth rate



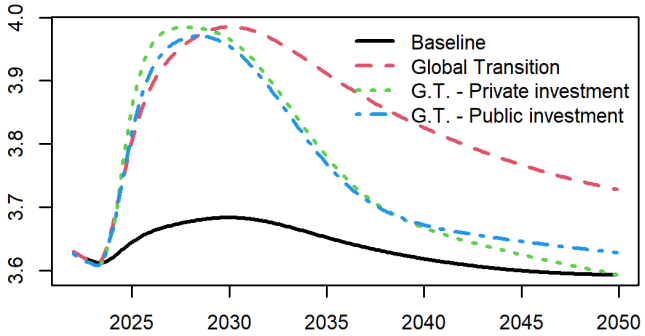
b - Trade balance % of real GDP



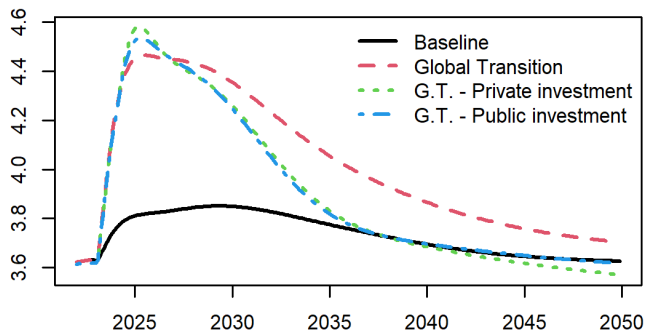
c - Nominal Exchange rate



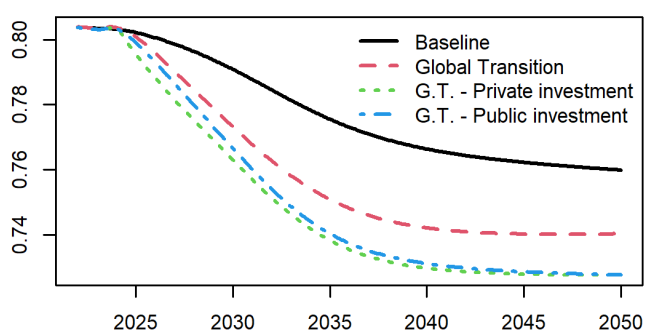
d - Producer inflation rate (%)



e - Consumer inflation rate (%)



