Long-term Growth Model Natural Resource Extension (LTGM-NR) - Instructions and a Worked Example[1]
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The LTGM-NR spreadsheet can be accessed at https://www.worldbank.org/LTGM and refers to LTGM-NR v1.0. See working paper Mendes et al (2022) "Assessing the Effects of Natural Resources on Long-Term Growth: An Extension of the World Bank Long Term Growth Model" for a description of the model. This document only describes how to use the LTGM spreadsheet and only the "Default" Submodel: First the structure, then a worked example to (approximately) replicate the results in Mendes et al (2022) for Angola.

1. Spreadsheet Structure

There are two submodels of the LTGM-NR (both submodels generate paths for a baseline and a scenario)
- the "Default" submodel – which has simple fiscal rules – discussed here and is sufficient for most users.
- the "External Balance" submodel – which takes account of other fiscal rules, and requires a more advanced treatment of the current account (for more advanced users and not discussed here)

For the default model flows flow as follow

Input Parameters → Graphs of assumptions → Model Calculations → Formatted model outputs → Graphs of Outputs
Tabs: (InputDataA/B)   (GraphsA/GraphsB_Default)   (Default, Default_s)   (GraphsDefault_X)   (GraphsB_Default)

Input tabs: Users choose the country and simulation parameters in tabs InputDataA and InputDataB:
- **InputDataA** contains parameters that affect both models, such as the country, selection of commodities, labor, resource rent and capital shares, and paths for TFP, human capital, demographics, commodity prices and future resource discoveries.
- **InputDataB** contains parameter that only affect the default submodel (Part I) or external balance submodel (Part II). For the default submodel, these include the government tax rate, path for private investment, fiscal rule and long-run public investment

GraphsA: Graphs the assumptions that affect all models (eg TFP, HC, discoveries etc). Other submodels specific assumptions are graphs in GraphsB_Default (and GraphsB_ExternalBalance GraphsB_ExternalBalance_PS).

Model calculations of the LTGM-NR – Read-only tabs (inputs taken from InputDataA and InputDataB)
- **Default –**calculations for the default model for the *baseline*
- **Default_s tabs. –**calculations for the default model for the *scenario* (denoted by "s")
- **ExternalBalance Model, ExternalBalance Model_s tabs:** calculations for the external balance model.

GraphsDefault_X (X=GDP, GDI, FR, INV, K, Q, R): Formats the Default model outputs that appear in the output graph for (GDP, Gross Domestic Income, Fiscal Variables, Investment, Capital Stock, Resource output (Q) and Reserves (R)). These are a "halfway house" between the model calculations in Default, Default_s and the graphs in GraphsB_Default. The equivalent graphs for the external balance model are hidden.

Output graph tabs: Contains all the graphs of assumptions and outputs. Click the yellow cells in the first columns to generate more options for how each graph is drawn (for example, in growth rates or as a share of GDP etc)
- **GraphsB_Default:** Contains all the graphs from the Default Model. Links to **GraphsDefault_X** (below)
- **GraphsB_ExternalBalance GraphsB_ExternalBalance_PS:** Contains graphs from the external balance model (we don't discuss those here)

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2. Replication for Angola in Mendes et al (2022) (approximate)[2]
2.1 Angola Baseline as in Figure 1

A. Start in tab InputDataA: (Parameters are listed in Mendes et al 2022 table 3)
Part 1: Set up (Country, Natural Resource Sectors and Time periods)
- Choose Country=Angola [cell B4] from the dropdown menu.
- Choose Resource Sector 1=Oil [cell C13], and keep the other two possible resource sectors blank [cells C14 and C15] as we are only simulating the oil sector.
- Choose base year for commodity prices =2010 from drop down menu [cell C18]

Part 2: Set Main Parameters and Initial Conditions
Notes: (i) remember to scroll all the way to the right and (ii) as we only choosing one resource sector, there will be many blank rows greyed out where options for the other sectors might go in other countries.
- Depreciation rate: most recent 20 year average from PWT10 (should be 4.4%) [C26]
- Elasticity of substitution across sectors is the default of 1 [C32]
- Aggregate labor share (economy wide): 5 years average PWT10 (should be 0.34) [C38]
    - Note that once we update the size of the oil sector, this is will automatically generate a non-resource labor share of 0.56
- Capital share of oil sector (1-resource rent share= $(1-\gamma)$)=0.66.
    - This needs to be manually entered in yellow cells [E55] and [E56] as is a bit different from the preloaded data (preloaded data uses averages, whereas this calibration uses medians).
- Initial GDPPC =$2,890 hardcoded in cells J45:K45
- Exports of oil at base prices =50.8% of GDP (hardcoded): J55:K55
- Initial oil price = $50/barrel hardcoded: O55:P55
- Initial capital to output ratio =2 hardcoded (baseline and scenario) cells T45 and U45
  (Check that capital is allocated across sectors to satisfy optimality in the dropdown menu of S56)
- Initial reserves are preloaded using most recent data from BP Energy (2017) of 9.52bn barrels (cell X56)

