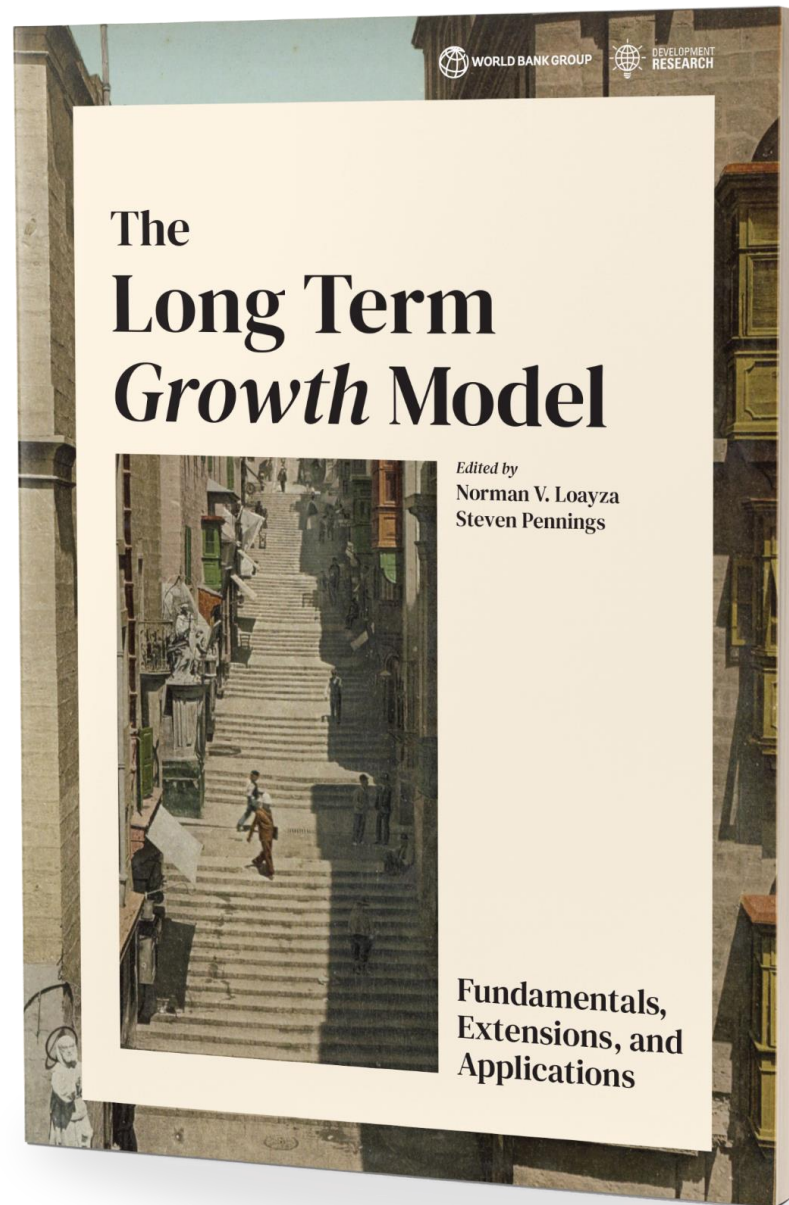# The Long Term Growth Model:
## Fundamentals, Extensions, and Applications
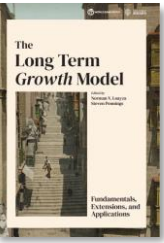
**Norman V. Loayza and Steven Pennings**

Policy Research Talk – March 21, 2023
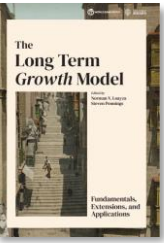
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www.worldbank.org/LTGM

The Long Term *Growth* Model

WORLD BANK GROUP · DEVELOPMENT RESEARCH

*Edited by*
Norman V. Loayza
Steven Pennings

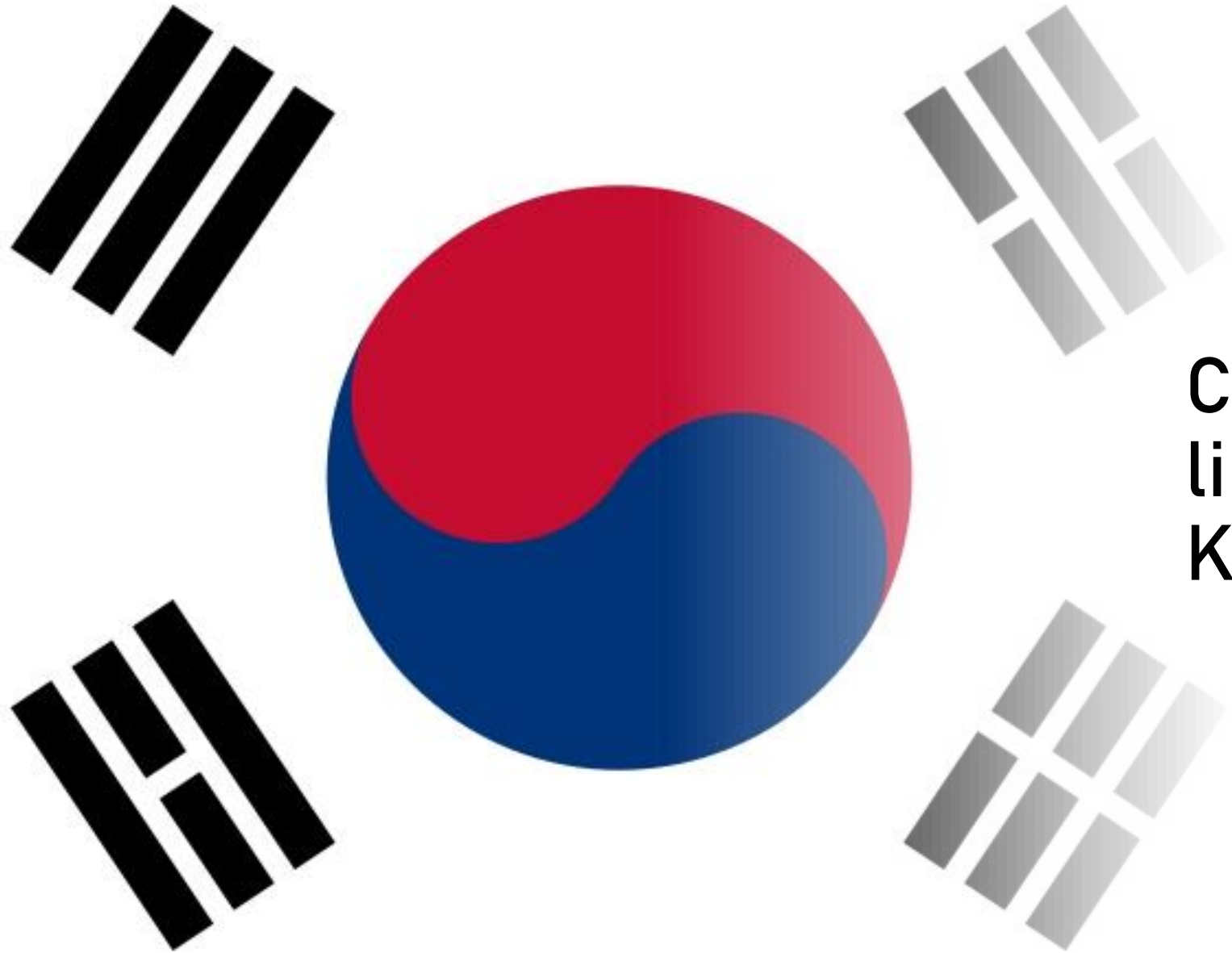Fundamentals, Extensions, and Applications
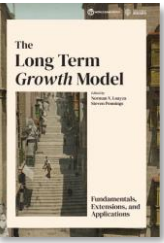
Football fans would like to play like Messi...

Pop singers would like to sing like Aretha Franklin...

