# Macroeconomic benchmarking and the *But-for-COVID* scenarios:

appendix to[a]

# *The Impact of COVID-19 and Associated Policy Responses on Global Food Security*

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## 1. The 2019 Benchmark

The model follows closely the GTAPINGAMS structure as documented by Lanz and Rutherford (2016). The structure is initially calibrated to GTAP 10 accounts for 2014 (nominal US dollars). The benchmark is then extended to 2019 based on the GDP growth and other macroeconomic data as reported by the IMF World Economic Outlook (or alternatively the USDA projection series). In particular, the consumption, public spending, investment shares of GDP are matched to the chosen (IMF or USDA) data series in the 2019 benchmark equilibrium. Aggregate export and import shares are also targeted. The trade shares are not exactly matched because there is an overall constraint that the global sum of net capital inflows must be zero. We use a constrained least-squares procedure that minimizes the proportional deviations from the data implied current account balances.

The IMF World Economic Outlook (IMF/WEO) series that we rely on are presented by ISO countries and regions and these are mapped to corresponding GTAP countries and regions. We further aggregate the GTAP countries and regions to the study-specific countries and regions of interest. In the context of Balistreri, Baquedano, and Beghin (2021) these include a set of 17 countries or regions that cover those most important for our food security analysis:

[a] This appendix provides a description of the benchmarking and scenarios developed to support our research on the impacts of COVID 19 on global food security (Balistreri, Baquedano, and Beghin, 2021). The development of these methods was supported in part by a cooperative agreement (58-3000-0-0043) between the U.S. Department of Agriculture, Economic Research Service, and the University of Nebraska—Lincoln.
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| | |
|---|---|
| IND India | PAK Pakistan |
| NGA Nigeria | ETH Ethiopia |
| CIS Commonwealth of Independent States | CSA Central Southern (and other) Asia |
| SEA South East Asia | LAC Latin America and the Caribbean |
| NAF North Africa | CAF Central Africa |
| EAF East Africa | SAF Southern Africa |
| WAF West Africa | CHN China and Hong Kong |
| USA USA | EUR Europe including GBR and CHE |
| ROW Rest of World | |

The specific series that we used from the IMF/WEO data to build a time series of macroeconomic targets (for 2019, 2020, and 2021) include:

| | |
|---|---|
| NGDPD | Nominal GDP in U.S. dollars |
| NID_NGDP | Total investment percent of GDP |
| GGX_NGDP | General government expenditures percent of GDP |
| BCA_NGDPD | Current account balance percent of GDP |
| TX_RPCH | Volume of exports percent change |

The IMF/WEO do not indicate exports as a percent of GDP so we use the series of growth rates applied to the GTAP 10 (2014) date to establish an estimate of aggregate exports. Aggregate imports are impled by the current-account balance.

## 2. The 2020 and 2021 COVID and *But-for-COVID* scenarios

With the 2019 benchmark equilibrium established we proceed to a set of scenairos consistent with the years 2020 and 2021. First we compute the *But-for-COVID* (BfC) equilibria as a base to which we can add the COVID shocks as implied by the IMF (or alternatively USDA) projections as well as sector specific shocks. For each region we need a set of four income targets (the 2020 BfC GDP target, the 2020 GDP COVID target, the 2021 BfC GDP target, and the 2021 COVID GDP target) to determine the implied structural productivity impacts of COVID on the macroeconomy. While the COVID inclusive targets can be read directly off of the IMF (or USDA) projections, we must estimate the BfC GDP targets.

### *2.1 Deriving the Income Targets*

For 2020 the general method of establishing the BfC GDP targets proceeds by calculating the average GDP growth rates for the country or region between 2014 and 2019 as indicated in the IMF/WEO data (or USDA data). This is the assumed trajectory going into 2020 in the absence of COVID. We impose this growth rate on 2019 GDP to get the 2020 BfC targets for most regions. There are some regions, however, that had insufficient historical growth between 2014 and 2019 relative to the projected growth in 2020 to indicate a realistic COVID income shock. For those

regions where the implied COVID income deviation was less than 1% (CIS -0.6%) or even slightly expansionary (NGA 0.5%, NAF 1.7%, EAF 1.3%, and WAF 0.3%) our BfC GDP targets were determined to be too low. For each of these regions we imposed the average deviation across all regions, -3.2%, to establish their BfC 2020 GDP targets.

