Long-Term Growth Model (LTGM)

MTI Forum Learning Module

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www.worldbank.org/LTGM (internet)

http://LTGM (intranet FURL)

2019 MTI FORUM
Building Bridges, Creating Connections

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Model Overview

- Countries want to grow at high rates
  - What growth rates are feasible? What would it take to achieve these goals?

- A simple model to analyze long-term growth
  - Based on celebrated Solow-Swan Model: savings and investment key
  - Also TFP, human capital, demographics, labor participation, FDI & external debt
  - Implications of growth for poverty

- Toolkit for use by country economists/policymakers in many countries
  - Spreadsheet-based for simplicity.
  - No macros; transparent, flexible & easy-to-learn

- Many extensions: public investment, WB HCI, TFP, Natural Resources….

Objectives of the Main LTGM

- Help policy makers in finding answers to 3 important policy questions:
  - Submodel 1: How much growth from a given investment profile?
  - Submodel 2: How much investment is needed to achieve given growth profile?
  - Submodel 3: How much growth from a given savings profile?
    - Requires assumptions on debt or current account balance
- Allow policy makers ample flexibility
  - Scenario analysis using many other variables: Productivity, Human Capital, Demographics, External sector
  - Growth → Poverty
- For long-run scenario analysis -- not short-run analysis or forecasting

Some examples of work using the LTGM

Used in 40+ countries for growth analysis and country reports (CEMs and SCDs):

- **Sub-Saharan Africa:** Cameroon (CEM), Cape Verde (SCD), Eswatini, Gabon, Guinea (SCD), Seychelles (SCD), Ghana (SCD), Malawi, South Africa, Ivory Coast, Mauritania Zambia (SCD), Zimbabwe
- **South Asia:** Bangladesh, Nepal (CEM), Sri Lanka (CEM)
- **Latin America & Caribbean :** Brazil, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Peru
- **East Asia & Pacific:** Cambodia, Korea, Laos, Malaysia, Philippines, Vietnam, Thailand
- **Europe and Central Asia:** Armenia (SCD), Bosnia, Georgia (SCD), Kyrgyz Republic (SCD), Tajikistan (CEM)
- **MENA:** Egypt (CEM), Syria
- **Eg Cameroon CEM 2016** – goal to boost growth to 8% become an UMI country by 2035.
  - Planned ↑Investment insufficient higher TFP growth → ↑competition to boost TFP
- **Honduras, Panama, Peru, Zambia, Bangladesh, Malaysia, Cambodia** – LTGM Training for govt officials

Outline of the Rest of the Talk

Part A: Main LTGM

1. Explanation of how the growth model works
   - Equations, parameters, assumptions and drivers of growth

2. Hands-on demonstration and tutorial
   - Examples: investment path -> growth, growth+inequality-> poverty, growth target -> required investment, savings+ CAB -> growth

Part B: Public Capital Extension (and other extensions)

- List of extensions
- Overview of LTGM-Public Capital extension
- Hands-on demonstration using LTGM-PC

Comments/Questions/Suggestions

A1. The Growth Model

Three Building Blocks of the Model

1. Production Function

$$Y_t(GDP) = A_t K_t^{1-\beta} (h_t L_t)^{\beta}$$

2. Capital Accumulation

$$K_{t+1} = (1-\delta)K_t + I_t$$

3. Demographics and Labor Market:

$$\boldsymbol{y_t^{PC}}(GDP\ per\ capita) = \frac{Y_t}{N_t} = \frac{Y_t}{L_t}\frac{L_t}{W_t}\frac{W_t}{N_t} = A_t k_t^{1-\beta} h_t^{\beta} \rho_t \omega_t$$

(W_t: working−age pop; N_t: total population; ρ_t: participation rate; ω_t: working-age-pop. to pop. ratio A_t: TFP; K_t: capital; h_t: human capital per worker; L_t: workers)

Growth Drivers

$$\boldsymbol{g_{y,t+1}} \approx g_{A,t+1} + \beta(g_{h,t+1} + g_{\omega,t+1} + g_{N,t+1} + g_{\rho,t+1}) + \left[\frac{1-\beta}{K_t/Y_t}\right]\frac{I_t}{Y_t} - (1-\beta)\delta$$

[GDP Growth] [TFP] [Human Cap] [Demographics] [Participation] MPK=1/mICOR [Investment]

- Common policy message: investment-led growth [by itself] is not sustainable in long run
  - ↑ K/Y reduces the effectiveness of investment over time (↓MPK)
  - Leads to an increase in the $\mathrm{m}ICOR_t = \frac{1}{1-\beta}\frac{K_t}{Y_t}$ (ppt increase I/Y needed for extra 1% growth)
  - Needs to be accompanied by other sources (e.g., human capital, TFP, participation)

External Sector (how to fund investment?)

1. Current Account Balance (CAB): $I_t/Y_t = S_t/Y_t - CAB_t/Y_t$

2. External Debt (we assume $\Delta NFA_t \approx 0$)

$$CAB_t = \Delta NFA_t - \Delta NFL_t = -\left(FDI_t + (D_t - D_{t-1})\right)$$

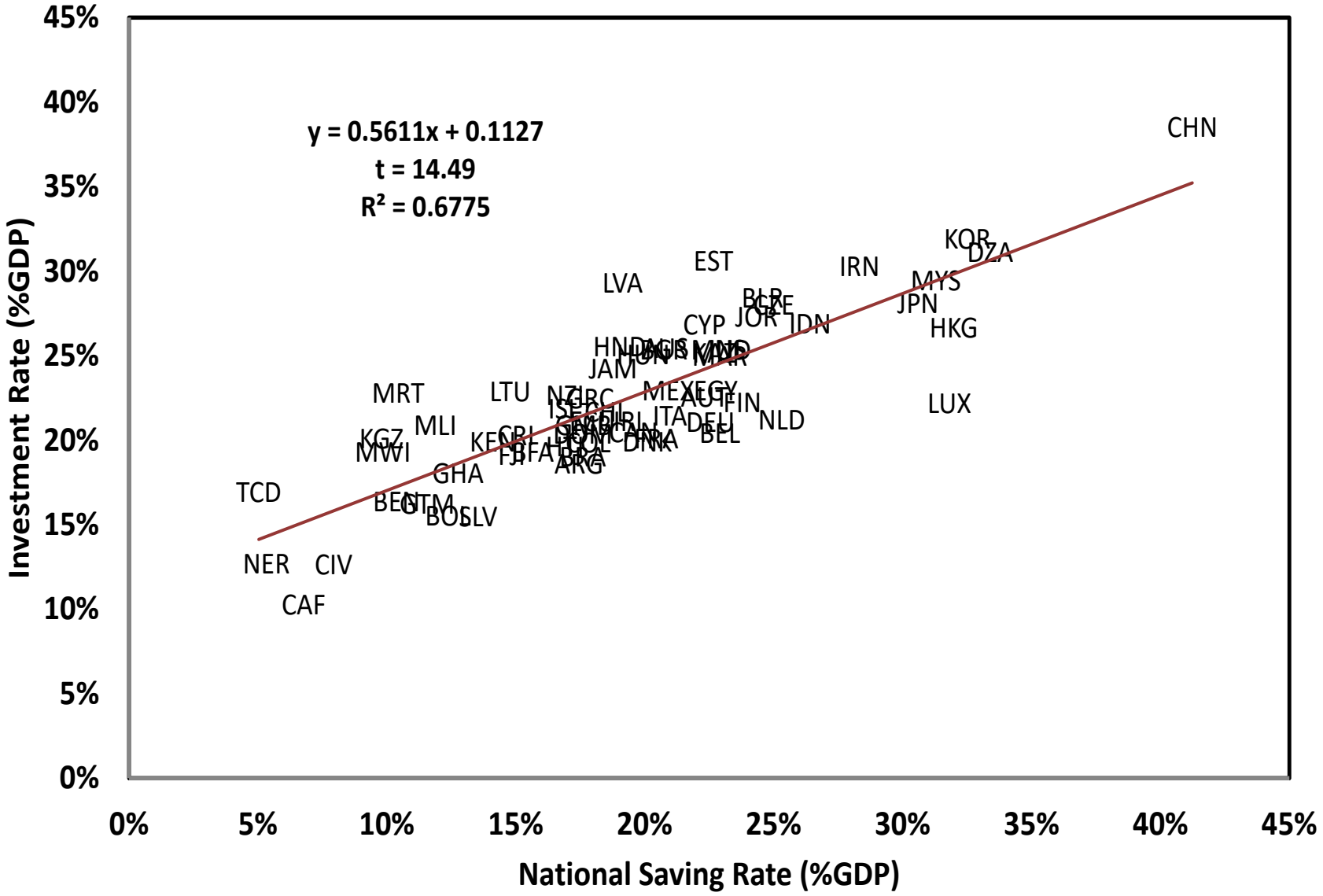
Change Net Foreign Liabilities; Foreign Direct Inv.; Change Total External Debt

$$\Rightarrow \frac{I_t}{Y_t} = \frac{S_t}{Y_t} + \frac{FDI_t}{Y_t} + \frac{D_t}{Y_t} - \frac{D_{t-1}/Y_{t-1}}{\left(1 + g_{y,t}^{pc}\right)\left(1 + g_{N,t}\right)}$$