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DEVELOPMENT RESEARCH

*Photo Credit: Mike Bouchard*
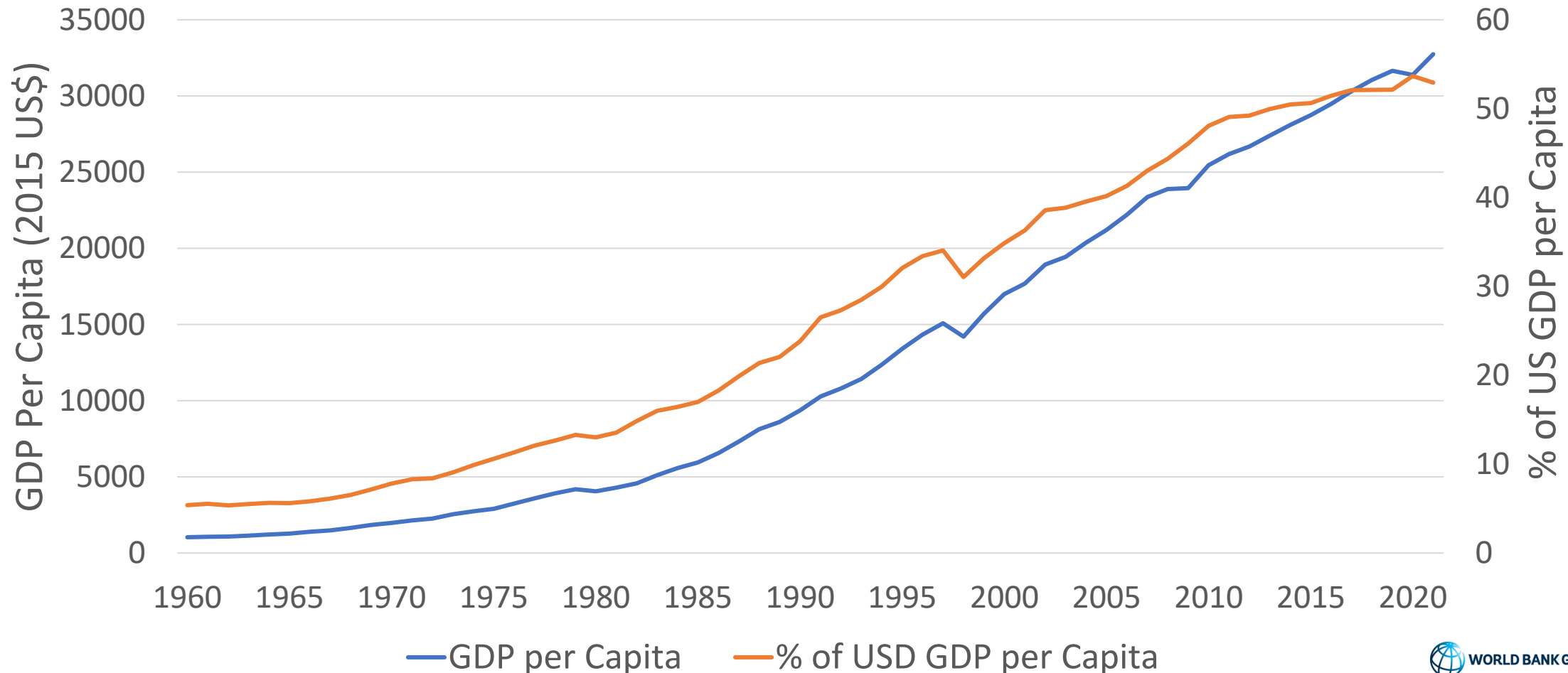
Countries would like to grow like Korea…

# Korea's economy has grown at an average annual rate of 7.2% (almost 6% per capita) for six decades!



Korea, Rep - GDP per Capita (1960-2021)

# Why the emphasis on growth?
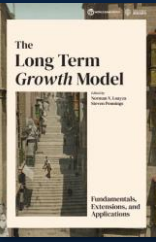
- Economic growth is the **foundation** on which social and economic development rests
  - It creates jobs and generates income
  - It fosters innovation and entrepreneurship
  - It can promote political and social stability
  - It provides resources to fund public services and infrastructure

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- Therefore, economic growth is the key to eliminating **poverty** and providing for **shared prosperity**
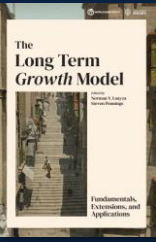  - Especially when it is inclusive, sustainable, and enduring
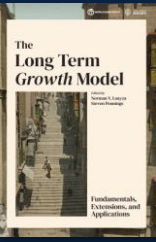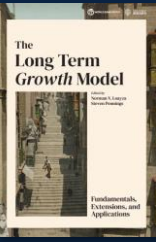
# Why the emphasis on growth?

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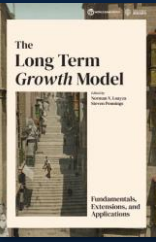- Not surprisingly, economic growth is often at the **top of policy agendas**

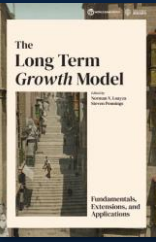# Is "dreaming big" on growth a good thing?

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# Is "dreaming big" on growth a good thing?
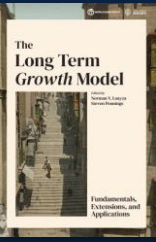
- Yes! ... if you are implementing a sound economic strategy to achieve realistic growth targets

- No! ... if it leads you to poor decision making and social frustration:
  - Unsustainable levels of public expenditures, deficits, and debt
  - Distorted plans for public and private consumption and investment
  - Unmet expectations, disappointment, and social unrest
  - Loss of credibility
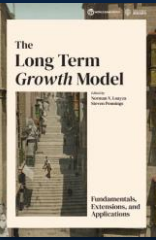
# The Long Term Growth Model: Origins

- It started as a "reality check"
  - Growth projections based on a standard neoclassical growth model (Solow-Swan)

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  - Growth projections based on a standard neoclassical growth model (Solow-Swan)
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  - A method to produce *alternative* growth scenarios
  - A way to understand the *determinants* behind those scenarios, including policy
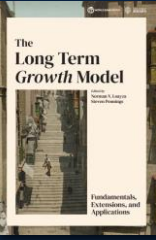
# The Long Term Growth Model: Origins

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- It then became an explanatory tool
  - A method to produce *alternative* growth scenarios
  - A way to understand the *determinants* behind those scenarios, including policy
- The interest in the LTGM generated a demand for richer models
  - The LTGM project became a suite of models, supported by academic papers and implemented by a set of toolkits
  - The toolkits are carried out in spreadsheets (without macros) – designed to be simple, transparent, and easy-to-use. Freely downloadable from www.worldbank.org/LTGM
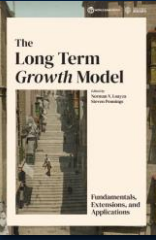
# Book Structure

## Fundamentals

The Standard Long Term Growth Model

# Book Structure

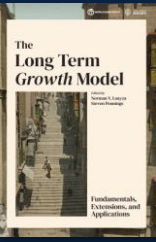## Fundamentals

The Standard Long Term Growth Model

## Extensions

Public Capital

Productivity Growth

Natural Resources

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Malaysia

Korea, Rep.

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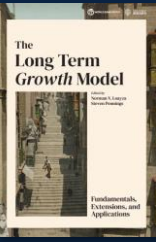
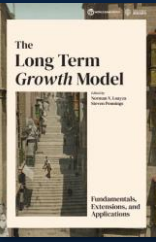Malaysia

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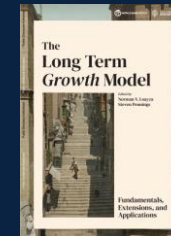
Malaysia

Korea, Rep.

Bangladesh

Syria

Egypt

Sri Lanka

# A Simple Model with 3 building blocks

### 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 (for GDP Per Capita, $y_t^{PC}$):

$$\boldsymbol{y_t^{PC}} = \frac{Y_t}{N_t} = \left[\frac{Y_t}{L_t}\right]\frac{L_t}{W_t}\frac{W_t}{N_t} = \left[A_t k_t^{1-\beta} h_t^{\beta}\right]\rho_t \omega_t$$

$A_t$: TFP; $K_t$: capital stock , $h_t$: human capital per worker; $L_t$: number of workers; $I_t$ investment
$W_t$: working–age pop; $N_t$: total pop.; $\rho_t$: labor participation rate; $\omega_t$: working-age-pop. to pop. ratio; $k_t$: capital/worker
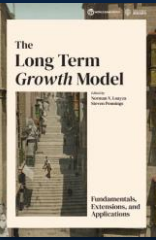
# Growth Drivers

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

Growth [GDP]     [TFP]     [Human Capital]   [Demographics]   [LF Participation]     MPK     [Investment]

# From conditions and assumptions to outcomes

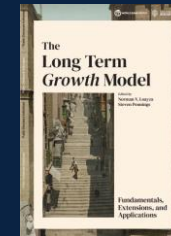**Initial conditions**
- K/Y
- capital/labor shares, depreciation rate

**Assumptions on future path of growth drivers**
- Productivity, Human capital, demographics
- Investment rate

**Scenario outcomes**
- Growth rates
- ... poverty rates too

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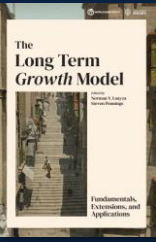
$$g_{Y,t+1} \approx g_{A,t+1} + \beta(g_{h,t+1} + g_{\omega,t+1} + g_{N,t+1} + g_{\rho,t+1}) + \left[\frac{1-\beta}{K_t/Y_t}\right]\frac{I_t}{Y_t} - (1-\beta)\delta$$

Growth [GDP]    [TFP]    [Human Capital]    [Demographics]    [LF Participation]    MPK    [Investment]

- **Result**: investment-led growth (by itself) is not sustainable in the long run
  - K/Y increases over time because of higher rates of investment
  - Leads to a fall in MPK $= \dfrac{1-\beta}{K_t/Y_t}$ (diminishing returns)
    - Each extra unit of investment adds less to growth than the previous one
    - Investment-led growth rate will fall over time
- **Policy advice:** Investment must be accompanied by other sources (e.g., human capital, productivity, labor-force participation) – a broad-based growth strategy.

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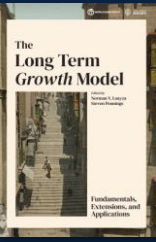
## Applications

Malaysia

Korea, Rep.