For 2021 we proceed slightly differently because the 2021 WEO growth projections actually exceed our average 2014-2019 historical growth rates for most countries, leading to an unexpected expansionary COVID relative to BfC scenario. To establish the 2021 BfC GDP targets we take the 2020 BfC GDP target and scale it by the ratio of WEO projected 2022 to 2021 GDPs. This uses the WEO projected region growth rate from 2021 to 2022 as a proxy for the BfC growth rate from 2020 to 2021. The logic is that the reported growth rate from 2020 to 2021 is still substantially contaminated by the projected COVID recovery. As an alternative, applying the 2020 to 2021 rates would give substantially similar results as compared to the 2020 scenarios because both the BfC and COVID growth rates are the same. Furthermore, we do not use the average growth rates as calculated from 2014 to 2019 to scale the 2020 BFC target because these are less applicable to the projections established in the WEO. Using this method did give us a positive COVID rebound for 2021 for a few regions (NGA 1.3% and WAF 0.5%) as well as Europe (EUR 3.2%), but for the majority of regions COVID income targets are well below the BfC estimates. For the USDA 2021 runs, we use the growth index for real GDP as implied by the USDA projections relative to 2019, which are relatively less optimistic about income recovery from COVID. The USDA growth indexes are applied to the established 2019 benchmark as given by the WEO 2019 data. This gives us a common starting point for the sensitivity analysis between IMF and USDA runs. Table 1 reports the IMF/WEO based GDP targets for each of our regions as percent deviations from the 2019 benchmarks. Table 2 presents the targets under the USDA projections.

We also incorporate information on COVID related changes in expenditure shares across the GDP components consumption, investment, government spending, and net trade. In the BfC scenario, however, the component shares adjust endogenously given the productivity adjustments necessary to achieve the BfC GDP targets. Overall adjustments in the component shares of GDP for the BfC scenario relative to the 2019 benchmark are minor given our static structure that assumes exogenous real investment, government spending, and international capital flows. The only changes in these values are due to changes in their prices relative to the chosen numeraire. For the COVID scenarios we impose the investment, government spending, and current account shares as indicated in the WEO/IEA series. The consumption share is a residual given our targeting of aggregate income (GDP). For many countries there is a large shift into public spending as a response to COVID, which we reflect in our equilibria. In the scenarios based on USDA aggregate GDP projections we still apply the shares (of consumption,

**Table 1.** IMF/WEO based COVID and BfC Income (GDP) targets:
percent deviation from 2019 benchmark and difference (COVID less BfC)

| | | Benchmark GDP ($B) | COVID (%) | | BfC (%) | | Difference COVID (%) - BfC (%) | |
|---|---|---|---|---|---|---|---|---|
| | | 2019 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 |
| Ethiopia | ETH | 92.6 | 4.3 | 1.5 | 11.3 | 10.1 | -7.0 | -8.6 |
| Southern Africa | SAF | 98.9 | -6.4 | 1.8 | -0.6 | 6.2 | -5.9 | -4.3 |
| Commonwealth of Independent States | CIS | 197.3 | -4.1 | 4.5 | -0.9 | 6.2 | -3.2 | -1.6 |
| Central Africa | CAF | 208.4 | -14.1 | -3.3 | -4.2 | 0.0 | -9.9 | -3.4 |
| West Africa | WAF | 244.7 | 4.1 | 16.9 | 7.4 | 16.4 | -3.2 | 0.5 |
| East Africa | EAF | 255.4 | 2.7 | 9.0 | 5.9 | 12.4 | -3.2 | -3.4 |
| Pakistan | PAK | 276.1 | -4.8 | 5.7 | 2.5 | 9.3 | -7.3 | -3.6 |
| Nigeria | NGA | 448.1 | -4.2 | 14.7 | -0.9 | 13.4 | -3.2 | 1.3 |
| North Africa | NAF | 689.0 | 0.8 | 9.2 | 4.0 | 10.3 | -3.2 | -1.1 |
| Central and Southern Asia including Other Asia | CSA | 856.0 | -13.2 | -1.8 | 3.0 | 13.9 | -16.2 | -15.7 |
| Latin America and the Caribbean | LAC | 1,085.5 | -11.5 | -2.6 | 1.0 | 7.0 | -12.4 | -9.5 |
| South East Asia | SEA | 1,871.9 | -3.4 | 4.9 | 5.2 | 14.2 | -8.6 | -9.3 |
| India | IND | 2,870.5 | -5.6 | 6.2 | 7.1 | 16.3 | -12.7 | -10.1 |
| China | CHN | 14,706.3 | 2.5 | 15.7 | 6.3 | 15.0 | -3.9 | 0.6 |
| Europe including Gt Brit and Switz. | EUR | 18,469.6 | -3.2 | 9.7 | -0.3 | 6.5 | -2.9 | 3.2 |
| USA | USA | 21,433.2 | -2.3 | 5.8 | 4.1 | 10.2 | -6.4 | -4.4 |
| Rest of World | ROW | 23,690.5 | -6.8 | 3.3 | -0.5 | 5.0 | -6.2 | -1.7 |