- Common policy message: need to increase savings or attract FDI to fund investment plans

Saving and Investment

Average, 1980-2008



Source: Hevia & Loayza (2012)

Solving the Model - Parameters

- Can solve the model in simple spreadsheet *without macros*
- Minimal Data requirements - only need data on **three** parameters
  - Labor share (β)
  - Depreciation rate (δ)
  - Initial Capital-to-Output Ratio $(^{K_0}/_{Y_0})$
- $\uparrow \beta, \uparrow \delta$ and $\uparrow {}^{K_0}/_{Y_0}$ all make growth harder via capital accumulation
- Users can choose preloaded data source & time horizon via dropdown menu – and compare in “data summary” tab

Solving the Model - required assumptions (future)

- Needed for all submodels :
  - Growth rate of TFP $(g_{A,t})$; Human Capital per worker $(g_{h,t})$;
  - Demographics: Population (g_N) & Working−age−pop ratio (g_ω)
  - Participation rates $(g_{\rho,t})$

- Submodel 1: Choose Investment share of GDP $(^{I_t}/_{Y_t})$
  - Model calculates returns the growth rate of GDP per capita (or GDP per worker)
- Submodel 2: Choose Growth rate of GDP per capita $(g_{y^{PC},t+1})$
  - Model calculates the investment share of GDP
- Submodel 3: Choose Savings share of GDP $(^{S_t}/_{Y_t})$ and CAB/Y or Ext. Debt/Y & FDI/Y
  - Model calculates the growth rate of GDP per capita (or GDP per worker)

Poverty and Growth

- 2030 Goals to eliminate extreme poverty & halve poverty (at national lines)
  - But what growth rates are required? How do current growth paths affect poverty?

- Based on Log-Normal approx. of the income distribution
  - Can analyze in Excel simply using preloaded data (no microdata required)
  - Automatically produces a Growth Elasticity of Poverty (GEP) (or users can add their own)

- Can assume constant inequality or reduced inequality (income Gini)
  - Lower inequality: (i) reduces poverty directly & (ii) increases effect of growth on poverty

- “Shared prosperity premium” where income of B40 grows faster
  - Translate this into path for Gini coefficient and examines effect on poverty rates

- Caveat: the “type” of growth doesn’t impact poverty (eg which sector grows)

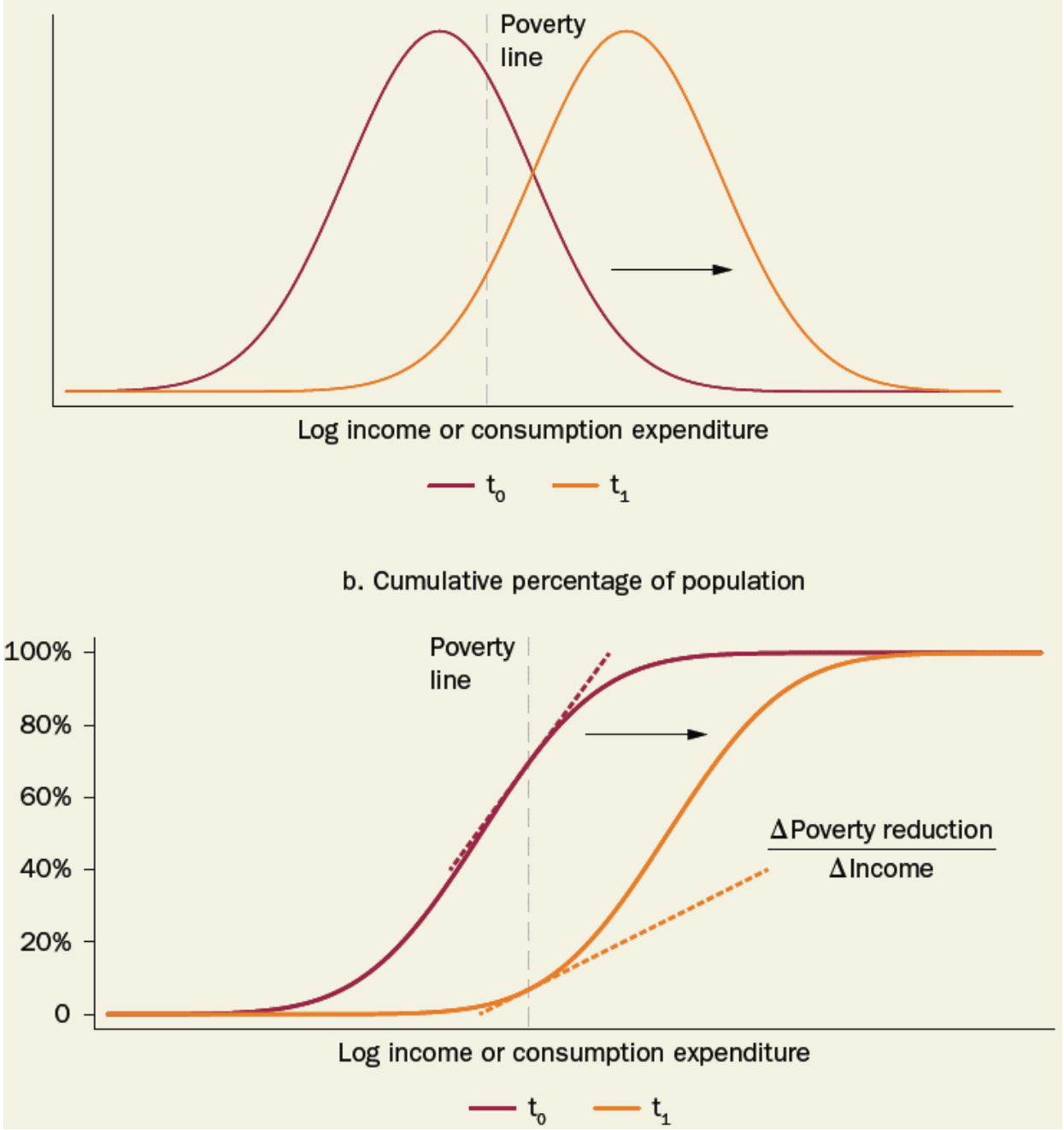
How poverty model works

- Assume a constant Gini coefficient over time.

- Growth increases everyone's income or consumption by the same percentage
  - Shifts the log distribution to the right

- Effect on poverty varies by how many people are near the poverty line
  - Larger ppt fall in poverty when poverty rate is close to 50%
  - Varies by country, poverty line & time

- In more equal countries (lower Gini coeff)
  - → more compressed distribution
  - → more ppl near poverty line
  - → larger effect of growth on poverty



Source: World Bank (2015) A measured approach to ending poverty

A2: Spreadsheet Tutorial
(Hands-on demonstration)

Download LTGM spreadsheet from www.worldbank.org/LTGM

LTGM Spreadsheet Structure

- Yellow - user can change/edit (dropdown menu or text box)

- *InputDataA_GeneralAssumptions* – Assumptions/parameters that affect all simulations (country, start year, TFP growth, K/Y, poverty etc)

- *GraphsA* plots all general assumptions in *InputDataA*.

- *InputDataB_ModelSpecAssumptions* –Assumptions for specific models
  - Model 1: Investment share of GDP →GDP Growth
  - Model 2: Growth rate → Investment share of GDP
  - Model 3: Savings share of GDP →GDP Growth

- *GraphsB* plots **results** of each model (and assumptions from *InputDataB*).