Bangladesh

Syria

Egypt

Sri Lanka

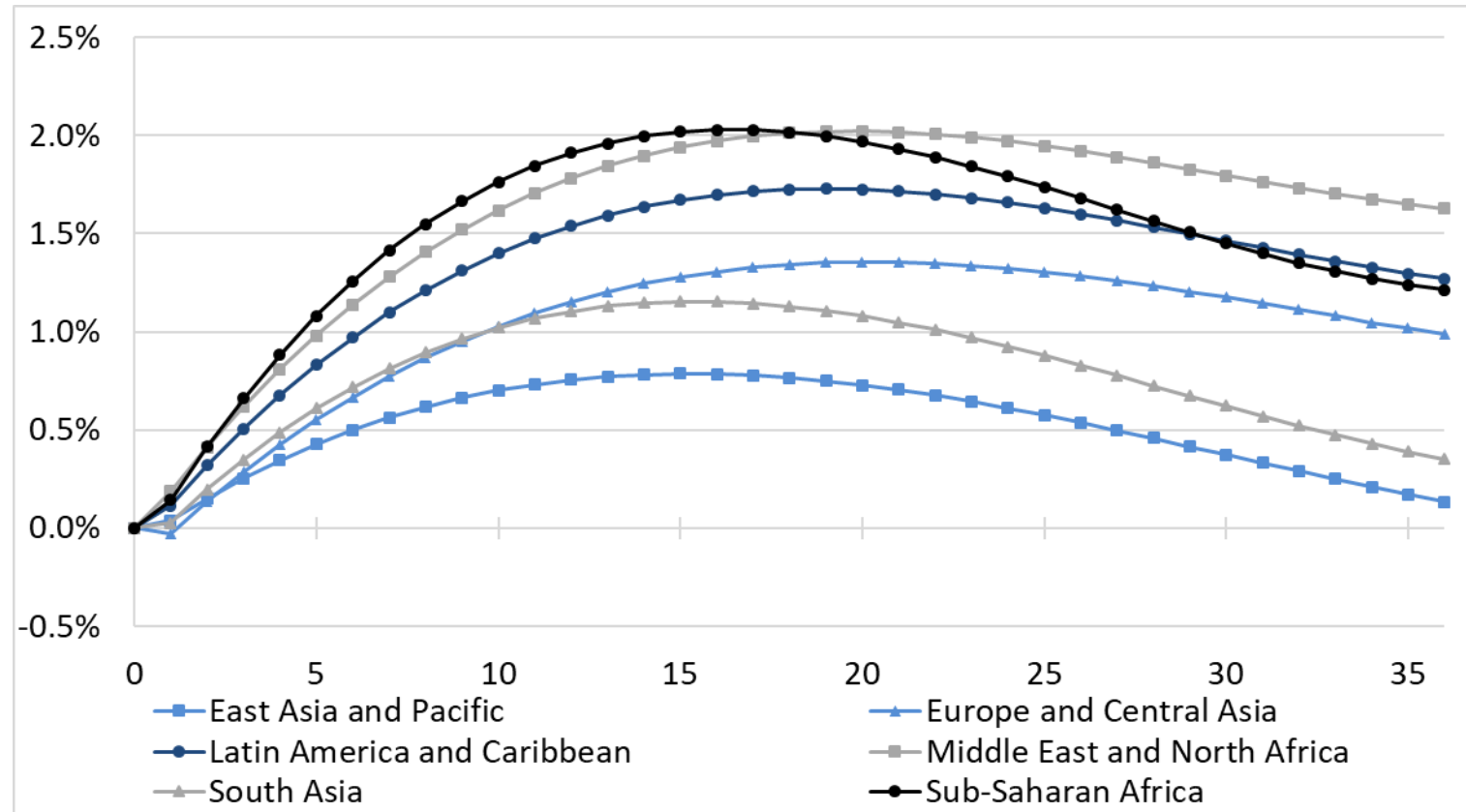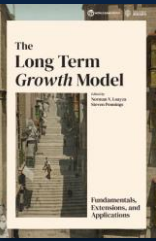# Productivity growth: $Y_t(GDP) = A_t K_t^{1-\beta}(h_t L_t)^{\beta}$

- Written with Young Kim
- Literature review on the determinants of TFP
- Build a TFP determinant index ($Index_{c,t}$)
  - Principal components of data in 5 areas
- Run cross-country regression: connect *determinant index* to TFP growth:
  - $Ave.TFP\ growth_{c;t,t-5} = \beta_1 ln(Index_{c,t-5}) + \beta_2\ ln(TFP\ level)_{c,t-5} +\ \delta_t + \theta_c$
- Higher index → faster TFP growth, with a diminishing effect

Innovation
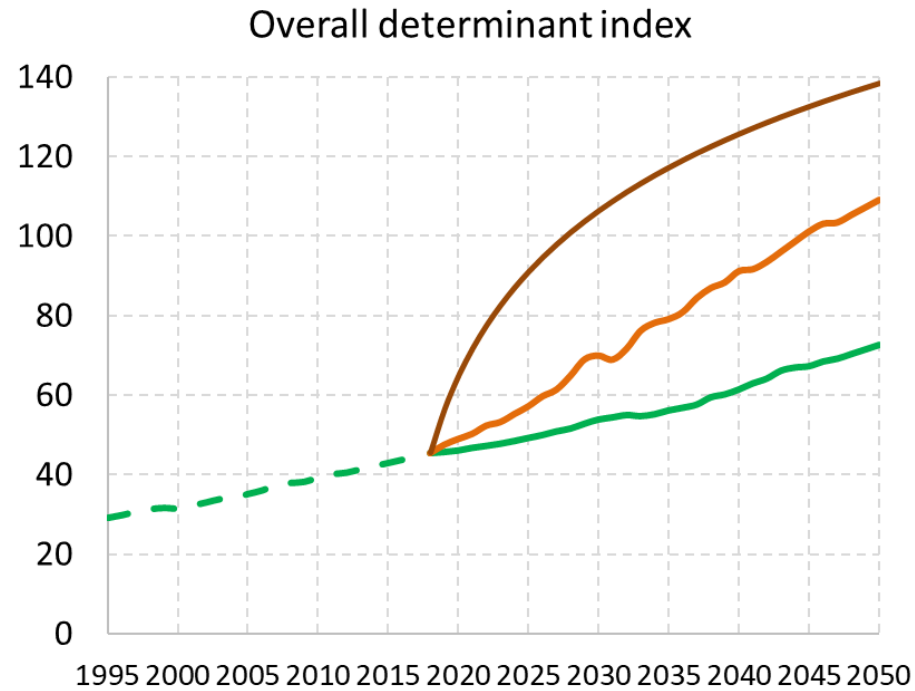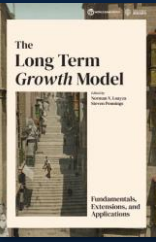
Education

Institutions

5 Productivity Determinants From Literature Review

Infrastructure

Market Efficiency

Korea, Rep. increased the index the most among all developing countries during 1985-2014.

### Overall determinant index



Legend:
- Trajectory of Colombia
- Trajectory of Korea, Rep.
- Korea's index (2014) in 10 years

### TFP growth rate



0.06%
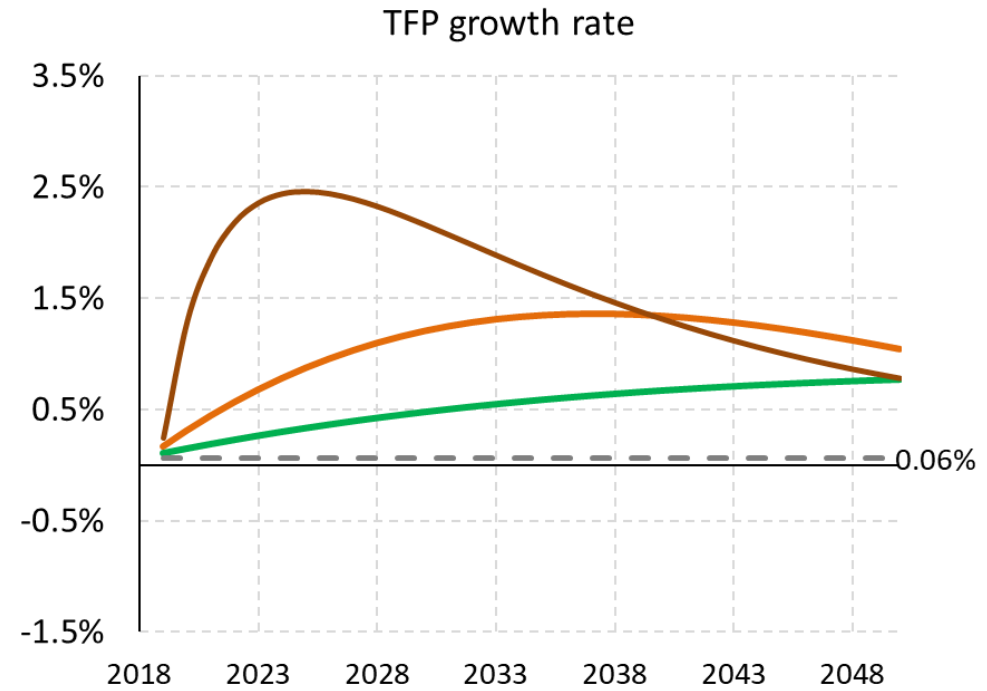
Legend:
- Trajectory of Colombia
- Trajectory of Korea, Rep.
- Korea's index (2014) in 10 years
- Historical average over 1995-2014

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# Book Structure



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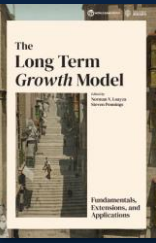
Malaysia

Korea, Rep.
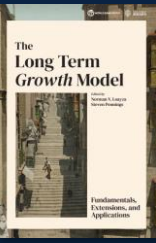
Bangladesh

Syria

Egypt

Sri Lanka

# Question: What is the quantitative effect of public investment (infrastructure) on growth?

- Crucial for development policy and lending institutions like the World Bank.

