DESA macroeconomic modelling tool and simulations for SDGs

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Outline

1. Modeling tool and methodology
2. Simulations
3. Modelling capacity building
Modelling tool and methodology

• Expanded World Economic Forecasting Model (WEFM-e)

• Assess impact of BRI on economic development of selected countries

• Simulate impact of investments in Infrastructure on income growth, labor market, fiscal sustainability, poverty reduction and so on
World Economic Forecasting Model

• Started linking country models in 1970s (LINK).
• Since 2005, integrated modelling tool covering 176 countries.

• Multi-country forecasting model
• Error-correction principle
• Supply, Demand, Monetary sides
UN World Economic Forecasting Model

- Population
- Labor participation
- Labor supply
- Export growth
- Exogenous total factor productivity
- Potential output
- Output
- Output gap
- Inflation
- Exchange rate against USD
- US inflation
- Personal consumption
- Investment
- Government consumption
- Exports and imports
- Shares on output
- Interest rates
- Output per capita
WEFM - production side

• Potential output growth depends on Trend growth of the Total Factor Productivity (TFP), change in the labor supply (labor force projection) and growth of exports

\[
\Delta YFT_t = \alpha [\Delta LFN_t + \Delta TFP_t] + (1 - \alpha)\Delta XTR_t
\]

• Trend growth of TFP depends on TFP growth itself with an error term guarantying that labor productivity does not systematically deviates from the trend growth of TFP

\[
\Delta TFP_t = \psi \Delta TFP_{t-1} + (1 - \psi)\Delta TFP_t + (1 - \psi) \frac{1}{3} \left( \frac{YER_{t-1}}{LNN_{t-1}} \right) - \Delta TFP_{t-1}
\]

• TFP growth is kept constant at 2%, 3% or 4% depending on the level of country development
Changes in WEFM-e

• Create simplified (reduced-form) version of complex non-linear relationships for
  • infrastructure investment and education level in production
  • labor participation based on GDP per capita and education level
  • Poverty reduction
  • Consumption and investment behavior in relation to expected growth and the real interest rate
  • Government debt accumulation and its impact on the country risk premium, real interest rate and the exchange rate with the back loop in private consumption and investment
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Simulations for Kyrgyz Republic

• total BRI related investment amounts to 1.3 USD billion and is spread across 7 years, from 2012 to 2018

• Investment growth is historically very volatile in Kyrgyzstan

• Medium period projection until 2023
Trend productivity growth

- **Original**
- **Modified**

Chart showing productivity growth trends from 2014 to 2023.
Potential output growth

- Original
- Modified
Poverty Headcount Rate

- 2014: 33%
- 2015: 31%
- 2016: 29%
- 2017: 27%
- 2018: 25%
- 2019: 23%
- 2020: 21%
- 2021: 21%
- 2022: 22%
- 2023: 23%

From 2014 to 2016, the poverty headcount rate decreased from 33% to 29%. After 2016, the rate fluctuated slightly, reaching 23% in 2023.
BRI related investment (SDG 9, 11) ...

• Increases in labor force participation and jobs (SDG 8)

• Decreases the gender gap (SDG 5, 8)

• Boosts the productivity growth (SDG 4, 8, 17)

• Leads to a faster output growth (SDG 8)

• Reduces poverty level (SDG 1, 10)

• Gov deficit and debt manageable (SDG 17)

• Overall, the magnitude of impacts is small, due to limited BRI investment.
Kazakhstan

- BRI related investments amounted $4.4 billion during 2012 – 2020. (Kyrgyzstan $1.3 billion)
Future work on WEFM-e

• Data

• Calibrations

• Region-integrated simulations

+ Qualitative studies
Outline

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Planned project activities

• Online access to simulation scenarios at www.brisdgs.org

• Interim report (mid 2019), and final report (mid 2020)

• Regional workshops – Tbilisi (Oct 2019), China (early 2020)

• National workshops in other countries - Kazakhstan, Azerbaijan, ... (2019-20).

• In-depth training course on modelling tools including WEFM - e if requested
Thank You!