- Submodel 1/1s/2/2s/3/3s -- see the formulas here (no macros)

- *DataSummary* – overview of historical data and parameters from different sources

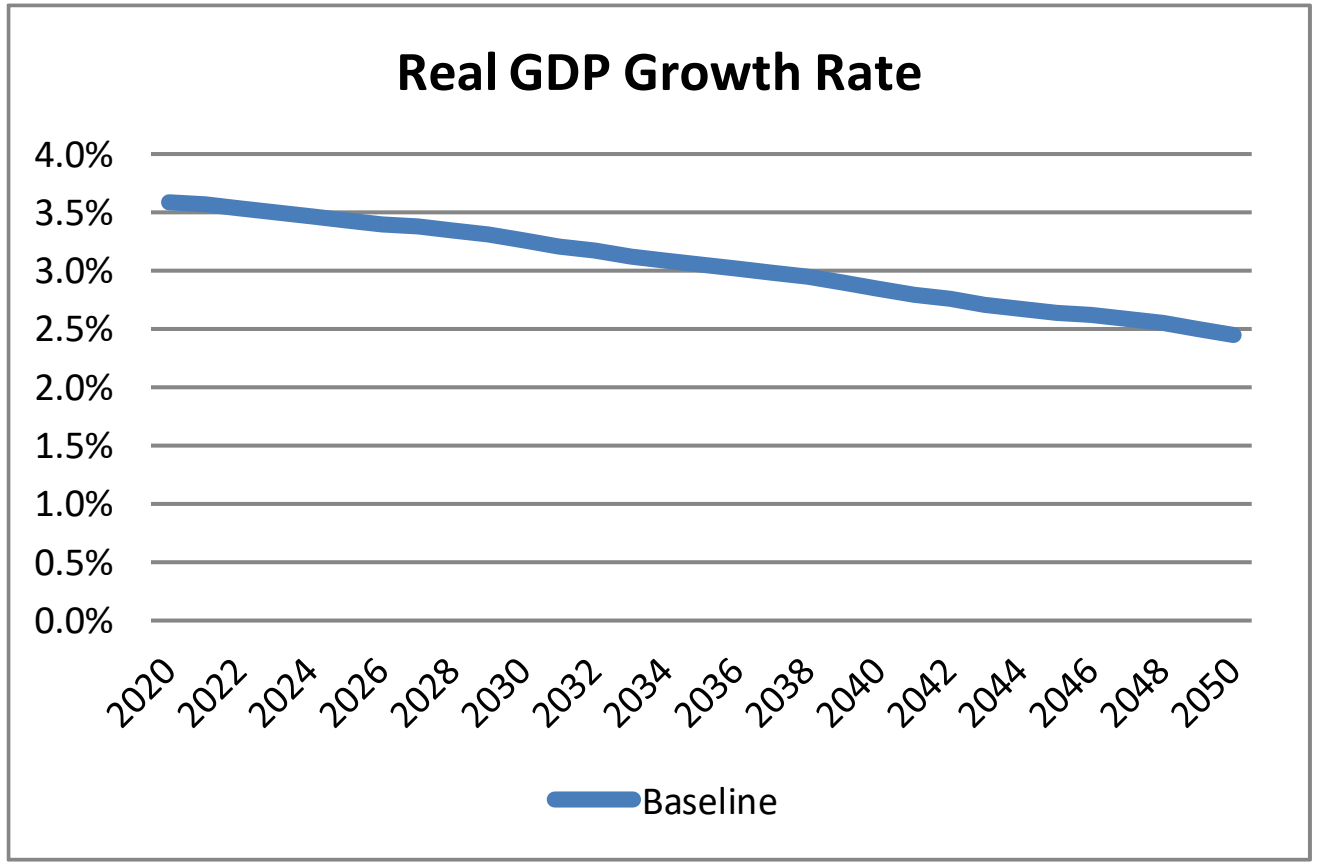
Baseline

Tab *InputdataA*: Choose general parameters

- Country=Peru [Cell B3; the Default]
- Initial year=2019 [Cell D/E7; the Default]
- Labor share $(\beta) = 53.8\%$

  [in cell C15 select PWT 9 LS. 3 Avg Wage]
- Depreciation rate $(\delta) = 4.2\%$ [the default]
- Initial $(K_0/Y_0) = 2.62$ [Cells I/J13; default]
- 0.004 (0.4%) Human capital growth initial & target [Cell D/E22; the default]
- 0.008 (0.8%) TFP growth – initial & target [Cell D/E31; the default]

Tab *InputDataB*: Choose the investment-to-GDP Ratio = 21% [Cell D/E6; the default]

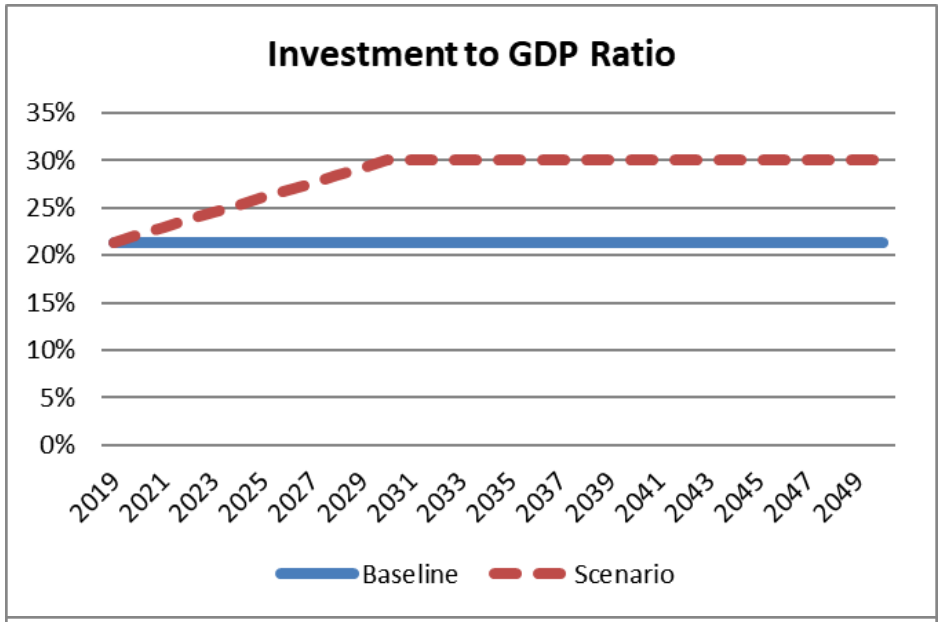


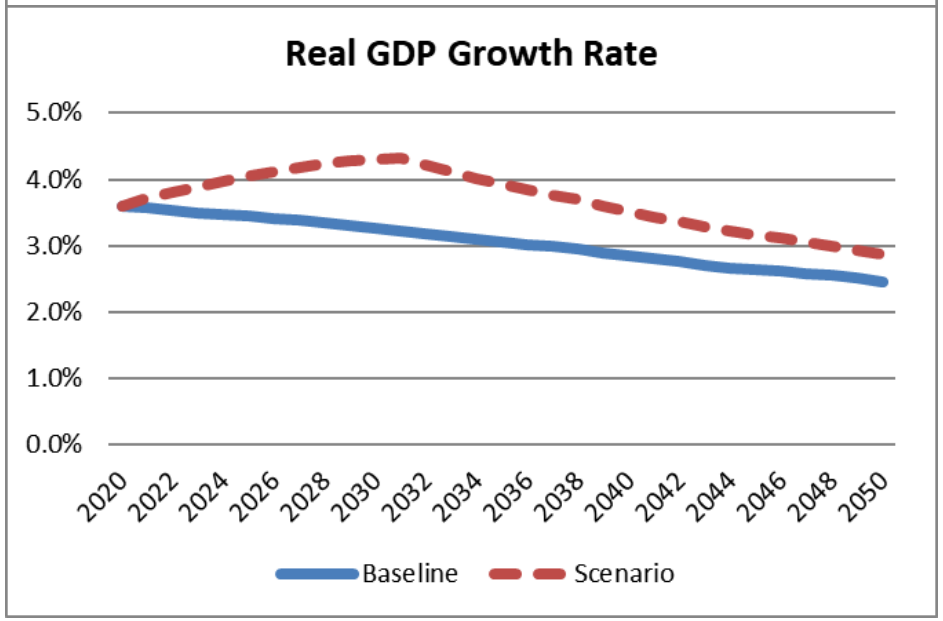
Should get this graph:

- 2020 growth of 3.6%
- 2050 growth of 2.5%

(i) Submodel 1: Investment → Growth

- Tab *InputdataB*: Submodel 1 specific assumptions
- Baseline – no change (target=initial)
- Scenario – 0.30 I/Y [Cell E9] by 2030 (set as target) [Cell E10]
- *Tab GraphsB - check get these graph for investment and growth→*
- *Growth should peak at 4.3% in 2031 in scenario*