- <u>View 1: large effect</u> – China's growth miracle, large human needs and "infrastructure gaps"
  - 700m without safe drinking water and 1.2bn with reliable electricity (WB 2016); Aschauer (1989).

- <u>View 2: small effect</u> – much of empirical evidence finds no impact. Corruption & politics key.
  - "…in many countries government investment spending has created little useful capital." (Pritchett 2000)
  - "…these governments use public investment as a vehicle to increase their rent-seeking." (Knack & Keefer 2007)

- <u>Confusion</u> about quantities, levels vs changes, effect on poorest countries and dynamics
  - Do levels or changes in public K affect growth? Do effects vary by country? How long do the effects last?

→ LTGM - Public Capital (PC) extension answers all of these questions in a simple spreadsheet

(joint work with Sharmila Devadas)

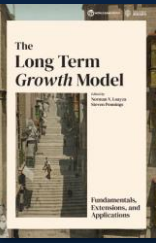# LTGM-PC splits total capital into public and private K

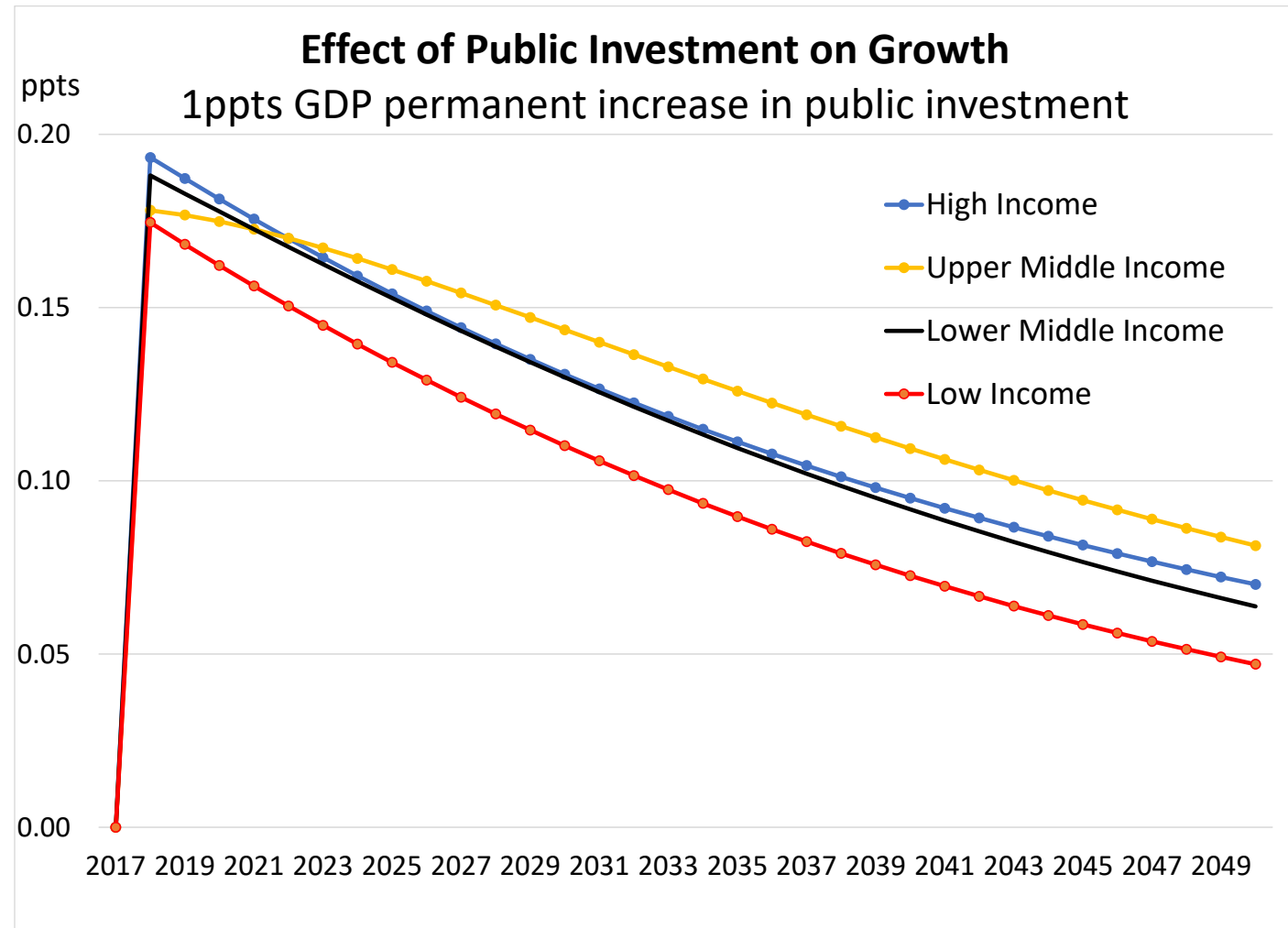- Standard LTGM (Ch 1):    $Y_t = A_t \, (K_t)^{1-\beta} (h_t L_t)^{\beta}$        $K_t$ = total capital stock

**G**overnment Capital $K_t^G$ (measured)

**P**rivate Capital $K_t^P$
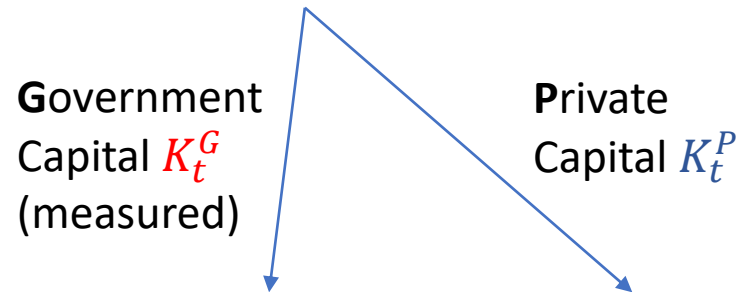
- LTGM-PC:        $Y_t = A_t \times \underbrace{[\theta_t K_t^G]}_{Efficient\ Public\ K}{}^{\phi} \times (K_t^P)^{1-\beta-\phi} (h_t L_t)^{\beta}$

- Lower "efficiency" ($\theta_t$<1) of public investment  (corruption & waste; Pritchett 2000)
  - Infrastructure efficiency index: electricity losses, unpaved roads, water losses

- $\phi$: 10% ↑public K boosts GDP by 1%-1.7% as in literature (Bom & Ligthart 2014)
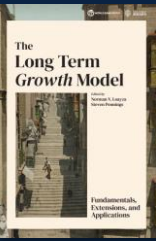
# Quantitative effect of permanent ↑ 1ppt Ig/Y

- Helpful, but no growth miracle

- **Modest & temporary** boost to growth

  - ↑0.15-0.2ppt in short run
    (excluding multiplier effects)

  - 0.05-0.1ppts after 30 years

- Effect depends on $K_t^G / Y_t$

- Diminishing MPK over time

- Similar *average* across income groups

  - Due to similar *average* $K_t^G / Y_t$

**Effect of Public Investment on Growth**
1ppts GDP permanent increase in public investment



Legend:
- High Income
- Upper Middle Income
- Lower Middle Income
- Low Income

Source: Loayza & Pennings (2022) Figure 2.3, Congestion (φ = 0.17) specification.