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Production side

- Endogenous growth models extended for government services in the form of infrastructure investment postulate:
  - Infrastructure investment …
    - Increase marginal product of private investment
    - Raise level of education
  - … and combined with higher government expenditures on education
  - Raise growth of the total factor productivity
- Agénor (2011) uses following form of production function
  \[ Y = K_P^\alpha \chi E^\beta K_G^{1-\alpha-\beta} \]

Capital is presented in form of service flow

Private capital

Level of education

Infrastructure investment
WEFM - production side

- Potential output growth depends on Trend growth of the Total Factor Productivity (TFP), change in the labor supply (labor force projection) and growth of exports

\[
\Delta Y'F'T_t = \alpha [\Delta LFN_t + \Delta TFP_t] + (1 - \alpha)\Delta XTR_t
\]

- Trend growth of TFP depends on TFP growth itself with an error term guarantying that labor productivity does not systematically deviates from the trend growth of TFP

\[
\Delta TFP_t = \psi \Delta TFP_{t-1} + (1 - \psi)\Delta TFP_t + (1 - \psi) \left[ \frac{1}{3} \left( \frac{YER_{t-1}}{LNN_{t-1}} \right) - \Delta TFP_{t-1} \right]
\]

- TFP growth is kept constant at 2%, 3% or 4% depending on the level of country development
WEFM-e: production side

- TFP growth depends on level of private investment, level of infrastructure investment and level of education
- Following Hong and Li (2017) a moving average is used in order to get smooth results, while splitting the investment in private and government

$$\Delta TFP_t = A\left[\frac{1}{5}(X_t + X_{t-1} + X_{t-2} + X_{t-3} + X_{t-4})\right] - B$$

Total investment

$$X_t = \frac{ITR_t}{YER_t}$$

Hong and Li (2017)

Government investment

$$X_t = P_t^{ITR} / YER_t + 1.04 \times G_t^{ITR} / YER_t$$

Extended version with extra elasticity taken from Fedderke and Bogetic (2009)

$$\Delta TFP_t = c_1 \left(\frac{R&D_t}{YER_t}, 3\right) + c_2 (SKRAT_t, 3) + c_3 (NX_t, 2) + c_4 (GINI_t, 1) + c_5 (ITR_t^{FR}, 2) + ECM_{t-1}$$
WEFM-e: production side

- TFP growth depends on level of private investment, level of infrastructure investment and level of education

\[
\Delta TFP_t = \left[ \left( \frac{G_{t-2}^{ITR}}{YER_t} + \frac{G_{t-1}^{ITR}}{YER_{t-1}} + \frac{G_t^{ITR}}{YER_{t-2}} \right) \cdot \frac{1}{3} \right] \cdot 1.04 + \left( \frac{P_{t-2}^{ITR}}{YER_t} + \frac{P_{t-1}^{ITR}}{YER_{t-1}} + \frac{P_t^{ITR}}{YER_{t-2}} \right) \cdot \frac{1}{3} \cdot 0.14286 + 0.07 \cdot \frac{S_{MS} + S_{HS}}{S_{LS}}
\]

Extra elasticity taken from Fedderke and Bogetic (2009)

Shares of Medium, High and Low skilled labor from the data on labor force participation by education

Extra elasticity taken from Miller and Upadhyay (2002)
WEFM: labor market

• Key variable is the labor participation rate, which changes in order to avoid long lasting discrepancy between labor productivity and trend growth of TFP

\[ LRX_t = LRX_{t-1} + 20 \left[ \frac{1}{3} \left( \frac{YER_{t-1}}{LNN_{t-1}} \right) \left( \frac{YER_{t-4}}{LNN_{t-4}} \right) - \Delta TFP_{t-1} \right] \]

• This helps to keep the model from an explosive path, but growing trend TFP lowers labor participation
WEFM-e: labor market

- Labor participation rate is split in “male” and “female” components
- In line with empirical literature (ADB, 2016) the female participation rate is made dependent on level of education ...

