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The impact of COVID-19 and associated policy responses on global food security

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Abstract

We analyze the impact of the COVID-19 pandemic and associated policy responses on the global economy and food security in 80 low- and middle-income countries. We use a global economy-wide model with detailed disaggregation of agricultural and food sectors and develop a business-as-usual baseline for 2020 and 2021 called "But-for-COVID" (BfC). We then shock the model with aggregate income shocks derived from the IMF World Economic Outlook for 2020 and 2021. We impose total-factor productivity losses in key sectors as well as consumption decreases induced by social distancing. The resulting shocks in prices and incomes from the CGE model simulations are fed into the USDA-ERS International Food Security Assessment (IFSA) model to derive the impact of the pandemic on food security in these 80 countries. The main effect of the pandemic was to exacerbate the existing declining trend in food security. Food insecurity increases considerably in countries in Asia through income shocks rather than prices effects. We also review trade policies that were put in place to restrict imports and exports of food, and we evaluate their potential for further disruption of markets focusing on the food-security implications.

KEYWORDS
COVID-19, food security, market disruption, pandemic, trade costs

JEL CLASSIFICATION
F14, I32, Q17, Q18

1 | INTRODUCTION

Global food security is an important concern, particularly in low- and middle-income countries. In these countries, depending on sources (SOFI, USDA), between 811 million (SOFI 2021) and more than 1 billion (Baquedano, Zereyesus, Christensen et al., 2021a) people are estimated to be food insecure while agricultural markets and trade remain volatile because of disruption in supply chains. Global food insecurity has been on the rise in recent years even before the COVID-19 pandemic which accentuated the growing insecurity (SOFI 2021). The COVID-19 pandemic and associated policies responses have had a considerable impact globally, disrupting agricultural and food supply chains, contracting trade and income in most countries—often impacting the vulnerable economic groups—and shrinking the travel and hospitability sectors an important source of revenue for not only OECD

economies but low- and middle-income countries. The food retail industry, in its food-away-from-home segment, has also been affected as many restaurants closed. Supply chains have been disrupted by labor shortages. The economic recovery in the second half of 2020 and first half of 2021 has been surprisingly fast in high-income countries, led by the United States (IMF, 2021b). But in low- and middle-income countries outside of China, reflecting less access to vaccines, it has been much slower (IMF, 2021b).

Governments responded to the pandemic first by imposing social distancing policies, and then by reopening in a staggered fashion with several key sectors reopening at a fraction of their pre-pandemic levels (travel, hospitality, and retailing in particular). Agriculture was recognized as essential by many governments and face fewer restrictions. Further, programs have been put in place to soften the blow of the income shocks for consumers and several industries including in low- and middle-income countries with the help of international financial institutions. In OECD countries considerable unemployment took place in 2020 and then a recovery in labor markets has been taking place in 2021 as economies started re-opening, but unemployment levels still remain high (IMF, 2021a).

As the pandemic remains a foreseeable health threat and force of disruption, it is important to assess the implications of these economic shocks and partial recovery on global food security. What have been the impacts of the pandemic and associated policies on global agricultural, food supplies and trade, income, and consumption levels? Our article assesses the impact of the pandemic and its various disruptions and policy responses on global food security, with its detailed impact on world food supplies and consumption by income group using aggregate income information derived from the IMF (2021a).

We use an integrated modeling structure combining a world Computable General Equilibrium (CGE) model based on the GTAPinGAMS structure (Lanz & Rutherford, 2016) with the USDA ERS' International Food Security Assessment (IFSA) model (Baquedano, Zereyesus, Christensen et al., 2021a; Baquedano, Zereyesus, Valdes et al., 2021b; Beghin et al., 2017) to assess the impacts of the COVID-19 pandemic shock of 2020, and the uneven recovery in 2021. The version of the IFSA model used in this article uses an expanded database and focuses on 80 low- and middle-income countries. The CGE model provides changes in real prices of food, and real income which are then incorporated into the disaggregated food demand system of the ISFA model to predict nutritional gaps and food insecurity by income decile in these 80 low-and-middle-income countries.