**Table 2.** USDA based COVID and BfC Income (GDP) targets:
percent deviation from 2019 benchmark and difference (COVID less BfC)

| | | Benchmark GDP ($B) | COVID (%) | | BfC (%) | | Difference COVID (%) - BfC (%) | |
|---|---|---|---|---|---|---|---|---|
| | | 2019 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 |
| Ethiopia | ETH | 92.6 | 3.1 | 7.2 | 8.9 | 15.3 | -5.8 | -8.1 |
| Southern Africa | SAF | 98.9 | -3.8 | -1.5 | 2.5 | 5.8 | -6.3 | -7.3 |
| Commonwealth of Independent States | CIS | 197.3 | -4.2 | -1.0 | 4.3 | 8.2 | -8.5 | -9.2 |
| Central Africa | CAF | 208.4 | -3.5 | -1.2 | 0.6 | 3.6 | -4.1 | -4.8 |
| West Africa | WAF | 244.7 | -1.1 | 3.7 | 5.7 | 11.5 | -6.8 | -7.8 |
| East Africa | EAF | 255.4 | 0.0 | 3.7 | 4.9 | 9.6 | -4.9 | -5.8 |
| Pakistan | PAK | 276.1 | -2.4 | -9.4 | 4.5 | 11.5 | -6.9 | -20.8 |
| Nigeria | NGA | 448.1 | -5.4 | -2.9 | 1.2 | 4.2 | -6.6 | -7.1 |
| North Africa | NAF | 689.0 | -6.6 | -7.9 | 3.6 | 8.6 | -10.2 | -16.5 |
| Central and Southern Asia including Other Asia | CSA | 856.0 | -10.2 | -4.5 | 2.4 | 7.8 | -12.7 | -12.3 |
| Latin America and the Caribbean | LAC | 1,085.5 | -9.2 | -6.5 | 2.6 | 6.0 | -11.8 | -12.6 |
| South East Asia | SEA | 1,871.9 | -3.5 | 1.0 | 5.7 | 11.8 | -9.1 | -10.8 |
| India | IND | 2,870.5 | -6.9 | -0.9 | 6.9 | 12.3 | -13.8 | -13.1 |
| China | CHN | 14,706.3 | 1.3 | 8.4 | 6.6 | 12.6 | -5.3 | -4.2 |
| Europe including Gt Brit and Switz. | EUR | 18,469.6 | -8.9 | -5.0 | 2.1 | 5.5 | -11.0 | -10.6 |
| USA | USA | 21,433.2 | -5.8 | -2.1 | 2.4 | 5.4 | -8.2 | -7.5 |
| Rest of World | ROW | 23,690.5 | -6.7 | -3.7 | 1.2 | 4.1 | -7.9 | -7.8 |

investment, government, and current account) from the WEO/IEA series so the only variation is in the aggregate GDP projections across regions.

*2.2 Application of the macroeconomic targets: the BfC baseline*

With the GTAPinGAMS structure calibrated to the 2019 benchmark we establish a new baseline equilibrium for the 2020 and 2021 BfC cases. The relevant macroeconomic targets are incorporated by adding a set constraints and a variables that alter the productivity of the three primary factors (unskilled labor, skilled labor, and capital). Let the new variable be denoted $\psi_r$, where $r$ is the region index. Given an endowment of factor $f$ of $E_{fr}$ consistent with the 2019 equilibrim, the endowment is adjusted to $\psi_r \cdot E_{fr}$ in the BfC baseline cases. The added variables $\psi_r$ are matched to the a regional constraints that the measured GDPs equal the targets.