\[ LRX_t^F = LRX_{t-1}^F + \theta [Skill\_ratio_t] \]

- ... while the male participation rate is stabilized as in the existing model

\[ LRX_t^M = LRX_{t-1}^M + 20 \left[ \frac{1}{3} \left( \frac{YER_{t-1}}{LNN_{t-1}} \right) - \Delta TFP_{t-1} \right] \]

- Total participation is defined as \( LRX_t = S_F \times LRX_t^F + S_M LRX_t^M \), where \( S_F \) and \( S_F \) are shares of female and male in the population;

- Growing female participation rate raises the overall labor force and through that the potential output growth
WEFM: demand side - Consumption

- Growth of personal consumption is determined by growth of real personal disposable income, change in population and shocks in inflation

\[ \Delta \log(PCR_t) \]

- Interest rate is not explicitly present
- Expectation channel is not present
- Closing of the output gap, i.e. difference between output \( (YER) \) and potential output \( (YFT) \) is not guaranteed
WEFM-e: demand side - Consumption

- Adding real interest rate and expectation channel through difference between expected output and potential output
  - Expectation of stronger potential output growth leads to higher consumption growth today
  - Standard interest rate channel – equilibrium real interest rate is approximated by a moving average

\[
\Delta \log(PCR_t) = \varphi_0 - \beta_1 [\log(PCR_{t-1}) - \log(RPDI_{t-1})] + \varphi_1 \Delta \log(RPDI_{t-1}) + (1 - \varphi_1) \Delta \log(POP_t) + \beta [YFT_{t+1} - YER_{t+1}] + \delta_1 [RIR_t - MA(RIR_t, 5)]
\]
WEFM: demand side - Investment

• Growth of investment is determined by discrepancy between level of investment and the gross domestic income (GDP adjusted by term-of-trade), and growth of personal consumption, government consumption and exports.

• Interest rate channel is missing

\[ \Delta ITR_t = \chi_0 - \beta_2 [ITR_{t-1} - GDI_{t-1}] + \chi_1 \Delta [PCR_t + GCR_t + \frac{XTR_t^N}{YED_t}] + \chi_2 \Delta ITR_{t-1} \]
WEFM-e: demand side - Private investment

- Investment is split in private and government investment
  - Private investment follow the same patter as total investment in existing version of the model
  - Impact of real interest rate is added to simulate eventual crowding-out effect of unsustainable fiscal policy

\[
\Delta P_{t}^{ITR} = \chi_0 - \beta [ITR_{t-1} - \alpha GDI_{t-1}] + \chi_1 \Delta \left[ PCR_t + GCR_t + \frac{XTR^N_t}{YED_t} \right] + \chi_2 \Delta P_{t-1}^{ITR} + \delta_2 [RIR_t - MA(RIR_t, 5)]
\]
WEFM-e: demand side - Government investment

- Government investment is critical – represents most of infrastructure investment
  - Modeled in proportion to government revenues to ensure sustainability
  - For practical simulations the data on government investment will be probably taken as exogenous

\[
\Delta G_t^{ITR} = \exists_1 \Delta G_{t-1}^{ITR} + (1 - \exists_1)(\Delta GGR_t - \Delta YED_t) + \exists_2 [G_{t-1}^{ITR} - \sigma(GGR_{t-1}/YED_{t-1})]
\]

Growth of government investment converges to the growth of government revenues

Level of government investment converges to chosen share on government revenues
WEFM: government budget deficit and debt

- Government consumption is related to weighted average of potential output and gross domestic income ...
  \[ \Delta GCR_t = \phi_1 \Delta YFT_t + (1 - \phi_1) \Delta GDI_t \]
- ... and government revenues to nominal GDP and nominal exports
  \[ \Delta GGR_t = \phi_2 \Delta YEN_t + (1 - \phi_2) \Delta XTN_t \]
- Budget deficit is difference between revenues on one side and government consumption and other expenditures on the other
  \[ GLN_t = GGR_t - GCR_t \times YED_t - G_t^{OTH} \]
  \[ \Delta G_t^{OTH} = \Delta YEN_t \]
WEFM: government budget deficit and debt