We find that the aggregate real income shocks and those affecting unskilled labor were the major cause of a considerable increase in food insecurity. With the number of food insecure increasing by 163.2 million in 2020 compared to a 2020 but for COVID-19 (BfC) baseline. This increase caused by the pandemic shock comes in addition to the increasing food insecurity estimated in the BfC baseline in 2020, relative to 2019 (84.2 million). India, Nigeria, Central and Southern Africa, and Central and Southern Asia accounted for most of this increase caused by long-term trends. The pandemic exacerbates food insecurity in India, Central and Southern Asia, Pakistan, Latin America and the Caribbean, South East Asia and East Africa. Interestingly, we find that effective unskilled labor use falls but their real wage increases, partially offsetting the blow of lower employment. Food insecurity patterns for 2021 (1042.5 million insecure people) imply a mitigation of income shocks with the uneven recovery and fewer food-insecure people than in 2020 but still above 2019 by 174.6 million.

Real food price changes contribute to a much lesser extent because the bulk of disruptions in food supply chains take place well beyond the farmgate, sparing most of agricultural production. Reliance on trade actually decreases in many countries during the pandemic because of reductions in food demand and increases in trade costs induced by logistics issues. Many real local food prices fall. These trade contractions also translate into income reductions in export-dependent countries. We also note that trade-restricting policies have been limited in scope and over time and have had no measurable impact on food security and markets. Not included in this exercise is the fact that world commodity markets had ample supplies in 2020, mitigating excessive price volatility, unlike during the 2007–2008 food crises.

Our article contributes to the set of analyses based on general equilibrium models used to investigate COVID-19′s impacts in different countries, including China (Zhao, 2020), the UK (Keogh-Brown et al., 2020), India (Sahoo & Ashwani, 2020), Brazil (Porsse et al., 2020) Kenya (Nechifor et al., 2021), Burkina Faso (Zidouemba et al., 2020), and global or regional levels (Beckman & Countryman, 2021; Djiofack et al., 2020; Keogh-Brown et al., 2020; Laborde et al., 2022; Maliszewska et al., 2020; McKibbin & Fernando, 2020; Sahoo & Ashwani, 2020; Zhang et al., 2020; Zhao, 2020).

Our analysis contributes to the literature on the economic impact of COVID-19 in several ways. The article considers the two phases of the pandemic, that is, the steep contraction of 2020 and the uneven path to recovery projected for 2021. Early studies had to make educated guesses on the likely income shocks and recovery paths of various countries. We differ from many previous analyses in the way we model the pandemic shocks with our calibration to the IMF outlook estimates as well as creating a counterfactual baseline. The combination of two

modelling frameworks (the multi-region general equilibrium model with the IFSA food-security model) is unusual, noting that IFPRI's evaluation by Laborde et al. (2022) has a related setup with a recursive dual structure.

CGE models are typically used to simulate the impact of exogenous shocks and policy changes on income, trade and welfare (Giesecke & Madden, 2013). Here, we follow Balistreri et al. (2018) and Bauer et al. (2005), He et al. (2022), Beckman et al. (2021), and Monte et al. (2018) by reversing the process. We take exogenously observed and projected changes in GDP under COVID-19, as well as trade and labor shocks and then recover the underlying fundamental conditions in labor and food markets, which are consistent with these large shocks in deviation from an established BfC baseline scenario. (See Section 2 and footnote 2 below).

2 | MODELING ASSUMPTIONS

2.1 | Scenario assumptions

The model uses GTAP 10 2014 nominal data for the initial calibration. The benchmark is then extended to 2019 based on the GDP growth and macro data as reported by the IMF and on the shares of consumption, public spending, investment, and trade including aggregate exports and imports.[1,2] The GTAP data are aggregated to 17 regions or countries covering low- and middle-income countries as well as major trade partners (e.g., China, Europe, and USA) capturing global economic activity. The GTAP data are also aggregated to focus on 30 sectors centered on agriculture, food, and those sectors with specific shocks related to the COVID-19 pandemic.