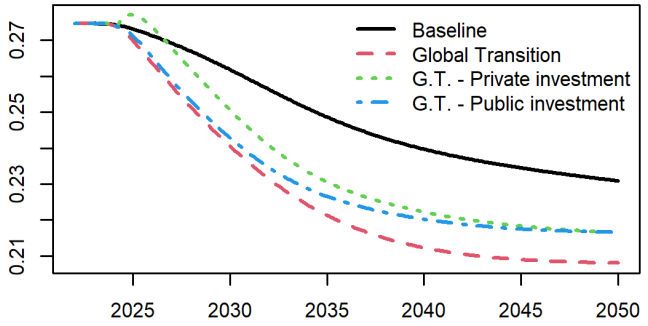
f - Consumption as a share of real GDP



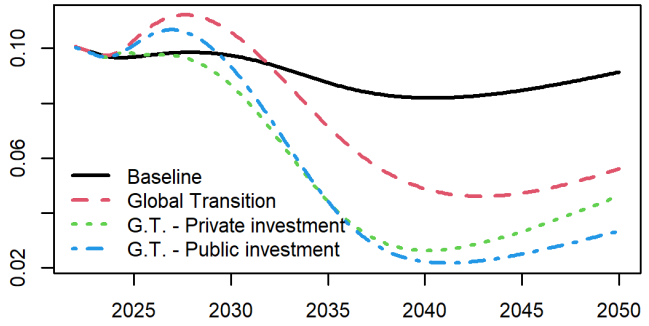
POLICY RESPONSES – EXPORTS DIVERSIFICATION

- Assuming export diversification via public or private investment

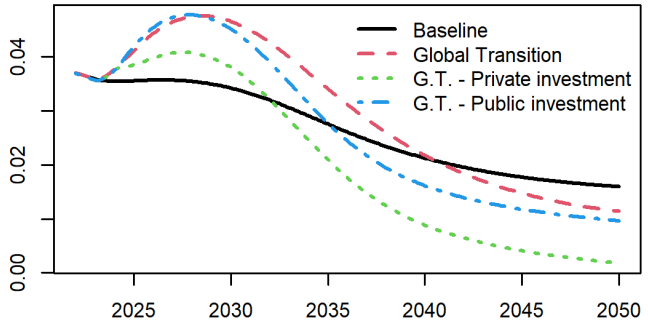
g - Investment as a share of real GDP



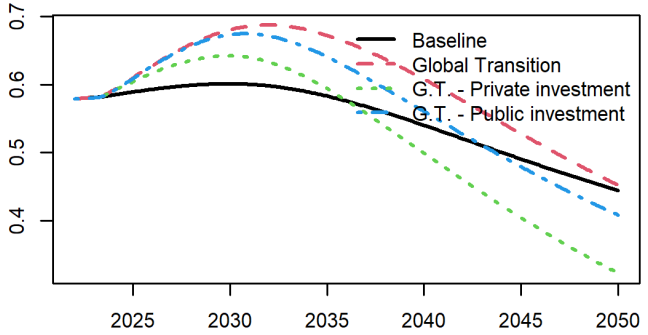
h - Unemployment rate(%)



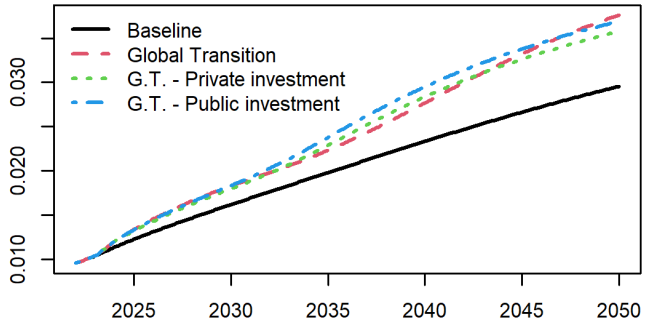
i - Fiscal deficit (%GDP)



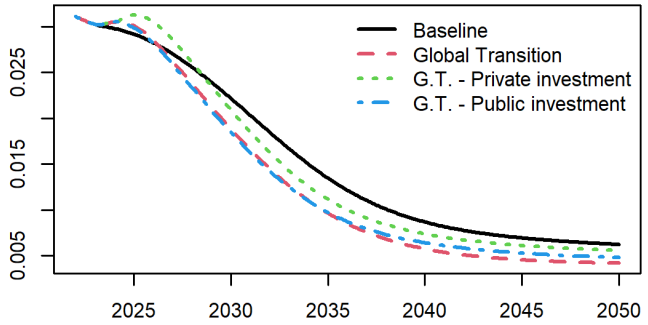
j - Government total debt (%GDP)



k - Current Account (%GDP)

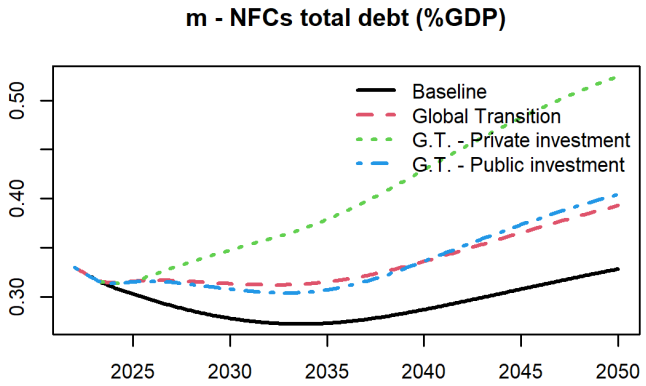


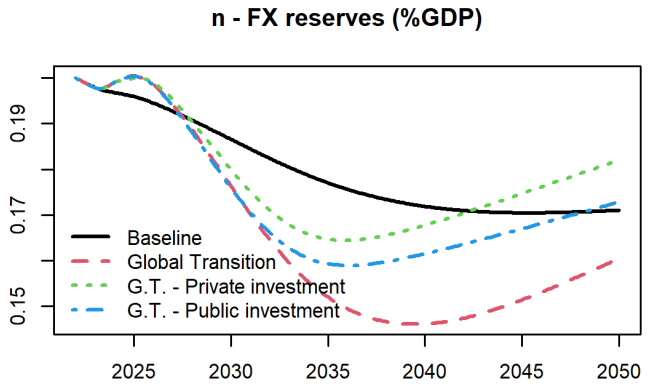
l - Financial Account (%GDP)