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# LTGM-PC Results Summary (see chapter)

1. Effect of public and private investment is heterogeneous across countries & over time
   - Depends on shortage of public capital and private capital *relative* to GDP
   - Need to have a tool like LTGM-PC to calculate effect on growth

2. In low-income (LI) countries: extra *private* investment has a larger effect on growth than *public* investment.
   - In LI: $K_P/Y$ is low: lack of credit and poor business environment

Less new
$K_G$ built

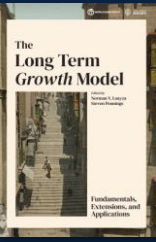3. *Level* of efficiency $\theta<1$ has *no effect* on impact of public inv. on growth (Berg et al. 2015)

$$g_{Y,t+1} \approx \cdots + \left[\frac{\phi}{\theta_t \, K_t^G/Y_t}\right] \frac{\theta_t^N I_t^G}{Y_t}$$
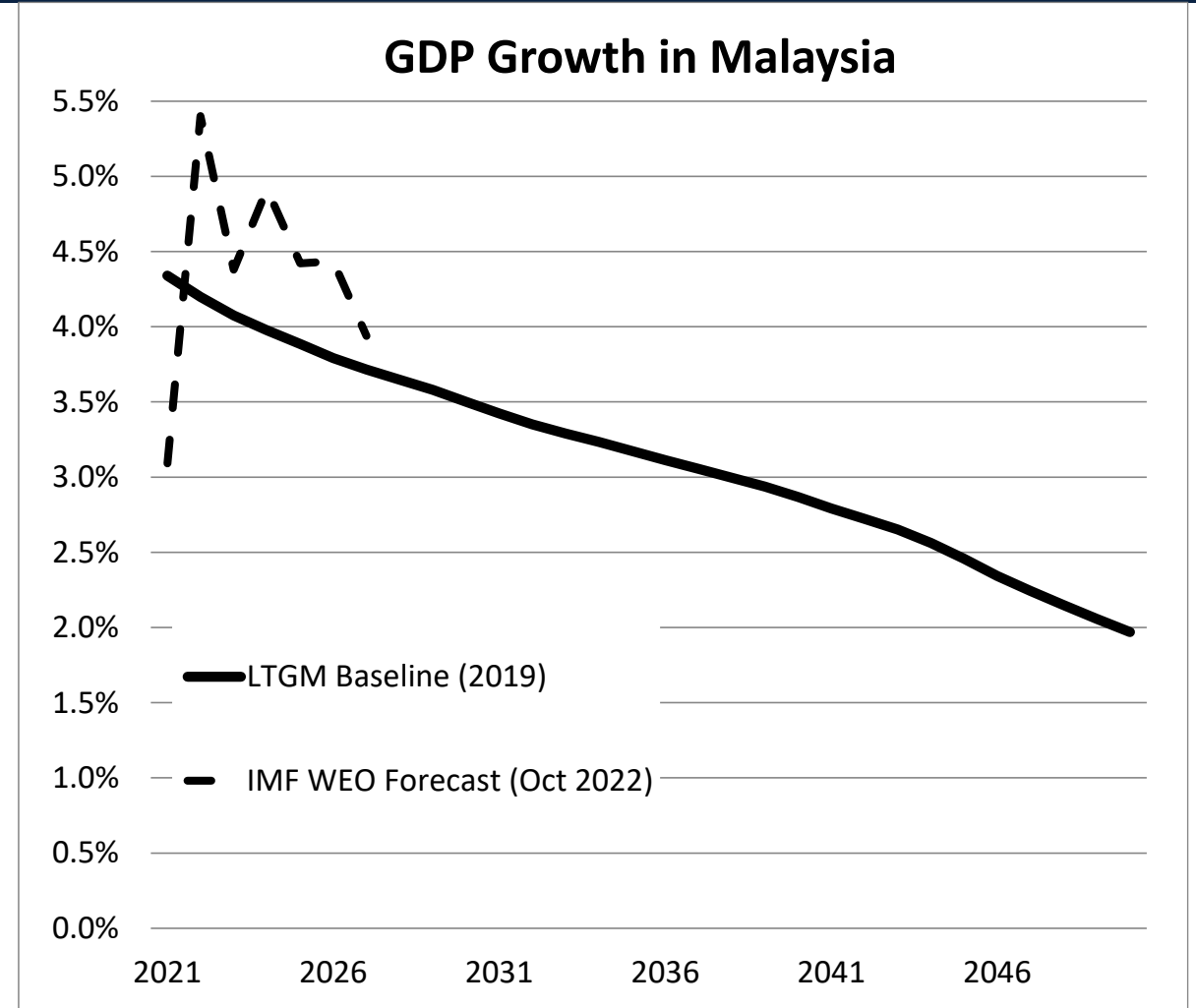
Greater need for $K_G$ : θ<1 increases $MPK_G$

4. But improving efficiency can boost growth
   - Especially in countries with high $I_G/Y$

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- Can we use higher public or private investment to sustain growth rate?

**GDP Growth in Malaysia**
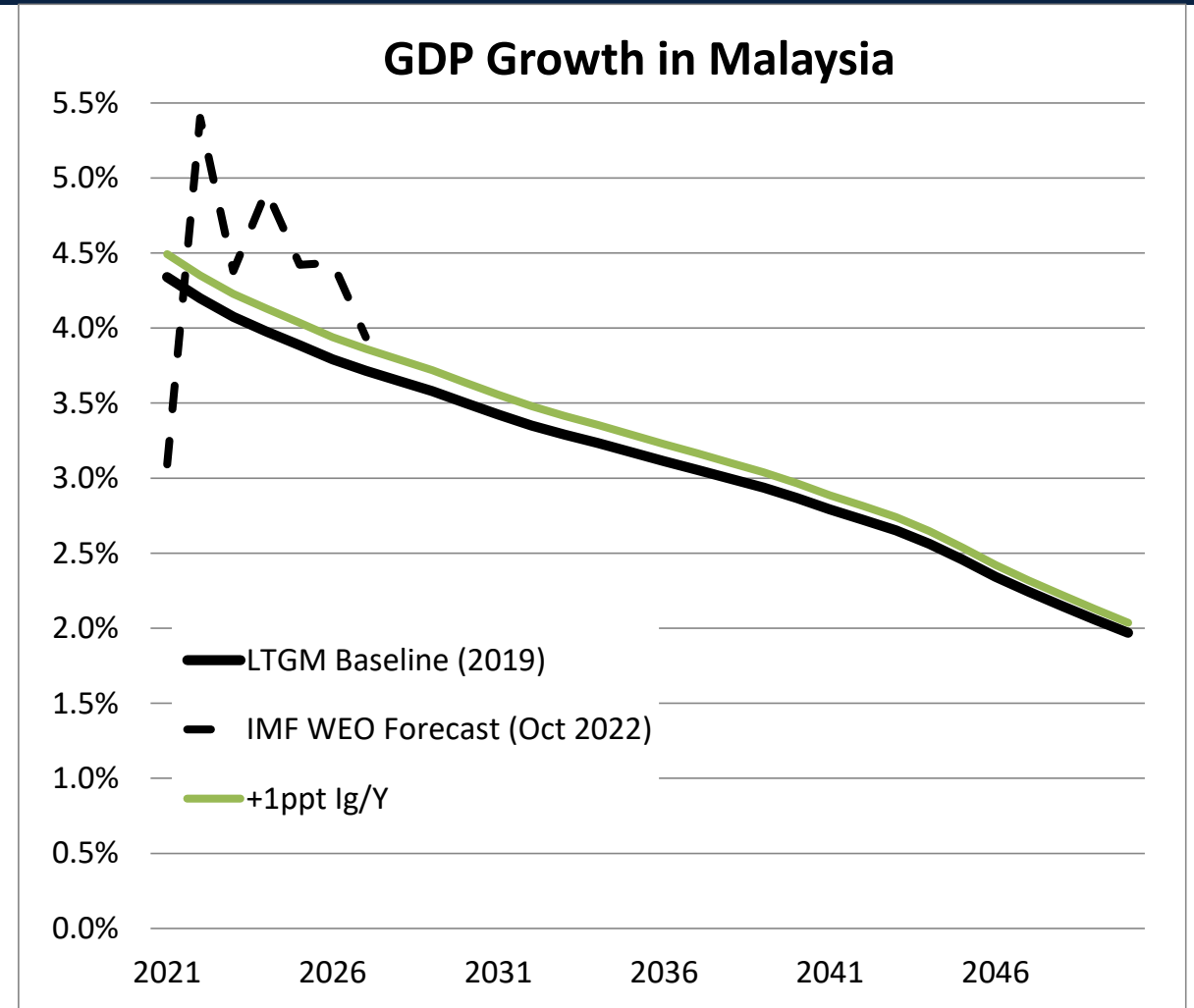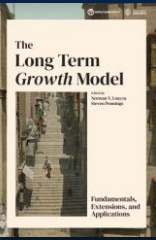


- LTGM Baseline (2019)
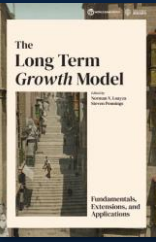- - - IMF WEO Forecast (Oct 2022)

# Application: Sustaining Growth in Malaysia (Ch 5)

- Can we use higher public or private investment to sustain growth rate?

- Permanent ↑investment:
  - ↑1ppt $I_G$/Y → 0.15ppts ↑SR growth

**GDP Growth in Malaysia**

— LTGM Baseline (2019)

--- IMF WEO Forecast (Oct 2022)

— +1ppt Ig/Y
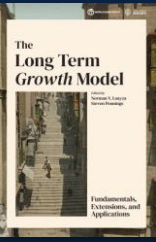
- Can we use higher public or private investment to sustain growth rate?

- Permanent ↑investment:
  - ↑1ppt $I_G$/Y → 0.15ppts ↑SR growth
  - ↑1ppt $I_P/Y$: → 0.30ppts ↑SR growth

### GDP Growth in Malaysia



Legend:
- LTGM Baseline (2019)
- IMF WEO Forecast (Oct 2022)
- +1ppt Ig/Y
- +1ppt Ip/Y

- Can we use higher public or private investment to sustain growth rate?