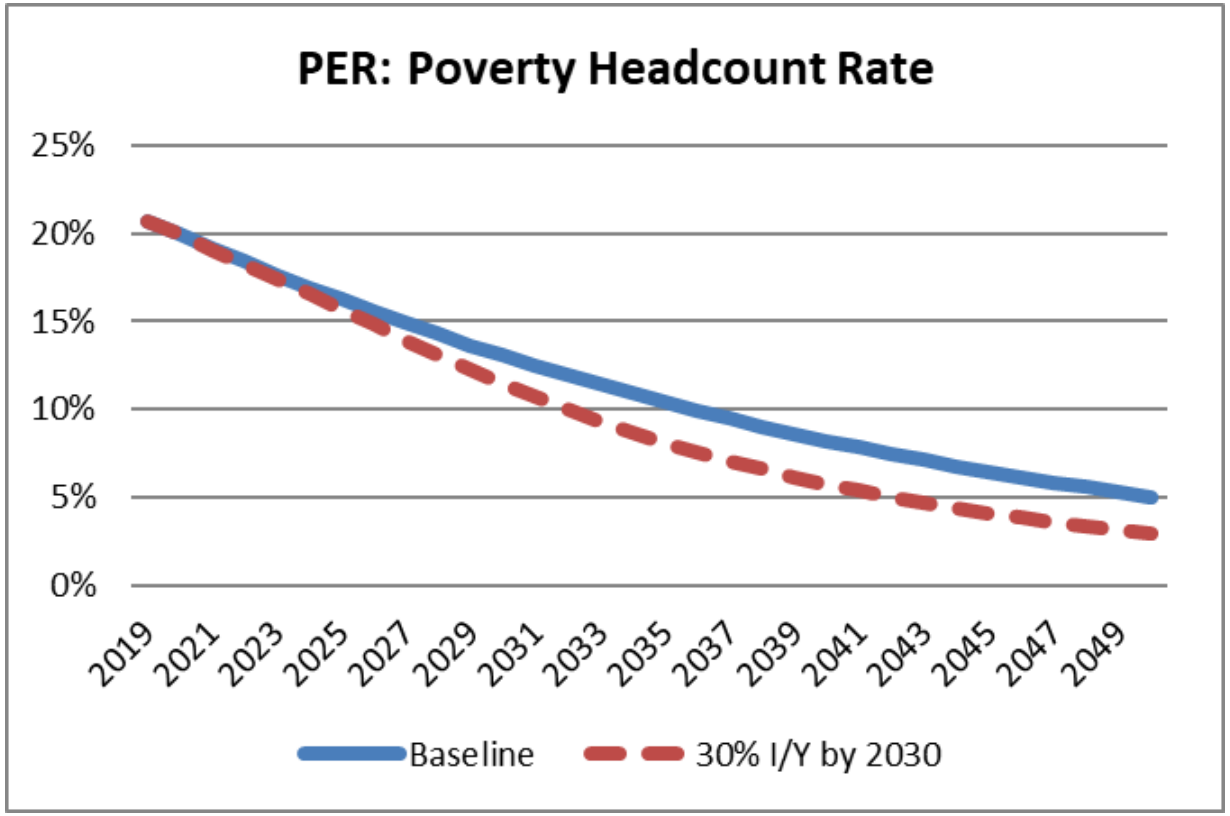
(ii) Submodel 1: effect of growth on poverty

Start with Model 1 simulation in (i)

InputdataA: Choose general parameters

- National Poverty line (default) [Cell C130]
- Initial poverty rate at 0.207 (default) [Cell D/E125]
- Set the Growth Elasticity of Poverty (GEP) on Automatic (the default) [Cell D/E133]
- Make sure the Gini coefficient option is chosen [Cell D/E140, the default]
- Initial Gini coefficient of income 0.438
    - Constant (initial= target) [Cell D/E137, default]

GraphsB - make sure you get this poverty →



By 2050 Results (Submodel 1/1s sheet bottom)

- *Poverty: 4.8% (baseline)* [Cell AJ 65 Submodel1]
  vs 2.9% (scenario) [Cell AJ 65 Submodel1s]

(iii) Submodel 1: Effect of ↓inequality on poverty

Goal: Lower inequality 43.8% → 40% by 2030

(in addition to effects of higher investment)

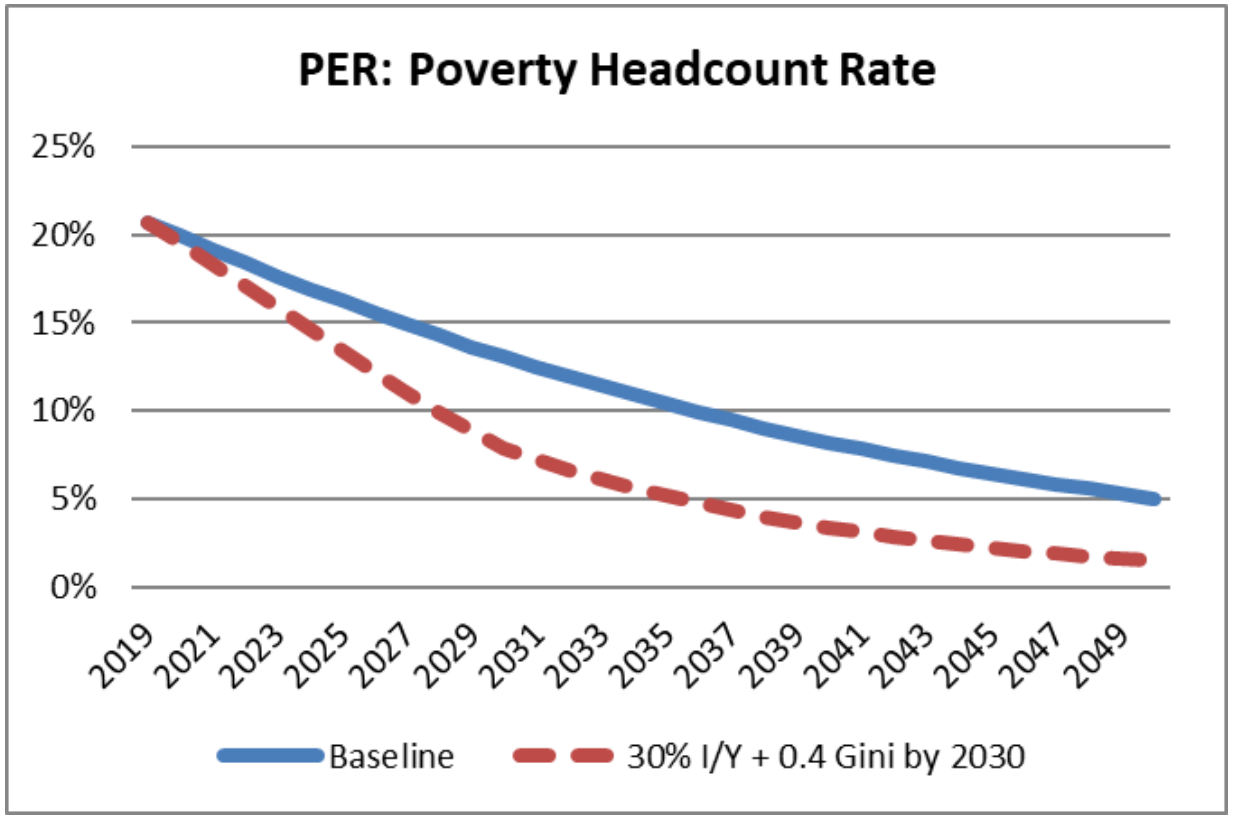
InputDataA: Make sure the Gini coefficient option is chosen [Cell D/E140, the default]

Start with Model 1 simulation in (ii)

InputdataA: parameters for poverty

- Scenario target Gini of 0.40 by 2030 [change Cell E144 in InputdataA]

GraphsB - make sure you get this poverty →



By 2050 Results (Submodel 1/1s sheet bottom)

- *Poverty: 4.8% (baseline)* [Cell AJ 65 Submodel1]
  vs 1.4% (scenario) [Cell AJ 65 Submodel1s]

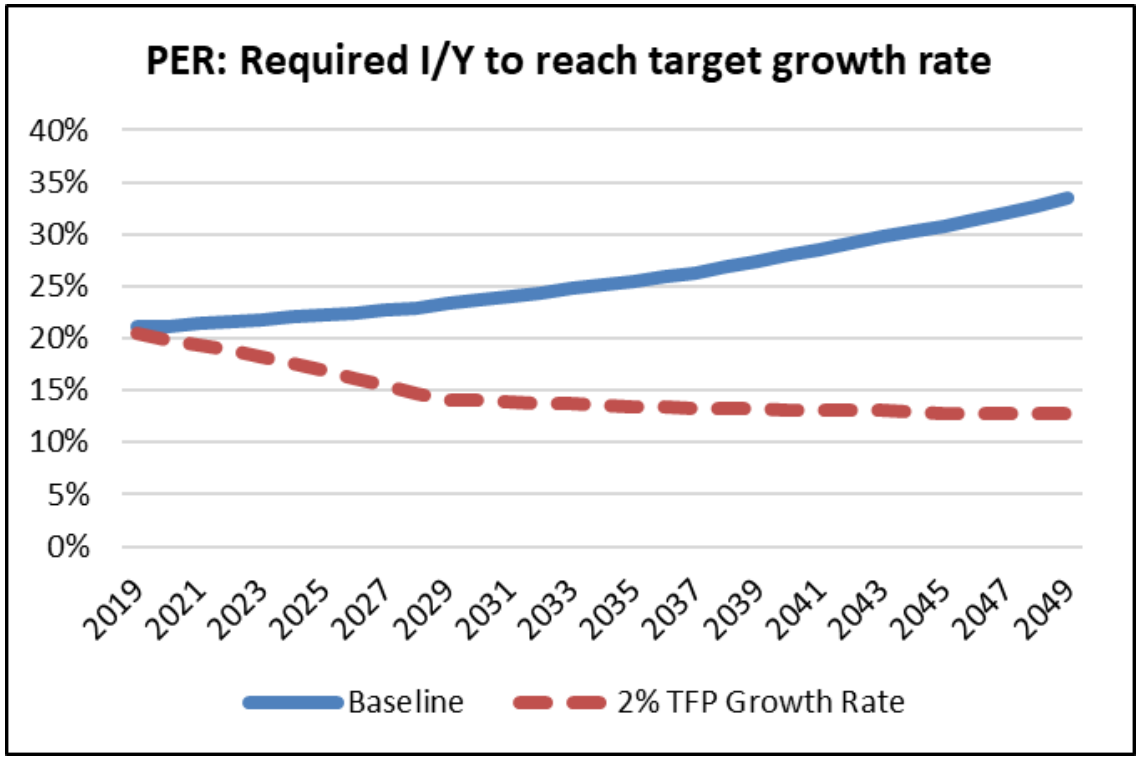
(iv) Submodel 2: Growth → Investment (w/ TFP)