• Government consumption is related to weighted average of potential output and gross domestic income...

\[ \Delta GCR_t = \phi_1 \Delta YFT_t + (1 - \phi_1) \Delta GDI_t \]

• ...and government revenues to nominal GDP and nominal exports

\[ \Delta GGR_t = \phi_2 \Delta YEN_t + (1 - \phi_2) \Delta XTN_t \]

• Budget deficit is difference between revenues on one side and government consumption and other expenditures on the other

\[ GLN_t = GGR_t - GCR_t \times YED_t - G_{t \text{OTH}} \]

\[ \Delta G_{t \text{OTH}} = \Delta YEN_t \]

Other government expenditures grow at the rate of nominal GDP
WEFM-e: government budget deficit and debt

• Other government expenditures are redefined as a combination of government investment and interest payments on existing debt

\[ G^\text{OTH}_t = (G^\text{ITR}_t \times YED_t) + G^\text{IRP}_t \]

• Interest payments depend on previous period government debt and interest rates

\[ G^\text{IRP}_t = GDN_{t-1} \times STI_{t-1} \]

• Budget deficit suddenly depends on interest rates and same applies for the debt

\[ GDN_t = GDN_{t-1} - GLN_t \]
WEFM: monetary policy

• Monetary policy block is for majority of countries reduced to a relative version of purchasing power parity (PPP) equation that determines the exchange rate depending on inflation differential

\[ EXR_t = EXR_{t-1} \times \left[ \frac{(\pi_t - \pi_{t,USA})}{100} + 1 \right] \]

Real exchange rate is assumed to be constant implicitly

• That works for all countries with fixed or managed exchange rate
  • Majority of countries in the world despite of official rhetoric
WEFM-e: monetary policy

- It allows to introduce a reverse version of the uncovered interest rate parity (UIP) equation and determine domestic nominal interest rate suing US rates and expected change in the exchange rate.

\[ STI_t = STI_{USA} + \left( \frac{EXR_{t+1}}{EXR_t} - 1 \right) \times 100 + PREM_t \]

- Risk premium depends on government debt:

\[ PREM_t = PREM_{t-1} \times \omega \left[ \frac{GDN_t}{YED_t} - \epsilon \right] + 1 \]
WEFM-e: monetary policy

- Real interest rate that enters equations for personal consumption and private investment is calculated using Fisher equation

\[ RTI_t = STI_t - \pi_{t+1}^{YED} \]

- And the risk premium enters also the PPP equation to capture the impact of mounting government debt on the exchange rate

\[ EXR_t = EXR_{t-1} \left[ \frac{(\pi_t - \pi_{t}^{USA})}{100} + 1 \right] \times \left[ \frac{PREM_t}{100} + 1 \right] \]
WEFM-e: monetary policy block

- In countries with floating exchange rate and well established monetary policy framework and monetary policy operations the nominal interest rate can be determined by an interest rate rule

\[
STI_t = c_1 STI_{t-1} + (1 - c_1)[MA(RIR_t, 5) + \pi_{t+1}^E + c_2(\pi_{t+1}^E - \pi^T) + c_3 \hat{Y}_t]
\]
WEFM-e: poverty reduction

• We follow the WB’s Long Term Growth Model (LTGM v4.1) developed by Pennings (2018)

• Assumptions:
  • Gini coefficient – 0.364 (for Laos, according to the latest data from the WB);
  • Poverty line, L – 0.8 USD/day (for Laos, according to the latest data from ADB);
  • $\ln(y^{PC}) \sim N(\mu, \sigma^2)$, where $y^{PC}$ is the income per capita in USD, $\mu$ is the mean of income per capita (in log) and $\sigma^2$ is the variance;

• The poverty headcount rate $P$, which is the proportion of people with incomes below the poverty line $L$
  • $P_t = \Phi\left(\frac{\ln L - \mu_t}{\sigma_t}\right)$, where $\Phi(.)$ is the standard normal CDF;