- Permanent ↑investment:
  - ↑1ppt $I_G/Y$ → 0.15ppts ↑SR growth
  - ↑1ppt $I_P/Y$: → 0.30ppts ↑SR growth
  - ↑2ppt $I_P/Y$: → 0.60ppts ↑SR growth

**GDP Growth in Malaysia**



Legend:
- LTGM Baseline (2019)
- IMF WEO Forecast (Oct 2022)
- +1ppt Ig/Y
- +1ppt Ip/Y
- +2ppt Ip/Y

- Can we use higher public or private investment to sustain growth rate?

- Permanent ↑investment :
  - ↑1ppt $I_G$/Y → 0.15ppts ↑SR growth
  - ↑1ppt $I_P/Y$: → 0.30ppts ↑SR growth
  - ↑2ppt $I_P/Y$: → 0.60ppts ↑SR growth

- But **cannot** sustain long-run growth
  - Due to diminishing MPK

- Need to consider combined reforms package (TFP, HC, FLFP) → see chapter

**GDP Growth in Malaysia**

Legend:
- LTGM Baseline (2019)
- IMF WEO Forecast (Oct 2022)
- +1ppt Ig/Y
- +1ppt Ip/Y
- +2ppt Ip/Y

# Book Structure

## Fundamentals ✓

| |
|---|
| The Standard Long Term Growth Model |

## Extensions ✓

| |
|---|
| Public Capital ✓ |
| Productivity Growth ✓ |
| Natural Resources |

## Applications ✓

| |
|---|
| Malaysia |
| Korea, Rep. |
| Bangladesh |
| Syria |
| Egypt |
| Sri Lanka |

- Commodity production is large share of GDP → first-order effect on LR growth
    - Can lead to poor results if apply "naïve" calibration of the standard LTGM.

- Goal is to address questions in resource-rich countries the standard LTGM can't answer:
    - How do resource discoveries and depletions affect long-run growth?
    - What is the effect of commodity price shocks on long-run growth?
    - How do fiscal rules governing revenues affect long-run growth?

- LTGM-NR adds commodity sector to standard LTGM (e.g. Oil, but could be copper, gold, etc.):

$$Y_t(GDP) = A_t K_{0,t}^{1-\beta} (h_t L_t)^{\beta} + p_T^{oil} Q_t^{oil}$$

- Spreadsheet tool with preloaded data for 56 resource-rich economies and 11 resource types
- Joint with Norman V. Loayza, Arthur Mendes and Fabian Mendez Ramos
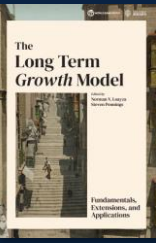
$$Q_t^{oil} = A_t^{oil} \underbrace{\left(R_{t-1}^{oil}\right)^{\gamma}}_{Reserves} \underbrace{\left(K_{t-1}^{oil}\right)^{1-\gamma}}_{Oil\ Capital}$$

- As reserves deplete ($\downarrow R_{t-1}^{oil}$): more capital/technology are needed to produce 1 barrel of oil

- Keep track of reserves based on production $Q_t^{oil}$ and exogenous discoveries:

$$R_t^{oil} = R_{t-1}^{oil} - Q_t^{oil} + Discovery_t^{oil}$$

- Allocate capital stock across sectors to equalize value of marginal product of capital

- Government taxes resource revenue, and can either **Invest** or **Save abroad** (or consume).

- Model captures long-run supply-side effects (through inv), not short-run demand-side effects

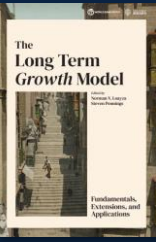# Application: An Oil Price Shock in Angola

- Scenario: large 10-year boom-bust oil price cycle

- Extra oil revenues worth ≈ 24% GDP, of which ≈ 70% accrue to the government

**Price of oil, Real 2010 U.S. Dollars/barrel**
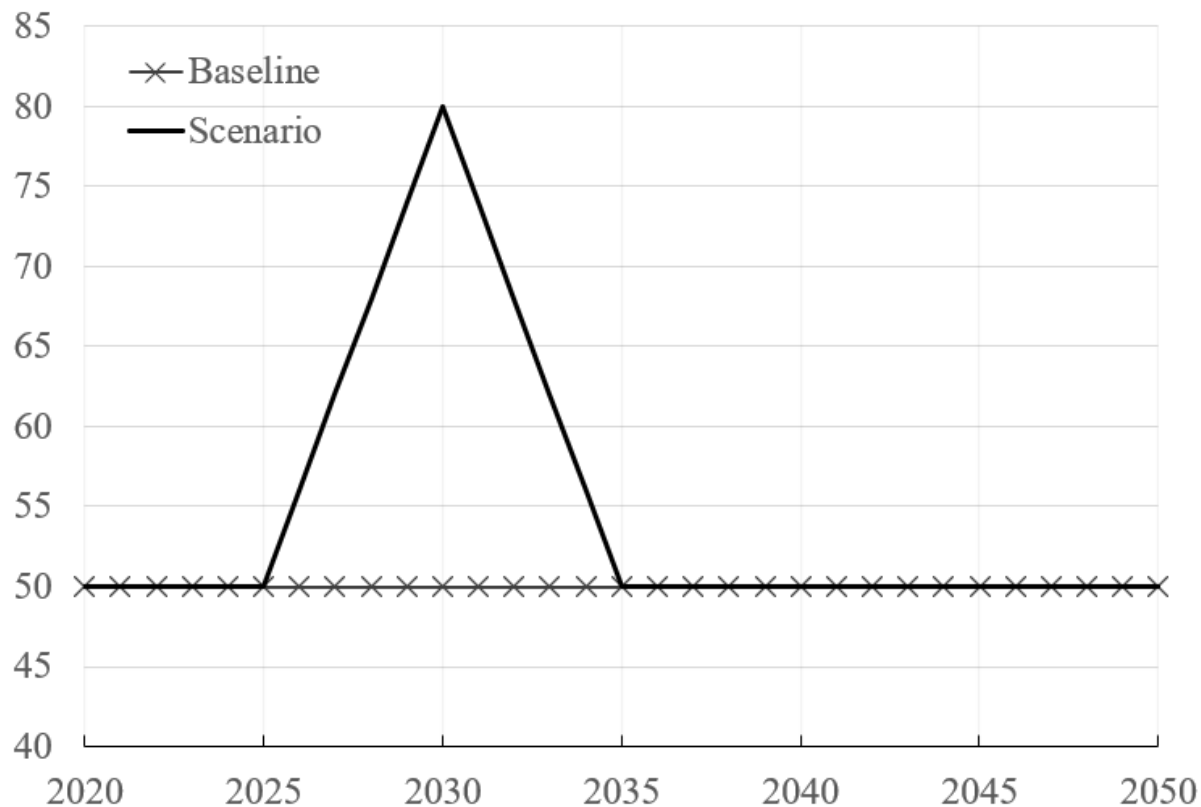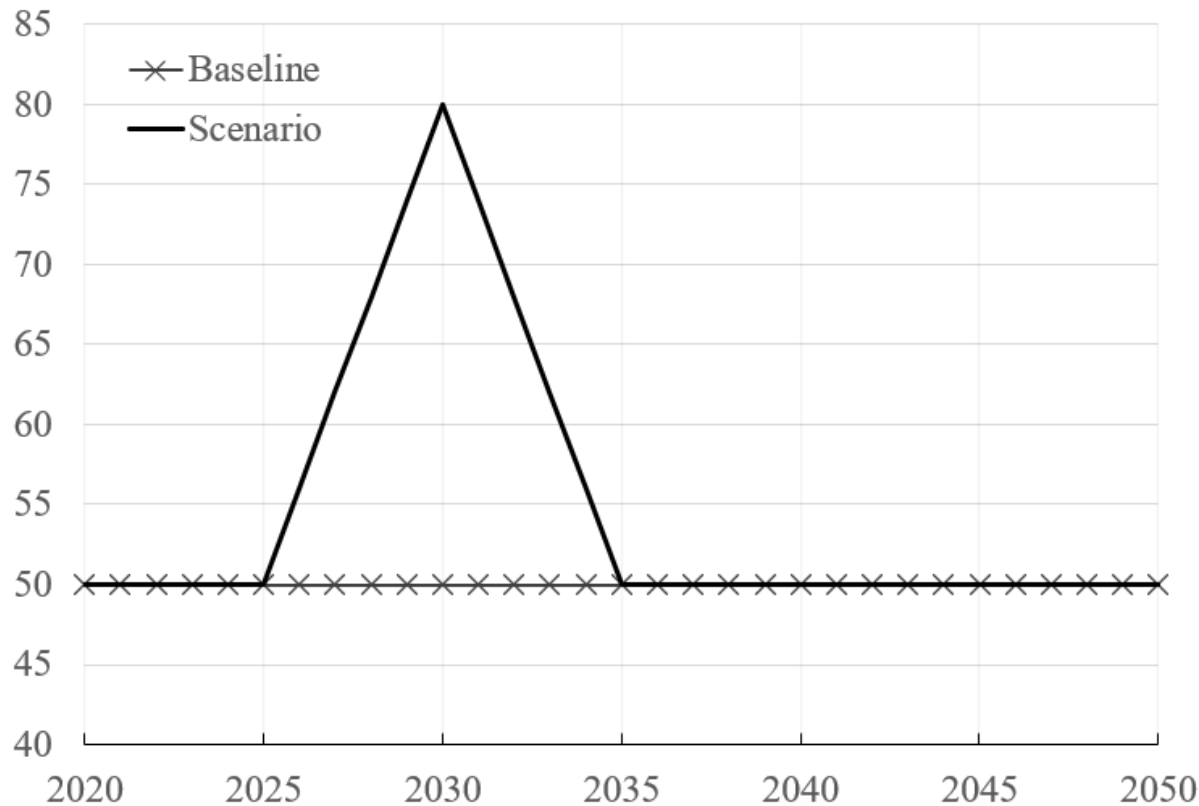
# Application: An Oil Price Shock in Angola