Tab *InputDataB:* target GDP growth rate is 3.5% in baseline and scenario [Cell D/E13 type 0.035]

InputdataA parameters for TFP growth

- Initial TFP growth of 0.008 (0.8% TFP growth) [Default Cell D/E29]
- Scenario: 0.02 (2%) [Cell E34] TFP growth target by 2030

GraphsB - check get this graph for investment →



By 2049: Required investment (Submodel 2/2s sheet)

- 0.327 (baseline) [Cell AI18] vs 0.124 (scenario) [Cell AI18]

Explanation: Declining marginal product of capital

(v) Submodel 3: Savings + CAB → Growth (ASSUMPTIONS)

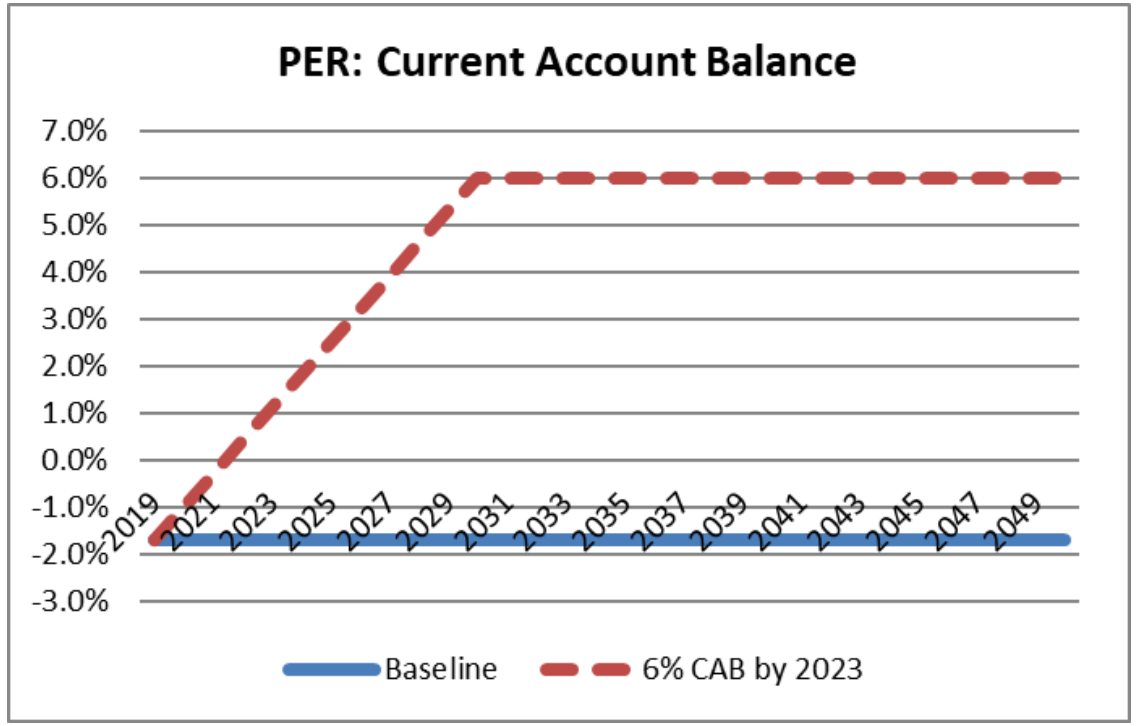
Reset TFP growth rate in scenario: type "=E31" in Cell E34 tab InputdataA

InputdataA: External Balance (previously didn't matter)

- Current Account Balance Constraint (dropdown menu) [Cell D/E60; the default]

- CAB target in Scenario: 6% GDP (0.06 CAB/GDP [Cell E69]) by 2030

- *GraphsA - check get this graph (CAB red/blue only)* →



(v) Submodel 3: Savings + CAB → Growth (RESULTS)

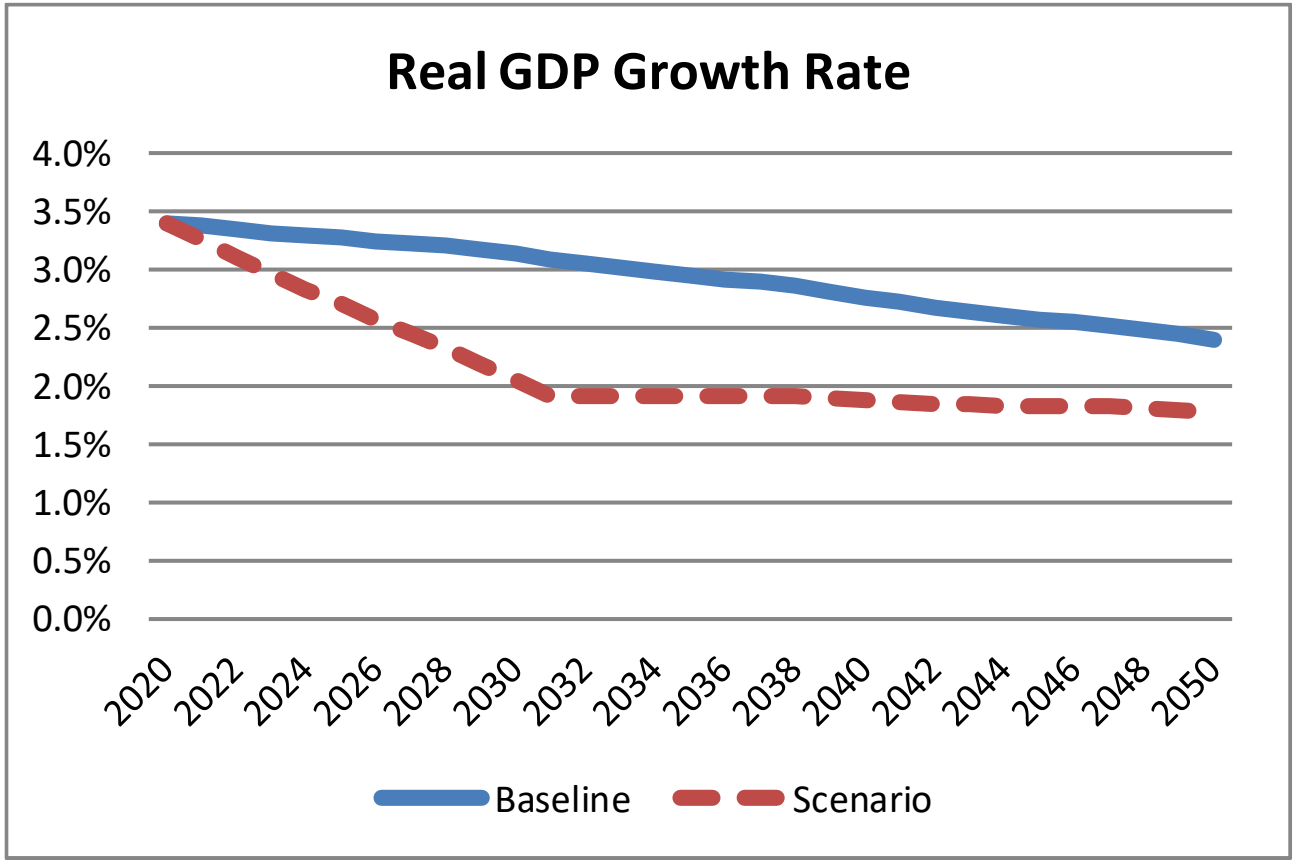
InputDataB - check savings is constant 19% of GDP [Cell D26 & E26]

GraphsB - check get GDP Growth →

(Headline GDP Growth, not per capita)

By 2030: GDP Growth result:

- 3.1% (baseline) [Cell P32 Submodel 3]
- 2.1% (scenario) [Cell P32 Submodel 3s]



Part B. Public Capital Extension (LTGM-PC) and other Extensions

Download LTGM-PC spreadsheet from www.worldbank.org/LTGM

LTGM Extensions

1. Public Capital extension (Devadas & Pennings 2018)

- TODAY Private & Public investment (quantity/quality) → growth

2. TFP Extension (Kim & Loayza 2018) - download at www.worldbank.org/LTGM

- Uses cross country regression to calculate path for TFP growth based on country's scores for:
  - innovation, education, market efficiency, infrastructure, and institutions

3. Human Capital Extension (beta)

- Adapts the World Bank HCI for growth analysis (schooling quantity/quality, health)
- Based on population cohorts – reforms affecting todays children affect growth in the future.
- Example from Malaysia box: increase HCI components to median of high income country

FIGURE 21
Simulations for Malaysia's rate of human capital growth

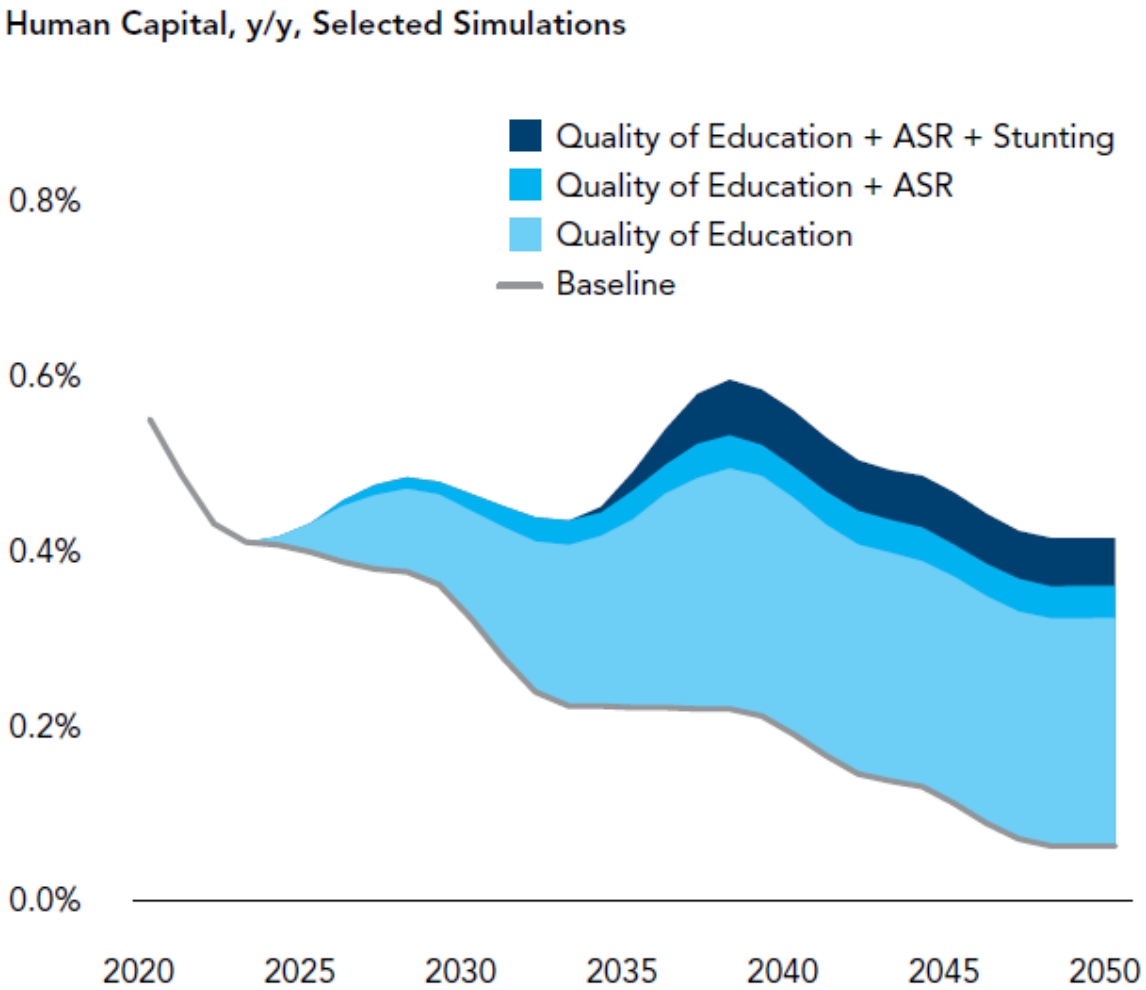
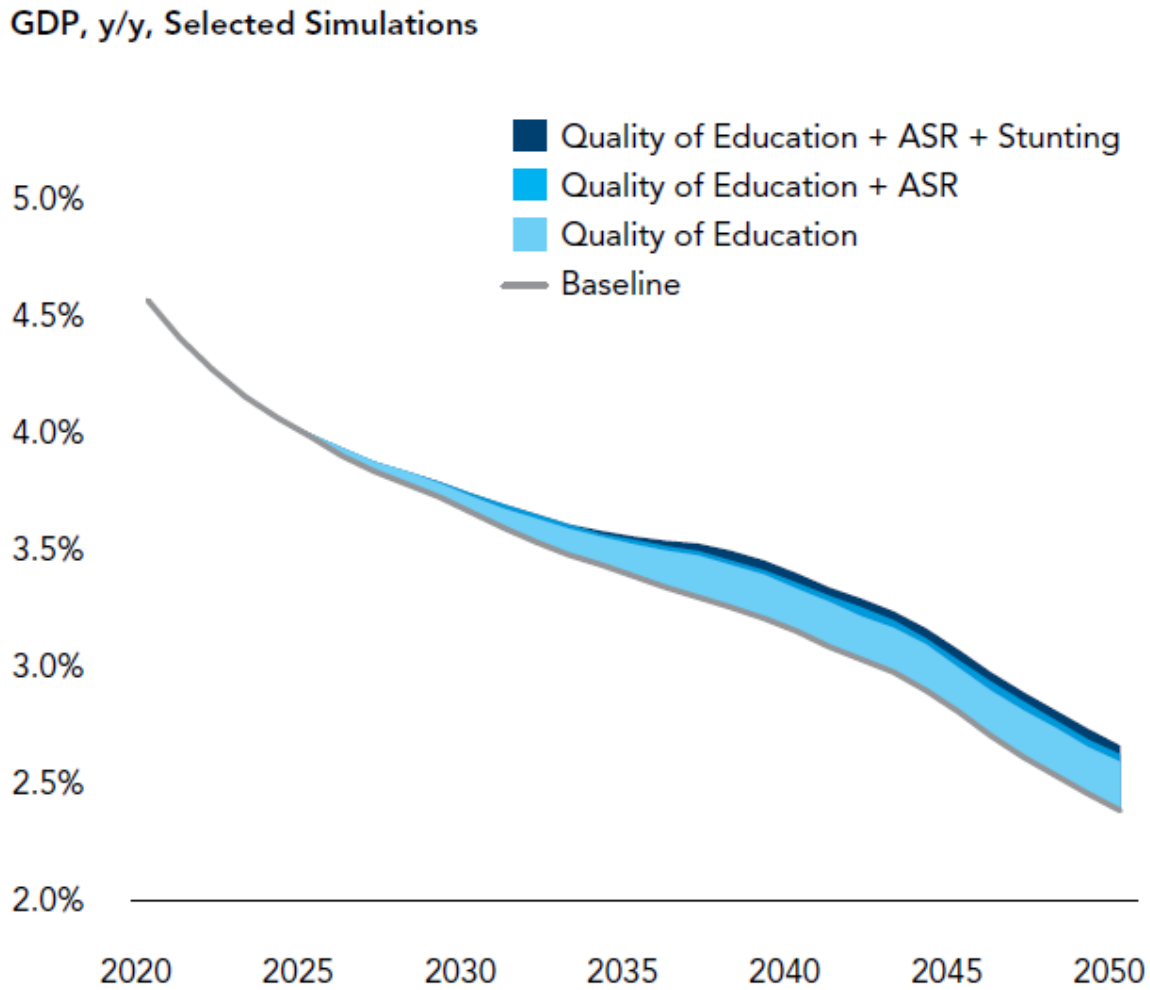


FIGURE 22
Simulations for Malaysia's long-term rate of GDP growth



Source: Malaysia Economic Monitor (June 2019)

LTGM Extensions (cont.)