The BfC scenario extends the average growth rate observed in countries between 2014 and 2019, to 2020 by applying the average growth rate to the 2019 observed GDP figures in the IMF's WEO projections. The 2020 IMF figures become the COVID-19 shock for 2020, inclusive of the fiscal stimulus put in place by various governments in OECD countries, but much less so in lower-income countries, except in West Africa. Many lower-income countries experienced a contraction of public expenditures. See Table 1. for details for 2020. For 2021, we proceed slightly differently because the 2021 WEO growth projections actually exceed our average 2014–2019 historical growth rates for many countries, leading to an unexpected expansionary COVID scenario relative to BfC scenario for many countries. To establish the 2021 BfC GDP targets we take the 2020 BfC GDP target and scale it by the ratio of WEO projected 2022–2021 GDPs. This uses the WEO projected region/country growth rate from 2021 to 2022 as a proxy for the BfC growth rate from 2020 to 2021. The logic is that the IMF-reported growth rates from 2020 to 2021 are still substantially contaminated by the projected COVID recovery, and are therefore inappropriate for the BfC baseline. Furthermore, if we did use the IMF growth rates from 2020 to 2021, we would get substantially similar results in the 2021 scenarios as compared to the 2020 scenarios because by construction the BfC and COVID growth rates are the same. We report the income levels for 2020 and 2021 under the developed BfC and the COVID scenarios (as well as the 2019 benchmark) in Table 2.

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.[3] The fiscal stimulus measures and contractions taken by governments in 2021 are shown in Appendix Table A.1. They follow a similar pattern as those of 2020.

Beyond matching aggregate value added in each country to the IMF GDP predicted shocks, we also shock Total Factor Productivity (TFP) in key sectors affected by the pandemic. The IMF macro forecast does not say anything about sector-specific shocks. This is the motivation to

[1] The WEO projections of aggregate imports and exports (measured in US dollars) at the regional level do not impose global consistency on capital flows. While we target regional trade imbalances based on the WEO projections, we use a transparent least-squares procedure to find the calibrated trade imbalance such that globally there is no net borrowing or lending. That is, the sum across regions of all net trade surpluses must be zero.

[2] In typical CGE applications technologies are held fixed while GDP and its components are endogenous to policy shocks. In our exercises, however, we are interested in finding a set of technical productivity shocks that are consistent with income (GDP) and other outcomes related to the scenarios. Our strategy, therefore, is to use the model in reverse. Variables, like GDP, are constrained and productivity levels are adjusted such that these constraints are consistent with an equilibrium. For each constraint there is an associated productivity instrument. As an example, GDP in a region (measured in units of local private consumption) is constrained to be equal to the projected target, and associated with this constraint is an instrument that scales the productivity of regional endowments of primary factors. In our aggregate treatment we abstract from decomposing these shocks along the lines of employment, unemployment, or productivity per worker. There is simply a scalar coefficient that adjusts the benchmark 2019 endowment of value-added factors which might be interpreted in different ways, especially with regard to the labor market. For additional details see the technical description in He et al. (2022), Section 3, which applies the same strategy of outcome targeting in the context of a multi-region model of China under COVID-19 productivity shocks.

[3] For some regions, however, the combination of the 2019 base and the historic growth rate indicates a BfC GDP that is "below" the WEO 2020 projections. We view this as an anomaly. For these regions (Nigeria, CIS, NAF, EAF, WAF) we recalculate the BfC 2020 GDP target as the WEO 2020 (COVID) projection less the average global income shock.