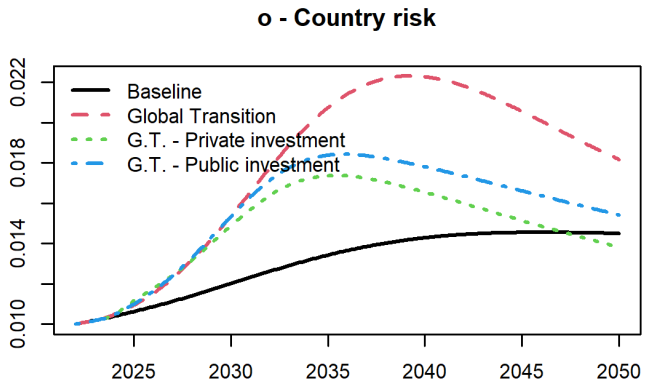


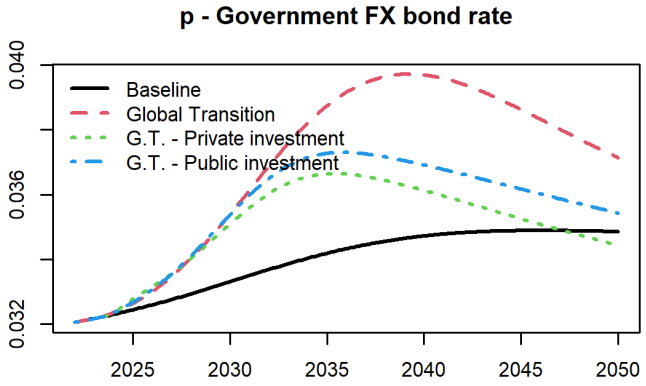
POLICY RESPONSES – EXPORTS DIVERSIFICATION

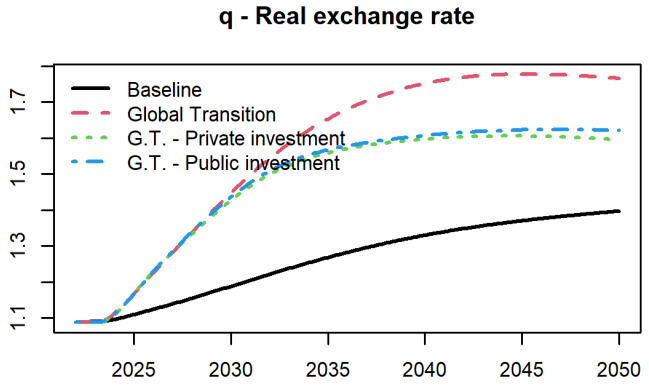
- Assuming export diversification via public or private investment

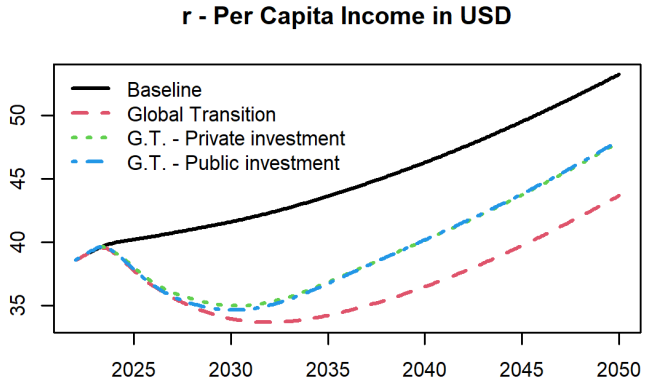












Insight 1: Can Colombia cope with a global low-carbon transition?

Exercise

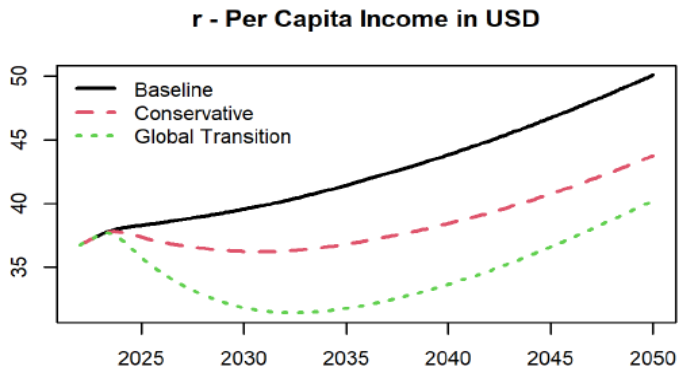
- We built scenarios regarding fossil fuel exports and alternative policies to cope with their effects for the period 2023-2050