4. Natural Resource extension (beta)

- Commodity export sector calibrated to commodity exporters all over the world
- Analyze the effect of long-run growth of
  - Commodity price changes
  - Commodity discoveries
- Analyze different fiscal rules for commodity revenues:
  - Balance Budget Rule, Structural Surplus Rule, Hartwick's Rule

5. Advanced Sectoral Growth Tool (in progress)

- 3 sectors - agriculture, manufacturing and services
- Structural transformation
- Distortions in the allocation of factors of production across sectors

LTGM-Public Capital Extension - Overview

1. Disaggregate total investment into public I_t^G (infrastructure) and private I_t^P

- What is effect on growth of 1ppt GDP ↑**public** investment? And when?
- Is that larger or smaller than the same size effect of private investment?

2. Introduce new quality/efficiency of public capital θ_t (between 0 and 1)

→ Measured as new Infrastructure Efficiency Index (IEI) based on:

- Water leaks, Power transmission losses, Unpaved roads

- What is the effect of **efficiency/quality** of public investment on growth?

The LTGM-PC production function

- New/changed parts in the LTGM-PC in red:

$$\boldsymbol{Y_t(GDP) = A_t\left(\theta_t K_t^G\right)^{\phi}(K_t^P)^{1-\beta-\phi}(h_t L_t)^{\beta}}$$

GDP

Total factor productivity

Efficiency of public capital

Measured public capital stock

Private capital

Human capital (schooling)

Labor

- Log linear approximation:

$$g_{Y,t+1} \approx \tilde{g}_{t+1} + \phi\left(\frac{\theta_t^N - \theta_t}{\theta_t}\right)\frac{I_t^G/Y_t}{K_t^G/Y_t} + \phi\left[\frac{I_t^G/Y_t}{K_t^G/Y_t} - \delta^G\right] + (1-\beta-\phi)\left(\frac{I_t^P/Y_t}{K_t^P/Y_t} - \delta^P\right)$$

Growth due to private Investment

Growth due to quantity of public K (more K_t^G)

Growth due to quality of public K (more θ)

Calibration of LTGM-PC to Malaysia

Variable	Baseline Value	Source/Comments
Labor share income	$\beta = 0.5$	Penn World Tables v9 (2014)
Deprecation rate	$\delta = 5.8\%$	Penn World Tables v9 (2014)
Total factor productivity (TFP) growth	$g_A = 0.9\%$ initially 0.6% by 2050	Similar to PWT v9: 30 years median; 15 year average
Human capital (HC) growth	$g_h = 0.6\%$ initially 0.1% by 2040	LTGM-Human Capital Extension Similar to 2011-14 average from PWT 9
Total investment rates	$I/Y = 24\%$	IMF Article IV (2019) -2020-23 average
Public Investment rate	$I^G/Y = 6\%$	
Private Investment rate	$I^P/Y = 18\%$	
Total Capital-to-output ratio	$K/Y = 2.25$	Steady state K/Y=(I/Y)/$(g_Y + \delta)$
Public capital-to-output ratio	$K_G/Y = 1.14$	IMF FAD Investment and Capital Stock Dataset. K_G/K=51%
Private capital-to-output ratio	$K_G/Y = 1.11$	
Population growth (2019-2050)	g_N=1.3%→0.4%	UN Population projections (via WB HDN)
Headline GDP growth in 2020	g_Y=4.5%	World Bank MTI forecasts (2019-2021)

Note: also assume that quality θ is constant

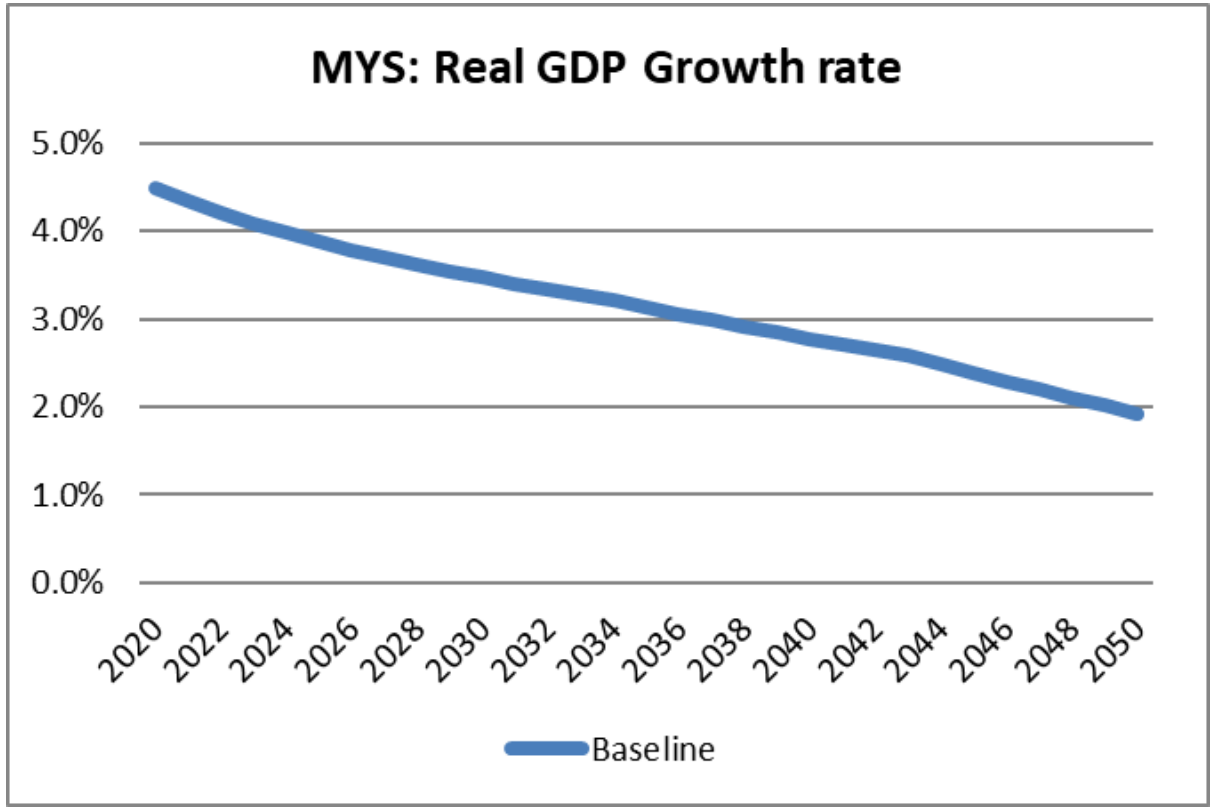
Baseline for the LTGM-PC

Tab *InputdataA*: Choose general parameters

- Country=Malaysia [Cell B3]
- Initial year=2019 [Cell D/E7; default]
- Labor share $(\beta) = 50\%$ [Cell D16 & E16]
- Deprec. rate $(\delta) = 5.8\%$ [Cell D/E13; default]
- Initial $(K_0/Y_0) = 2.25$ [Cell I13 & J13]
- Human capital growth
  - Initial 0.006 (0.6%) [Cell D32 & E32]
  - Target: 0.001 (0.1%) [Cell D37 & E37] by 2040
- TFP growth
  - Initial 0.009 (0.9%) [Cell D41 &E41]
  - Target 0.006 (0.6%) [Cell D46 & E46]
    - by 2050 [Cell D47 &E47]

Tab *InputDataB*:

- Choose the public investment-to-GDP Ratio = 6% [Cell D8 & E8]
- Choose the private investment-to-GDP Ratio = 18% [Cell D18 & /E18]



Should get this graph:

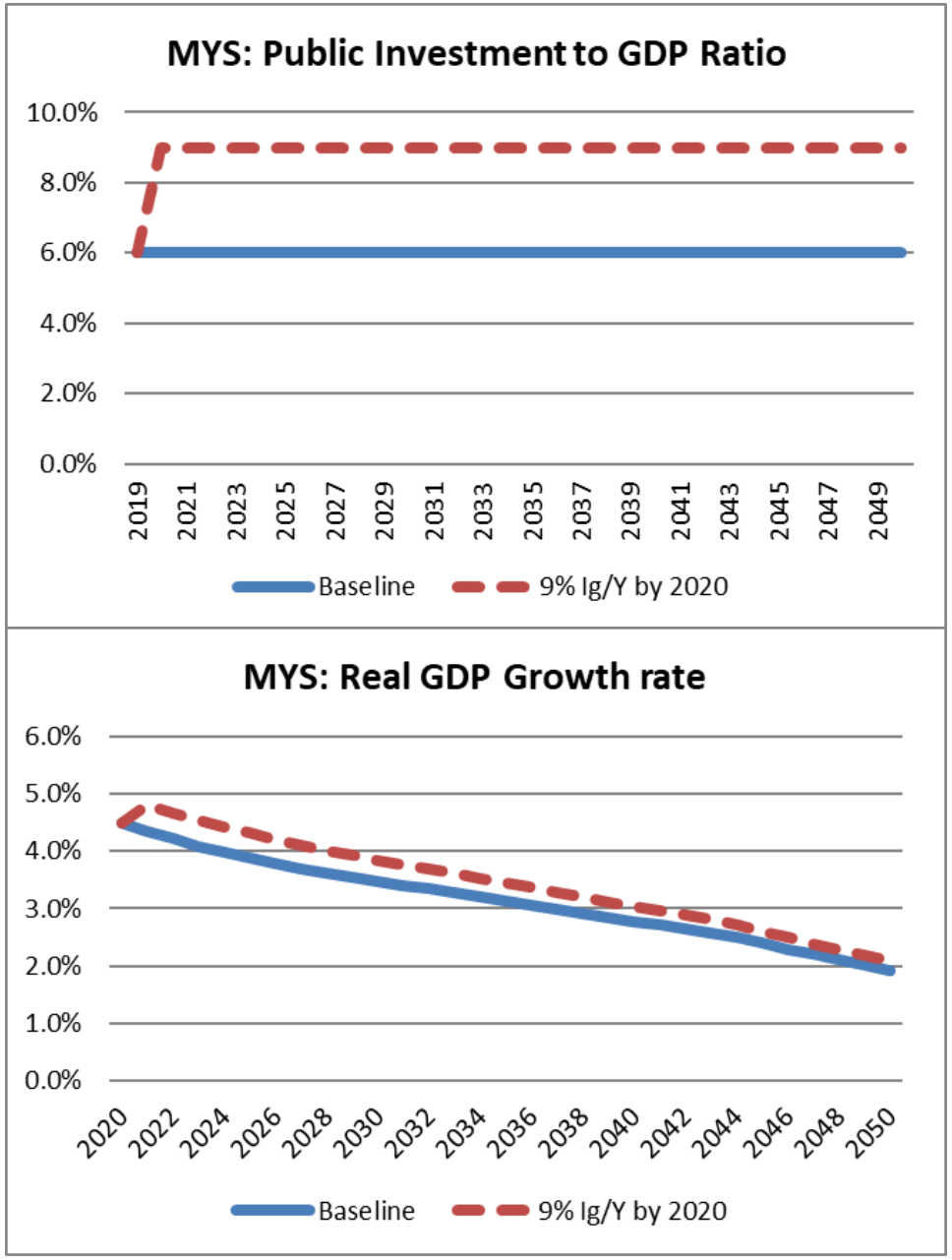
- 2020 GDP growth of 4.5%
- 2050 GDP growth of 1.9%

(vi) Submodel 1: Public Investment→ Growth

- Public Investment Shock (InputDataB):
- Permanent 9% (0.09) of GDP [Cell E13] by 2020 [Cell E14]

- *GDP Growth results in 2030:*
  - *3.5% (baseline)* [Cell P38 in *Submodel 1*]
  - *3.8.% (scenario)* [Cell P38 in *Submodel 1s*]

GraphsB - make sure you get these graphs for Public Investment & GDP Growth →



(vii) Submodel 1: Private Investment→ Growth

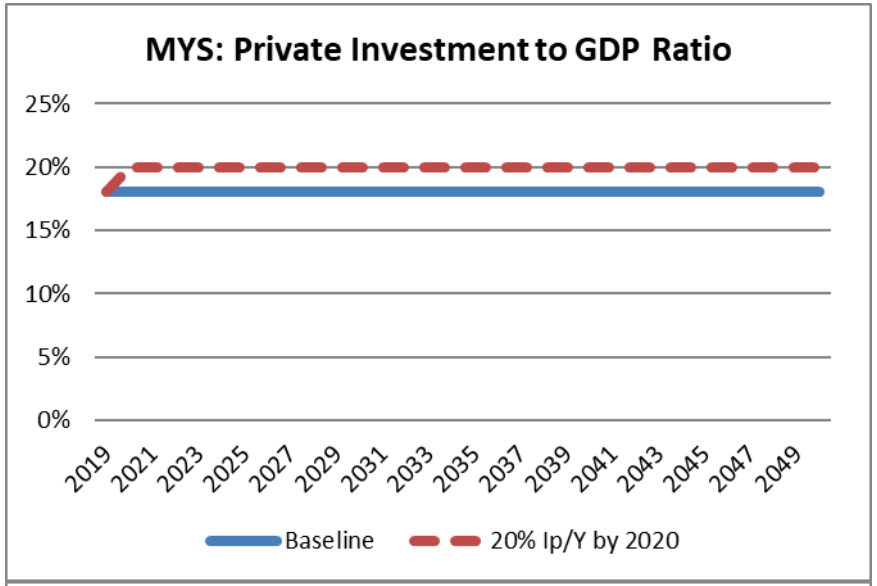
- Reset Public Investment: 6% (0.06) of GDP target [Cell E13 in InputDataB]

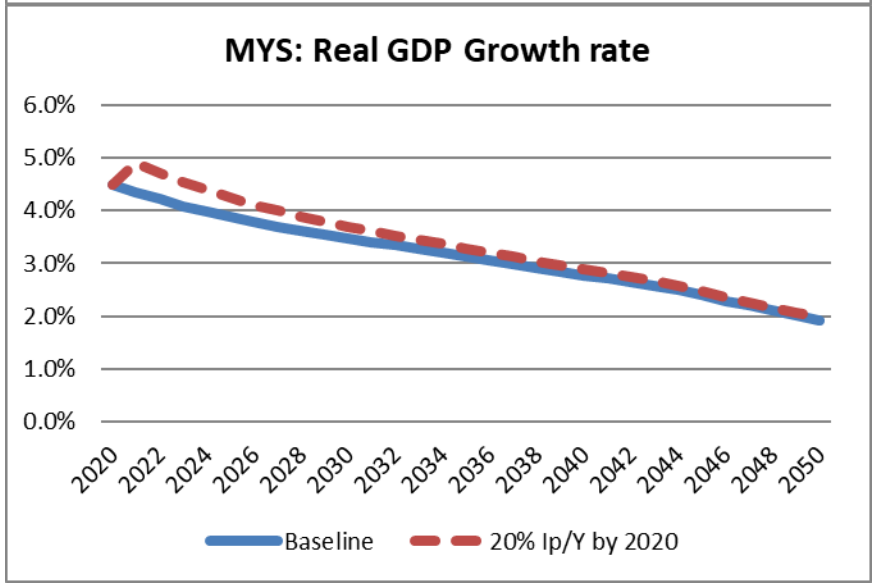
- Private Investment Shock:
  - permanent 20% (0.20) of GDP [Cell E23]
  - by 2020 [Cell E24] in InputDataB

GDP Growth results in 2030:

- *3.5% (baseline)* [Cell P38 in *Submodel 1*]
- *3.7% (scenario)* [Cell P38 in *Submodel 1s*]

GraphsB - check get this graph for Public Investment & GDP Growth →





Thank you!

Questions/comments/suggestions

- Latest version available at www.worldbank.org/LTGM (or http://LTGM on intranet)
- Always trying to improve the LTGM -- your comments and suggestions are welcome
- Please contact us if you would like to use the model in your country:
  - Steven Pennings (spennings@worldbank.org),
  - Norman Loayza (nloayza@worldbank.org), or
  - Jorge Guzmán (jguzmancorrea@worldbank.org)
- We can also provide help with analysis, presentations, training etc

Input/Output: Three Versions of the Model

	Submodel 1	Submodel 2	Submodel 3
Purpose	**Growth** given **Investment**	**Investment** given **Output/Growth Target**	**Investment/Growth** given **Savings**
Inputs:	Investment rate $\left(\frac{I_t}{Y_t}\right)$	Growth rate of GDP (g_Y) **OR** Growth rate of GDP per capita $\left(g_Y^{pc}\right)$ **OR** Time path of GDP (GDP_t) **OR** Poverty	Savings rate $\left(\frac{S_t}{Y_t}\right)$
Outputs:			
GDP	Growth rate of GDP (g_Y), Growth rate of GDP per capita $\left(g_Y^{pc}\right)$, Level of GDP (GDP_t), Poverty rate	Other three of the four measures	Growth rate of GDP (g_Y), Growth rate of GDP per capita $\left(g_Y^{pc}\right)$, Level of GDP (GDP_t), Poverty rate
Savings/ Investment	Savings rate $\left(\frac{S_t}{Y_t}\right)$	Investment rate $\left(\frac{I_t}{Y_t}\right)$, Savings rate $\left(\frac{S_t}{Y_t}\right)$	Investment rate $\left(\frac{I_t}{Y_t}\right)$
External Sector	CAB to GDP $\left(\frac{CAB_t}{Y_t}\right)$ **OR** External Debt to GDP $\left(\frac{D_t}{Y_t}\right)$	CAB to GDP $\left(\frac{CAB_t}{Y_t}\right)$ **OR** External Debt to GDP $\left(\frac{D_t}{Y_t}\right)$	CAB to GDP $\left(\frac{CAB_t}{Y_t}\right)$ **OR** External Debt to GDP $\left(\frac{D_t}{Y_t}\right)$