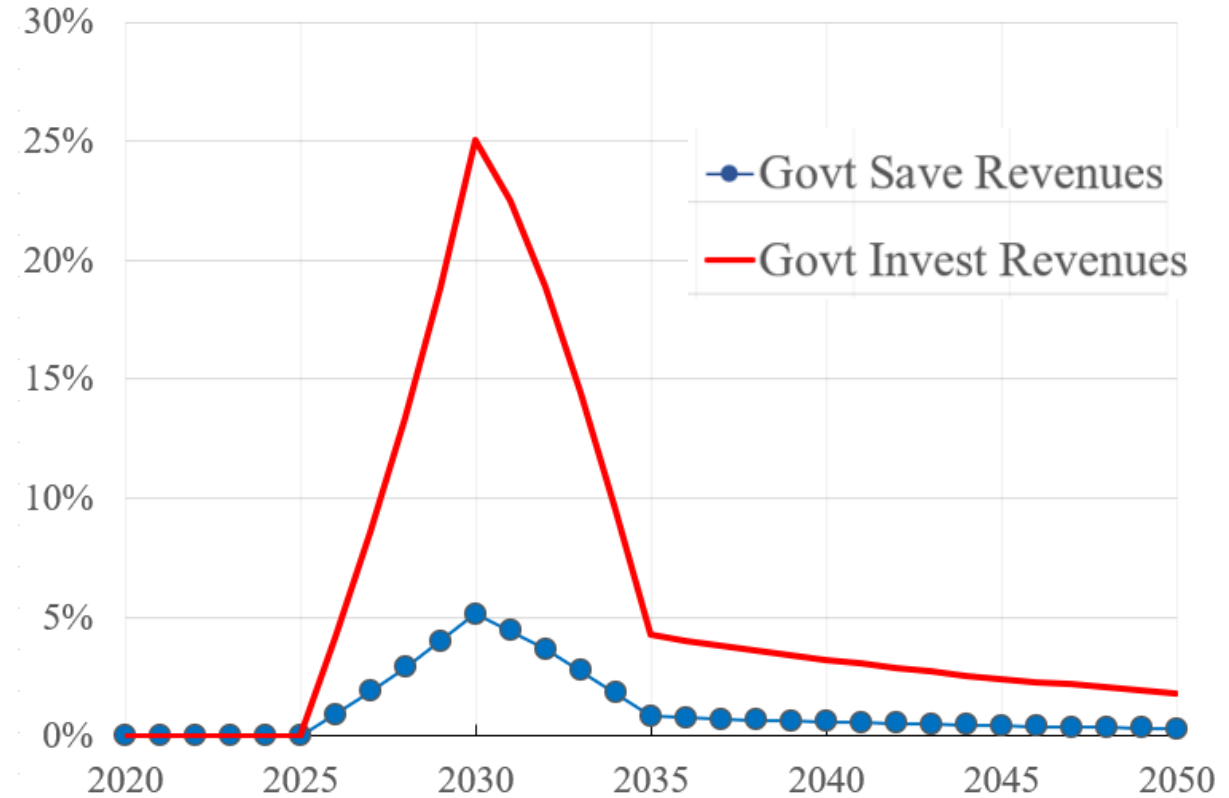- Scenario: large 10-year boom-bust oil price cycle

- Extra oil revenues worth ≈ 24% GDP, of which ≈ 70% accrue to the government

- Big change in investment depending on whether government invests or saves the windfall
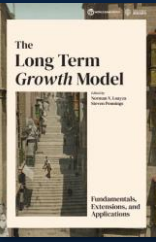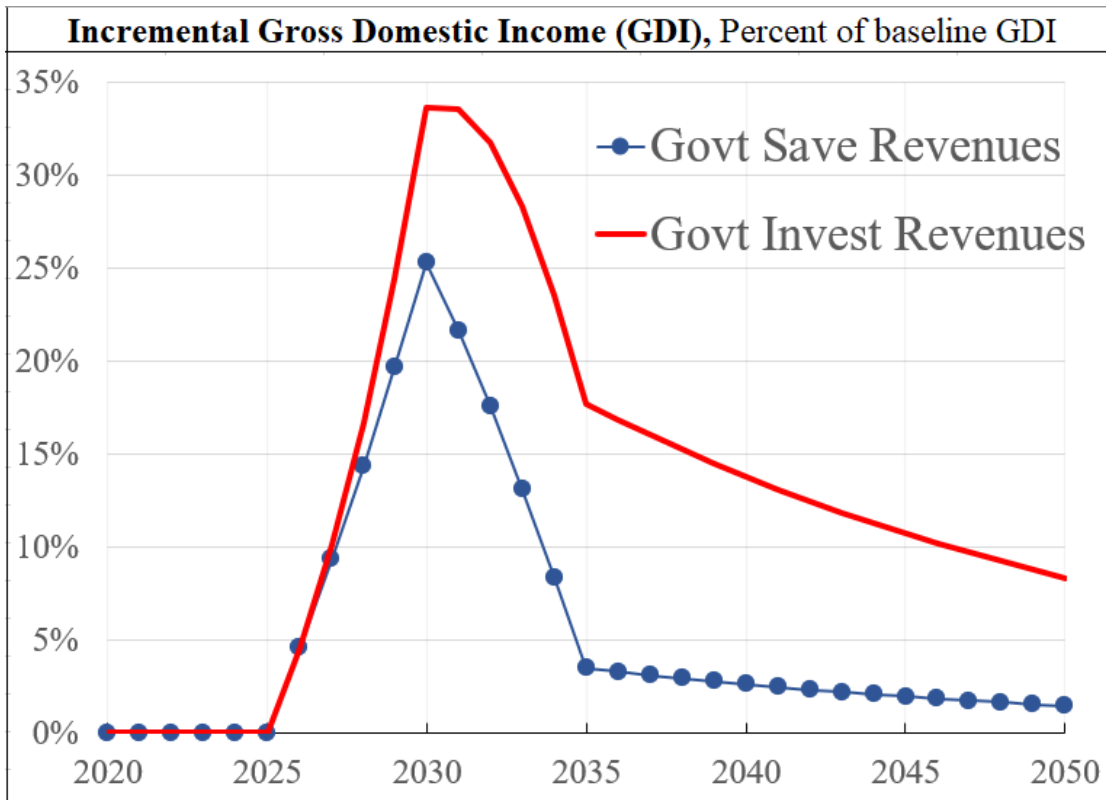


Price of oil, Real 2010 U.S. Dollars/barrel



Deviation in Total investment, Percent of GDI

# Effects of commodity price shocks on GDP vs GDI

- Oil prices have a big effect on Gross Domestic **Incomes** (GDI), mostly due to 24ppts extra oil revenues

**Incremental Gross Domestic Income (GDI),** Percent of baseline GDI
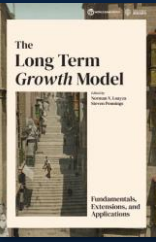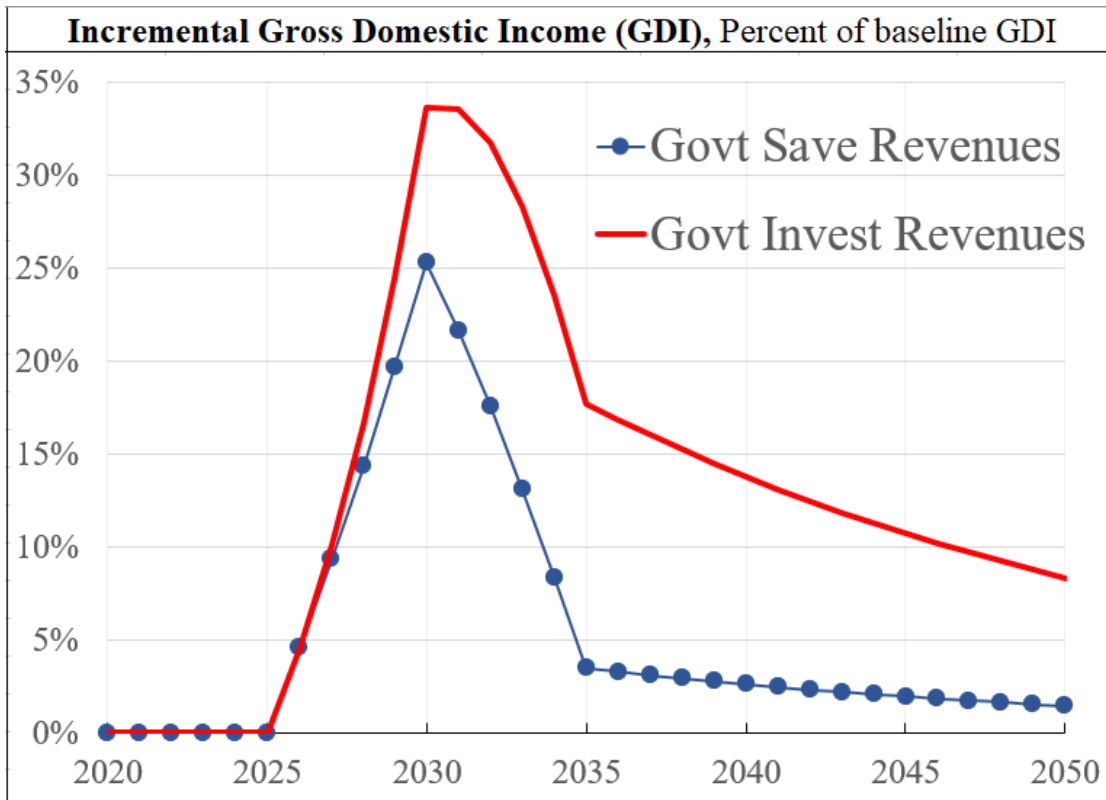
# Effects of commodity price shocks on GDP vs GDI