Part 3: Set paths for exogenous variables: Demographics and Labor Markets
- Demographics variables should all be on "automatic mode", which are based on UN forecasts:
    - Population growth dropdown menu on "Automatic (UN forecast)" [D80:E80]
    - Male Population share dropdown menu on "Automatic (UN forecast)" [D90:E90]
    - Working age Population share dropdown menu on "Automatic (UN forecast)" [D100:E100]
- Labor Market Participation variables should be set to the most recent observation (2019) from the dropdown menu for male [C112] and female [C123].
    - Most important is that the future participation rates should be the same as the current rates for male and female. That is D115=D113, E115=E113, D124=D126, E124=E126.[3]

Part 4: Set paths for exogenous variables: Human Capital and Total Factor Productivity (TFP)
- Human Capital Growth: Initial value *hardcoded to 0.7%* in baseline [D135] and scenario [E135].[4] Human capital growth should be constant so future values in baseline [D140] and scenario [E140] should be equal to those initially [D137] and [E137]
- TFP growth in the non-resource sector should be *hardcoded* to 1%, which is the median across lower middle income countries over 2000-19 (though that is not in the dropdown menu). This means we need to type 1% for

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baseline [D144] and scenario [E144]. TFP growth in the non-resource sector should also be constant over time for baseline [D149=D144] and scenario [E149=E144].

- TFP growth in the oil sector should be *hardcoded* at 0%, in baseline [D153] and scenario [E153]. This is the median across oil exporters over 2000-19, but that is not in the dropdown menus. It should also be held constant, by setting the target values equal to initial for baseline [D158=D155] and scenario [E158=E155]

Part 5: Set paths for exogenous variables: Natural Resource Prices

- We will revisit this to replicate the scenario with an oil price shock. But for now set the oil price level as constant $50. Choose "DEFAULT: Automatic (price level target)" from the dropdown menu [D184]
  - The targets should be equal to initial for baseline [D192=D182] and scenario [E192=E182].
- The reference price of oil (for fiscal rules) should be set equal to the initial value. This is done manually by setting the reference price equal to the initial price of oil. That is for each of Cells I236:Al236 equal to D182 (and likewise for the scenario, were cells I237:Al237 are equal to E182).
- The reference (structural) production of oil (for fiscal rules):
  - Baseline: Set equal to actual production for in the baseline, that is set the dropdown menu on C248 equal to "Default: structural production = actual production".
  - Scenario: Set equal to actual production in the baseline, that is set the dropdown menu on C249 equal to "Structural production in scenario equals actual production in baseline".[5]

Part 6: Set paths for exogenous variables: Discoveries of Natural Resources

- *Hardcode* discoveries each year at 400m barrels of oil per year in baseline [D263] and scenario [E263].[6] We will revisit this below for the discoveries shock.
- Make sure the target for discoveries by 2050 equals initial discoveries for baseline [D268=D265] and scenario [E268=E265].

B. InputDataB – parameters specific to the Default model.
We only need to input parameters in the top section (Part I) of tab InputDataB as we are not using the External Balance Model.

- Government tax rate of the oil sector is *hardcoded* to 0.7 in Cell D7 and E7 (now in tab *InputDataB*)[7]
- Initial private investment rate *hardcoded* to 20% of GDI in baseline [D13] and scenario [E13][8]
  - Set the target equal to the initial rate in baseline [D18=D15] and scenario [E18=E15]
- Long-run public investment. *Hardcode* initial target to 6% of GDI in baseline [D31] and scenario [E31].
  - Set the target to 2% of GDI, *hardcoded* in baseline [D36] and scenario [E36] by 2050 [D37 &E37].[9]
- ***Fiscal Rule. There are three options depending which line of Figure 4 and 6 the user wants to replicate (they won't make a difference in the baseline as structural resource revenues = actual revenues).
  - Hartwick rule ($\theta = 1$). Choose from dropdown menu [C23] (D22 and E22 must be blank)
  - If Structural Surplus Rule ($\theta = 0$). Choose from dropdown menu [C23] (no further choices required) (D22 and E22 must be blank)
  - If Balanced budget rule ($\theta = 0.2$) Choose from dropdown menu [C23] AND *hardcoded* 0.2 for baseline [D22] and scenario [E22]