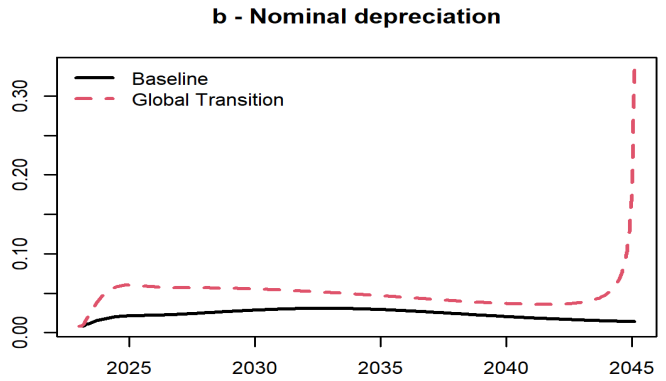
Main results

- A global low-carbon transition will lead to lower economic growth and higher unemployment in the medium term, budget and current account deficits, public indebtedness, currency depreciation, inflation and country risk
- Macroeconomic and financial fragility may lead to a currency crisis

Policy messages

- Policies of re-industrialisation, export diversification and GVC integration can mitigate but not eliminate these impacts
- Since the results of these policies take time to materialize, they must be implemented with priority





Insight 2: The road to financing and implementing Colombia's NDC

Exercise

- We built different scenarios regarding public investment in climate change mitigation and adaptation to meet Colombia's NDC by 2050

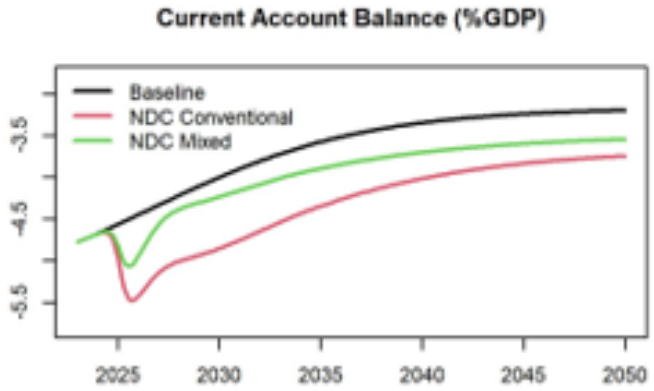
Main results

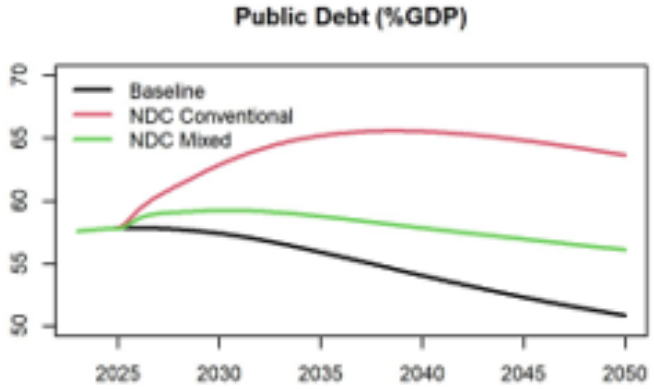
- Public green investment has co-benefits in terms of economic growth and employment, but it will generate additional pressures on public finances and the current account
- Financing the green investment with conventional debt instruments at market rates will lead to a public debt 14pps higher than the baseline by 2050 (i.e., scenario with no investment in NDC)

Policy messages

- A mixed financing strategy reduces fiscal and external sector pressures and facilitates the transition. One example:

40% Green Taxes + 40% Green Bonds + 20% Grants + 15% Greenium





GEMMES AND CLIMRISK

FSMAT (FINANCIAL SECTOR MITIGATION AND ADAPTATION TOOL)

- Joint project with AFD and World Bank
- Based on GEMMES
- Utilizes international databases to be able to calibrate/estimate GEMMES
- First for 6 pilot countries, then for over 100 countries
- Inputs -> Mitigation/adaptation policy, combination of green financial instruments (bonds, loans, etc.)
- Output ->Macrofinancial performance and emission reduction/damage adaptation

THANK YOU!

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