- Oil prices have a big effect on Gross Domestic **Incomes** (GDI), mostly due to 24ppts extra oil revenues
- However, oil prices **do not** directly affect real potential GDP (constant export prices; Kehoe & Ruhl 2008)

**Incremental Gross Domestic Income (GDI),** Percent of baseline GDI

# Effects of commodity price shocks on GDP vs GDI

- Oil prices have a big effect on Gross Domestic Incomes (GDI), mostly due to 24ppts extra oil revenues

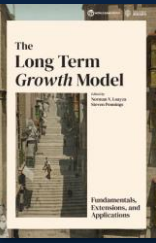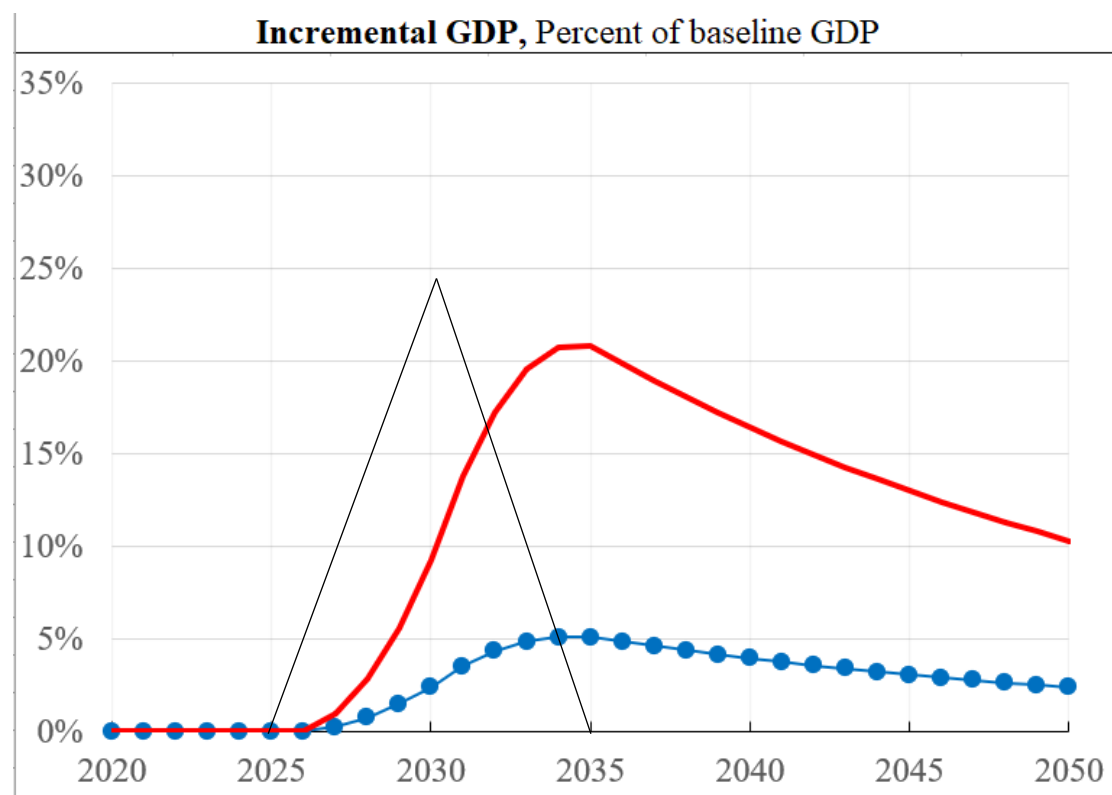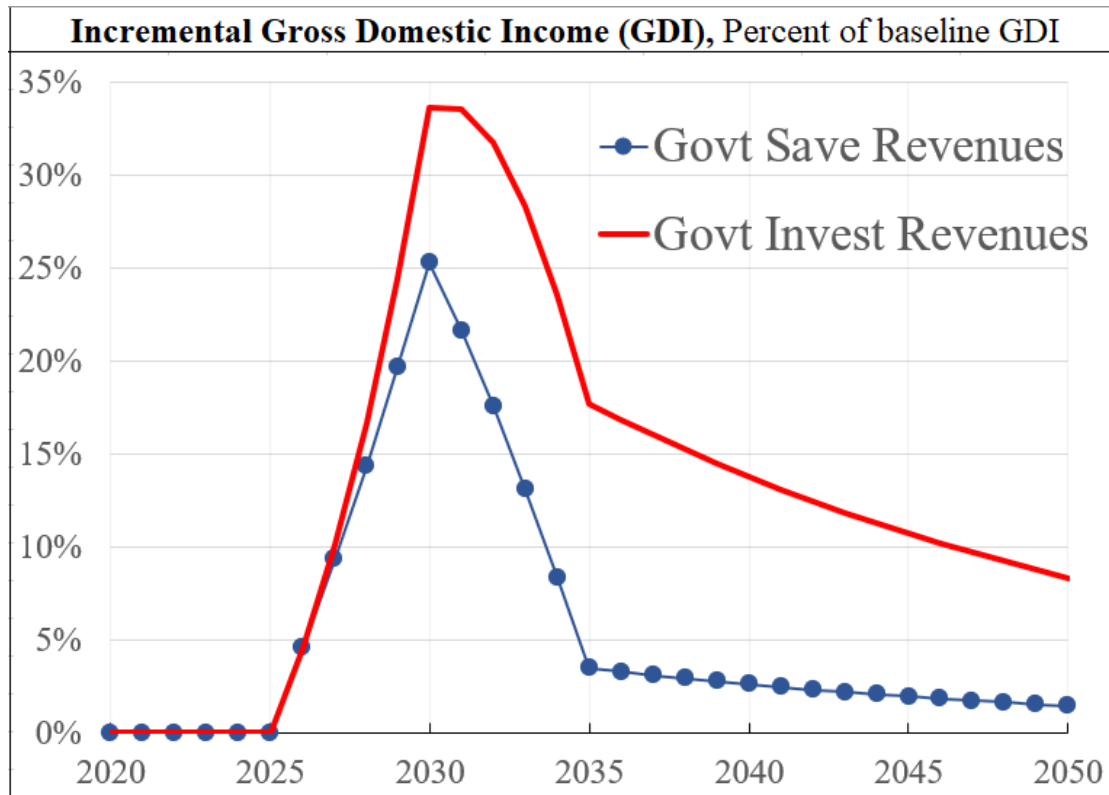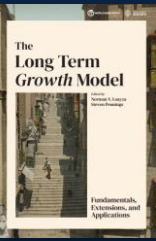- However, oil prices **do not** directly affect real potential GDP (constant export prices; Kehoe & Ruhl 2008)

- Instead boost **indirectly**: depends if the government saves (SSR) or invests the revenues (Hartwick Rule)
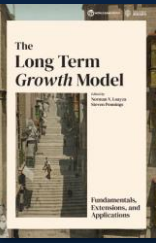


**Incremental Gross Domestic Income (GDI),** Percent of baseline GDI

**Incremental GDP,** Percent of baseline GDP

- Govt Save Revenues
- Govt Invest Revenues

# Lessons: among a multitude of findings,
## four takeaways are worth highlighting.

1. Although all fundamental drivers of growth matter, their relative importance varies across countries.

   → Growth performance, constraints, and opportunities also vary with country context.

2. Investment-led growth strategies are unsustainable in the long run

3. In the medium term, investment may raise growth but would need to be accompanied by matching savings

4. High growth usually involves fast productivity growth

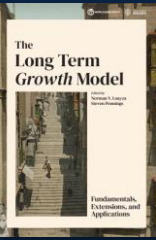# LTGM developed by DEC in partnership with MTI

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[www.worldbank.org/LTGM](www.worldbank.org/LTGM)

# Thanks!