• The aim is to calculate $P_{t+1}$;
WEFM-e: poverty reduction

• **Step 1**: standard deviation $\sigma$ is calculated using the Gini coefficient from $G_t = 2\phi \left( \frac{\sigma_t}{\sqrt{2}} \right) - 1$
  
  \[ \sigma_t = \sqrt{2} \cdot \Phi^{-1} \left( \frac{G_t + 1}{2} \right) \]

• Based on assumptions about Gini coefficient and the equation above, $\sigma_t$ equals 0.669 (and is constant over time, as Gini is constant);

• **Steep 2**: calculate the initial value of $\mu_t$:
  
  • Based on the assumption of poverty line, $L$ and the initial value of headcount rate, $P$ (to be 0.234 for Laos, according to the latest WB data), we can calculate initial value of $\mu_t$ from:
  
  \[ \mu_t = \ln(L) - \sigma_t \cdot \Phi^{-1}(P_t); \]

  • For the initial period of 2010, $\mu_t = 0.2626$. 
WEFM-e: poverty reduction

• **Step 3**: next step is to calculate the future values of $\mu_t$:
  • The economic growth will shift the whole income distribution to the right by increasing the mean, $\mu$;
  • Therefore, growth of the GDP per capita can be written as:
    \[
    1 + g_{y,t+1}^{PC} = \frac{\exp\left(\mu_{t+1} + \frac{\sigma_{t+1}^2}{2}\right)}{\exp\left(\mu_t + \frac{\sigma_t^2}{2}\right)}
    = \exp\left(\mu_{t+1} - \mu_t + \frac{1}{2} (\sigma_{t+1}^2 - \sigma_t^2)\right)
    \]
  • From this equation we can get the equation for $\mu_{t+1}$:
    \[
    \mu_{t+1} = \ln\left(1 + g_{y,t+1}^{PC}\right) + \mu_t - \frac{1}{2} (\sigma_{t+1}^2 - \sigma_t^2)
    \]
    • Using the approximation rule $(1 + g) \approx g$ (for small enough $g$), the equation above becomes:
    \[
    \mu_{t+1} = g_{y,t+1}^{PC} + \mu_t - \frac{1}{2} (\sigma_{t+1}^2 - \sigma_t^2)
    \]
Development – poverty reduction

• Step 4: having the values of $\mu_{t+1}$, we can now calculate the future values of poverty headcount rate, $P_{t+1}$;

• We can use the following equation:

$$P_{t+1} = \Phi\left(\frac{\ln L - \mu_{t+1}}{\sigma}\right)$$
WEFM-e: Data Issues (1)

- Different measures have been proposed in the literature to measure the infrastructure investment;
  - Commonly used measure – GFCF;
    - Not all components of GFCF are related to infrastructure;
- To overcome this problem, the ADB (2017) report proposes three alternative measures, which (potentially) more accurately estimate infrastructure investment;
- The description of the ADB (2017) methodology was sent to National Consultants in November 2018;
WEFM-e: Data Issues (2)

• Examination of the effect of R&D and Human Capital on TFP requires collection of more data:
  • Time series data on R&D expenditure (as a % of GDP) by country can be found in the following sources:
    • The World Bank data;
    • The UNESCO database (Science, Technology and Innovation section);

• Note: significant portion of the data might be missing for some countries, therefore, the National Consultants are encouraged to look for the data in other sources;
WEFM-e: Data Issues (2’)

• The data on Human Capital can be extracted from the International Labour Organization’s (ILO) database;

• The data on following variables can be collected:
  • Labour force participation rate by sex, age and education;
  • Labour force participation rate by sex and age – ILO modelled estimates, July 2017;
  • Employment distribution by education (by sex and age);
  • Employment-to-population ratio by sex and age;
  • Unemployment rate by sex, age and education;
  • Unemployment rate by sex and age – ILO modelled estimates, May 2018;
  • Unemployment distribution by education (by sex and age);

• The ILO database give an option to choose these specific variables with a desired time range.