C. Results for baseline Note that these number are unchanged as we change the fiscal rules above.

- **Tab: GraphsA** Various graphs of model inputs from InputDataA

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[5] This setup allows for a discoveries shock in the scenario below.
[6] The 25th percentile of discoveries across oil producers over 1990-2017 from BP Energy.
[7] This is the 2001-2013 average from IMF-WCE, which is not in the dropdown menu.
[8] IMF-FAD 2015-2017 average, which is similar to the 5 year average in the dropdown menu, but not exactly.
[9] Historically public investment has been very high in Angola (above 10 percent of GDP), but is expected to fall significantly over time, especially due to the likely decline in oil revenues.

- **Tab: GraphsB_Default.** Choose GDP Per Capita Annual growth rate from the dropdown menu in Cell A38. The Graph should have a U-shape, with growth around 1.5% in 2023 to 1.7% in 2048 (the last year in the graph). These numbers are very similar to those quoted in Mendes et al (2022) Figure 1.
- **Tab: GraphsDefault_GDP** Contains the GDPPC growth path from BF57:AH57 for the baseline.

2.2 Angola Oil Price Shock as in Mendes et al (2022) Figure 4

To replicate the oil price shock to $80/b in Figure 4, start with the baseline (=scenario) as described in Section 2.1. To add the oil price shock in the scenario:

- **InputdataA:**
  - **Oil Prices:** Change D184 to "Manual" and check that in baseline, all the values are $50/barrel for 2020-49 in cells I182-AL182. Next, input the path of the temporary oil price boom and fall in the scenario I186-AL186.
    - $50/b for 2020-25 and 2035-49
    - 2026 & 2034: $56;
    - 2027 & 2033: $62;
    - 2028 & 2032: $68;
    - 2029 & 2031: $74;
    - 2030: $80
  - **Discoveries:** Are now *endogenous* to fix reserves. Set Cell C264 to "Hold reserves per worker constant over time" from the dropdown menu (this simplifies the exercise).
  - **Reference production of natural resources:** set "Structural production = actual production" in the dropdown menu in cell C249 for the scenario (this simplifies the exercise).
- **GraphsA:** check that there is a price spike from $50 in 2025 to $80 in 2030 and then back to $50 by 2030, but only for the scenario (constant at $50/b in the baseline): see Tab: **GraphsA** cell C40.
- **InputdataB:** choose one of the three fiscal rules as indicated in above (search ***) – these now matter
- **GraphsB: - Incremental GDI (Figure 4B)** cell A21 choose "Scenario relative to baseline, Share of baseline GDI" in the dropdown menu to replicate Figure 4B in Mendes et al (2022).
  - *With a Hartwick rule:* GDI Scenario less baseline should peak at 34% in 2030 and drop to low 10% by the late 2040s.
  - *With a Structural Surplus Rule:* GDI Scenario less baseline should peak at 26% in 2030
  - *With a Balance Budget Rule (20%):* GDI Scenario less baseline should peak at 27% in 2030
- **GraphsB: - Incremental GDP (Figure 4C)** cell A38 choose "Scenario relative to baseline, Share of baseline GDP" in the dropdown menu to replicate Figure 4C in Mendes et al (2022).
  - *With a Hartwick rule:* GDP Scenario less baseline should peak at 21% in 2035 and drop to just above 10% by the late 2040s.
  - *With a Structural Surplus Rule:* GDP Scenario less baseline should peak at 5% in 2035
  - *With a Balance Budget Rule (20%):* GDP Scenario less baseline should peak at 8% in 2035
- **GraphsB: - GDP Growth (Figure 4D)** cell A38 choose " Scenario relative to baseline, Annual growth rate" in the dropdown menu to replicate Figure 4D in Mendes et al (2022).
  - *With a Hartwick rule:* GDPPC growth Scenario less baseline should peak at 4.3% in 2031 and drop to -0.8% by 2036.
  - *With a Structural Surplus Rule:* GDPPC growth Scenario less baseline should peak at 1.1% in 2031
  - *With a BBR (20%):* GDP Scenario less baseline should peak at 1.8% in 2031
- **GraphsB: - Public Investment (Figure 4E)** cell A4 choose "Scenario relative to baseline, Share baseline GDI" in the dropdown menu to replicate Figure 4E in Mendes et al (2022).
  - *With a Hartwick rule:* Public Investment increment should peak at 19% in 2030.
  - *With a Structural Surplus Rule:* Public Investment increment should peak at 0.15% in 2034.
  - *With a BBR (20%):* Public Investment increment should peak at 3.5%% in 2030.

