The Long Term Growth Model: Fundamentals, Extensions, and Applications

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Football fans would like to play like Messi...
Pop singers would like to sing like Aretha Franklin...
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!
Economic growth is the foundation on which social and economic development rests. It creates jobs and generates income, fosters innovation and entrepreneurship, promotes political and social stability, and provides resources to fund public services and infrastructure. Therefore, economic growth is the key to eliminating poverty and providing for shared prosperity, especially when it is inclusive, sustainable, and enduring. Not surprisingly, economic growth is often at the top of policy agendas.
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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Is “dreaming big” on growth a good thing?

• Yes! ... if you are implementing a sound economic strategy to achieve realistic growth targets
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• 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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  • A method to produce *alternative* growth scenarios
  • A way to understand the *determinants* behind those scenarios, including policy

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• 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](http://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
Book Structure

Fundamentals
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Applications
- Malaysia
- Korea, Rep.
- Bangladesh
- Syria
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The Standard Long Term Growth Model

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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, \( y_t^{PC} \)):

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

\( A_t \): 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

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

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

• **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 = \( \frac{1 - \beta}{K_t/Y_t} \) (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.
The Standard Long Term Growth Model

Public Capital
Productivity Growth
Natural Resources

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:
  - \(\text{Ave. TFP growth}_{c,t,t-5} = \beta_1 \ln(\text{Index}_{c,t-5}) + \beta_2 \ln(\text{TFP level})_{c,t-5} + \delta_t + \theta_c\)
  - Higher index \(\rightarrow\) faster TFP growth, with a diminishing effect

5 Productivity Determinants From Literature Review

- Innovation
- Education
- Institutions
- Infrastructure
- Market Efficiency
Regional simulation: what if countries could replicate the trajectory of Korea in the TFP overall determinant index?

Korea, Rep. increased the index the most among all developing countries during 1985-2014.
Country simulation: Peru following Korea (world leader) or Colombia (regional leader)
The Standard Long Term Growth Model

Fundamentals

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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.

  - **View 1: large effect** – 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).

    - “…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)

- Confusion 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): \[ Y_t = A_t \left( K_t \right)^{1-\beta} \left( h_t L_t \right)^\beta \] where \( K_t \) = total capital stock

- LTGM-PC: \[ Y_t = A_t \times \left[ \theta_t K_t^G \right]^\phi \times \left( K_t^P \right)^{1-\beta-\phi} \left( h_t L_t \right)^\beta \]

  - Efficient Public K

- 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* $K_t^G / Y_t$

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

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

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

\[ g_{Y,t+1} \approx \cdots + \left[ \frac{\phi}{\theta_t} \frac{K_t^G}{Y_t} \right] \frac{\theta_t^N I_t^G}{Y_t} \]

- Greater need for $K_G$: $\theta<1$ increases $MPK_G$
- Less new $K_G$ built
Application: Sustaining Growth in Malaysia (Ch 5)

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

GDP Growth in Malaysia

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

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<th>Year</th>
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Can we use higher public or private investment to sustain growth rate?

Permanent ↑investment:
- ↑1ppt $I_G/Y \rightarrow 0.15$ppts ↑SR growth
- ↑2ppt $I_P/Y : \rightarrow 0.30$ppts ↑SR growth
- But cannot sustain long-run growth

Due to diminishing MPK

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

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- ↑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 Application: Sustaining Growth in Malaysia (Ch 5).
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Motivation: Growth in resource-rich economies

- Commodity production is a large share of GDP → first-order effect on long-run (LR) growth
  - Can lead to poor results if apply “naïve” calibration of the standard Long-Run Growth Model (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
Production of Natural Resources in the LTGM-NR

\[ Q_{oil}^t = A_{oil}^t \left( \frac{R_{oil}^{t-1}}{Reserves} \right)^\gamma \left( \frac{K_{oil}^{t-1}}{Oil\ Capital} \right)^{1-\gamma} \]

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

- Keep track of reserves based on production \( Q_{oil}^t \) and exogenous discoveries:
  \[ R_{oil}^t = R_{oil}^{t-1} - Q_{oil}^t + Discovery_{oil}^t \]

- 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 $\approx 24\%$ GDP, of which $\approx 70\%$ accrue to the government
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
Oil prices have a big effect on Gross Domestic Incomes (GDI), mostly due to 24ppt extra oil revenues.

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

Instead, the effect is indirect: depends if the government saves (SSR) or invests the revenues (Hartwick Rule).

Effects of commodity price shocks on GDP vs GDI.
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Effects of commodity price shocks on GDP vs GDI

![Graph showing incremental gross domestic income (GDI) as a percent of baseline GDI from 2020 to 2050, with two lines: one for government saving revenues and one for government investing revenues.](image-url)
• Oil prices have a big effect on Gross Domestic Incomes (GDI), mostly due to 24 ppts 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).

**Effects of commodity price shocks on GDP vs GDI**
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
co-TTLs:
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Steven Pennings

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