Nominal GDP in the model for region r, measured in numeraire units, is given by

$$PC_r C_r + PI_r \bar{I}_r + PG_r \bar{G}_r - P^w \overline{KA}_r,$$

where $PC_r$ is the price of the consumption composite (true-cost-of-living index) and $C_r$ is the quantity of private consumption. Similarly, $PI_r$ and $PG_r$ are price indexes associated with the goods used for real investment, $\bar{I}$, and real government spending, $\bar{G}$. Associated with the real capital account surplus, $\overline{KA}$, is the price of international capital-flow assets, $P^w$. We assume that $P^w = \sum_r \theta_r PC_r$, where $\theta_r$ is region-r's benchmark weight in global consumption ($\theta_r = C_r^{2019} / \sum_r C_r^{2019}$).[1] The price indexes are necessary because the real quantities (C, I, G, and T) are measured in inherrently different units. That is, the mix of component goods in private consumption are different from the mix of component goods in investment. Nominal sums across components, like income, are put into common units via the price indexes. Furthermore, the added constraint must maintain price homogeneity (Walras' Law applies) in the general equilibrium. We must chose a consistent set of units for interpreting the developed GDP targets. We chose the regional cost-of-living index ($PC_r$) such that the constraint is as follows:

$$PC_r \widehat{GDP}_r = PC_r C_r + PI_r \bar{I}_r + PG_r \bar{G}_r + P^w \overline{KA}_r, \tag{1}$$

where $\widehat{GDP}_r$ is the target established in the previous section. Numerically, the added variable, $\psi_r$, adjusts until this added constraint is satisfied.[2]

[1] In a static model that accommodates observed trade imbalances one must chose the real units that are transfered via capital flows. In our case we assume that the composite commodity associated with private consumption is transfered in proportion to benchmark consumption shares. This avoids allocating importance to one good or region, which can generate exagerated terms-of-trade effects when there are movements in the price of that good.

[2] Technically, the equilibrium is solved as a mixed complementarity problem (MCP),

*2.3 Sectoral total-factor-productivity shocks*

We take the deviations (COVID-BfC) to measure the impact of the pandemic relative to the baseline. We then rely on these underlying conditions and parameters to derive the implied real income shocks for unskilled labor and food price changes consistent with the observed and projected shocks in deviation from the BfC baseline.

Beyond matching aggregate value added in each country to the IMF and USDA GDP predicted shocks, we also shock Total Factor Productivity (TFP) in key sectors. This reflects the uneven nature of the scenario with a reduction in the productivity of all factors in sectors deeply affected by the pandemic and border closing—trade (wholesale and retail), warehousing and support activities, water transport, and other transport. We also capture the sharp decrease in demand in sectors for which consumers scaled back their consumption because of self-imposed or required distancing to abate health risk. We do this by scaling back the utility weight into the utility function. This corresponds to a decrease in effective utility of the good affected by the decrease. Demands are scaled back for hospitality and tourism related sectors (accommodations and food services, recreational and other services, and air transport). Finally, we capture the loss of productivity in perishable agriculture (meat and dairy, and vegetables, fruit, and nuts) as in Laborde et al. (2021). These shocks work their way through the model and translate into labor productivity changes and labor income, in particular for unskilled labor categories, which exacerbates food insecurity issues. Table 1.b summarizes the shocks in percent deviation from the BfC baseline for 2020 for the two sets of runs (IMF and USDA). Shocks for 2021 are shown in Appendix Table A.1. The TFP and demand shocks are shown in Table 1.c for 2020. Corresponding TFP and demand shocks for 2021 are set at 50 percent of the 2020 shocks.

The estimated changes in real income, income distribution and in real food prices are then fed recursively in USDA's IFSA model (Beghin et al., 2017; Baquedano et al, 2020) to predict food insecurity consequences of COVID-19 in 80 low- and middle-income countries.

Additional assumptions

Regarding aggregation of sectors, all agricultural and food sectors are kept as in GTAP10, although we aggregate Meat and Dairy products into a single category we aggregate all nonfood manufacturing into a large single manufacturing sector. We keep the three GTAP transport sectors disaggregated, as well as warehousing with wholesale and retail trade, accommodation food and service activities (tourism-hospitality related), and recreation to simulate sector specific shocks in TFP and demand as discussed above. The detail sectoral aggregation is shown in Appendix Table B.1.

The IFSA model estimates the calorie intake per income decile in 80 low- and

where there is a complementary slack relationship between $\psi_r$ and equation (1).

middle-income countries. The various food goods are aggregated in 4 groups (major grain, other grains, roots and tubers, other food) and then further aggregated into grain calorie equivalent to yield a total calorie intake. The specification follows a PIGLOG formulation relying on income, price

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