- **GraphsB: - Private Investment (Figure 4F)** This figure is not available in the LTGM-NR spreadsheet as written, but Total Investment can be constructed by setting cell A55 to "Scenario relative to baseline, Share of baseline GDI". Private investment is the difference between total investment displayed here and public investment in the dot point above. For example for the Hartwick rule, public investment increases 19% GDI and total investment increases 25% of GDI yielding private investment to be around 6.5% of GDP higher as in Figure 4F (with some rounding).

2.2 Angola Discoveries Shock as in Mendes et al Figure 6

To replicate the oil discovery shock Figure 6, start with the baseline (=scenario) as described in Section 2.1:

- **InputDataA:**
  - Put discoveries on Manual model (choose "Manual" from the dropdown menu in Cell D267)
  - *Hardcode* discoveries in of 400,000,000 in every year 2000-49 in the baseline (cells I262-AL262) and every year of scenario from 2020-24 (cells I266-M266) and 2026-49(cells O266-AL266)
    - *Hardcode* a discovery in 2025 of 2,700,000,000 barrel (2.7bn or 2.7e09) [Cell N266]
  - If you started from the oil price shocks in in Section 2.2 you need undo changes to oil prices, endogenous discoveries and Reference production of natural resources, these are worth double checking
    - Oil prices are at $50/bl (Cell D184= "DEFAULT: Automatic (price level target)")
    - Reference production for scenario equals actual production in baseline (Cell C249= "Structural production in scenario equals actual production in baseline")
- **GraphsA:** check that there is a spike in discoveries in the scenario around cell C76 (and oil prices are constant at $50/bbl)
- **InputdataB:** choose one of the three fiscal rules as indicated in above (search ***) – these now matter
- **GraphsB: - Reserves (Figure 6B)** cell A89 choose "Total reserves: Levels" in the dropdown menu to replicate Figure 6B in Mendes et al (2022). Should be an increase in reserves from about 8bn to more than 10bn in 2025 (path is roughly similar across fiscal rules).
- **GraphsB: - Production of Oil (Figure 6C)** cell A106 choose "Level (per day)" in the dropdown menu to replicate Figure 6C in Mendes et al (2022). Should be an increase in production from about 2mil b/d to 2.2mil b/d from 2025-25. The Path of production should reach almost 2.5m bpd by in the Hartwick rule, and more like 2.4m bpd in a structural surplus rule or balanced budget rule (which is well above the baseline)
  - **GraphsB: - Incremental GDP (Figure 6D)** cell A38 choose "Scenario relative to baseline, Share of baseline GDP" in the dropdown menu to replicate Figure 6D in Mendes et al (2022).
    - *With a Hartwick rule:* GDP Scenario less baseline should peak at 8.3% in 2038 and drop to around 5% by the late 2040s.
    - *With a Structural Surplus Rule:* GDP Scenario less baseline should peak at 4.4% in 2031, and then fall to about 1% by the late 2040s.
    - *With a Balance Budget Rule (20%):* GDP Scenario less baseline should peak at 3% in 2033.
  - **GraphsB: - Public Investment (Figure 6E)** cell A4 choose "Scenario relative to baseline, Share baseline GDI" in the dropdown menu to replicate Figure 6F in Mendes et al (2022).
    - *With a Hartwick rule:* Incremental Public Investment increment should peak at 3.2% in 2033.
    - *With a Structural Surplus Rule:* Public Investment increment is zero.
    - *With a BBR (20%):* Public Investment increment should peak at 0.51% in 2033.
  - **GraphsB: - Private Investment (Figure 6F)** This figure is not available in the LTGM-NR spreadsheet as written, but Total Investment can be constructed by setting cell A55 to "Scenario relative to baseline, Share of baseline GDI". Private investment is the difference between total investment displayed here and public investment in the dot point above. For example, for the structural surplus rule, public investment is constant and total investment increases 0.6% of baseline yielding private investment to be around 0.6% of GDI higher as in Figure 6F.