TABLE 1 Shocks (COVID-BfC baseline) in percent deviation from 2020 run

Variable shock	GDP target	Balance of Payments	Government expenditures	Investment	Capital	Skilled labor	Unskilled labor
Central Africa	−9.9%	−9.9%	−10.3%	−8.5%	−1.1%	−1.1%	−14.3%
China	−3.8%	−4.1%	7.9%	.0%	−7.8%	−7.8%	−10.8%
Commonwealth of Independent States	−3.2%	−3.2%	8.9%	−11.9%	.0%	.0%	−2.2%
Central & Southern Asia + Other Asia	−16.2%	−16.2%	−4.0%	−12.6%	−11.7%	−11.7%	−32.0%
East Africa	−3.2%	−3.2%	−3.3%	−10.8%	−7.0%	−7.0%	−9.3%
Ethiopia	−7.0%	−7.0%	−8.3%	−16.6%	−13.7%	−13.7%	−19.1%
Europe including GBR and CHE	−2.9%	−3.5%	15.0%	−5.9%	−.4%	−.4%	−2.1%
India	−12.7%	−12.7%	3.0%	−18.4%	−13.6%	−13.6%	−28.6%
Latin America & the Caribbean	−12.4%	−12.4%	−2.4%	−22.1%	−7.8%	−7.8%	−23.8%
North Africa	−3.2%	−3.1%	2.0%	−11.1%	−5.2%	−5.2%	−7.4%
Nigeria	−3.2%	−3.2%	−5.3%	−2.9%	.3%	.3%	−1.5%
Pakistan	−7.3%	−7.3%	.1%	−6.8%	−6.4%	−6.4%	−15.3%
Rest of World	−6.2%	−7.1%	11.3%	−4.5%	−2.3%	−2.3%	−9.1%
Southern Africa	−5.9%	−5.8%	.4%	−1.0%	−1.7%	−1.7%	−7.4%
South East Asia	−8.6%	−8.6%	2.1%	−15.4%	−9.4%	−9.4%	−18.7%
USA	−6.4%	−5.2%	24.6%	−5.2%	−6.9%	−6.9%	−13.2%
West Africa	−3.2%	−3.2%	21.6%	−3.5%	−8.7%	−8.7%	−11.3%

TABLE 2 GDP levels in 2019, 2020BfC, 2020COVID, 2021BfC, 2021COVID ($ billion nominal dollars)

Country-regions	2019	2020 BfC	2020 COVID	2021 BfC	2021 COVID
Central Africa	208.4	199.7	179.1	208.5	201.5
China	14706.3	15638.4	15072.3	16917.4	17011.0
Commonwealth of Independent States	197.3	195.5	189.1	209.4	206.2
Central and Southern Asia + Other Asia	856.0	881.8	743.1	974.7	840.3
East Africa	255.4	270.5	262.2	287.1	278.3
Ethiopia	92.6	103.1	96.6	101.9	94.0
Europe + GBR and CHE	18469.6	18420.0	17878.8	19668.4	20252.2
India	2870.5	3073.7	2708.8	3339.0	3049.7
Latin America and the Caribbean	1085.5	1096.1	961.2	1161.0	1057.7
North Africa	689.0	716.7	694.4	759.8	752.4
Nigeria	448.1	444.0	429.4	508.2	514.0
Pakistan	276.1	283.0	262.8	301.8	291.9
Rest of World	23690.5	23563.3	22090.0	24878.6	24466.1
Southern Africa	98.9	98.4	92.6	105.1	100.8
South East Asia	1871.9	1969.6	1807.7	2137.8	1964.0
USA	21433.2	22313.2	20932.8	23620.4	22675.3
West Africa	244.7	262.7	254.8	284.7	286.1

include these in the calibration of the COVID scenario. The sector-specific TFP shock reflects the asymmetric 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 and distancing policies.[4] We also capture the sharp decrease in demand in sectors for which consumers scaled back their consumption because of self-imposed or

[4] The TFP shocks are imposed similarly in all countries and regions, which is a limitation as situations differ. It is transparent however.

TABLE 3 2020 Selected sectoral shocks TFP (−1.25%) and demand shocks (−7.5%)*

Meat and Dairy	−1.25
Vegetables fruit and nuts	−1.25
Trade	−1.25
Warehousing and support activities	−1.25
Water Transport	−1.25
Other Transport n.e.c.	−1.25
Accommodations and food services	−7.50
Recreational and other services	−7.50
Air Transport	−7.50

*These shocks are specific to listed sectors. Other sectors than those listed do not incorporate these shocks.

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. (2022). 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 summarizes the shocks in percent deviation from the BfC baseline for 2020. Shocks for 2021 are shown in Appendix Table A.1. The TFP and demand shocks are shown in Table 3 for 2020. Corresponding TFP and demand shocks for 2021 are set at 50% 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 (Baquedano, Zereyesus, Christensen et al., 2021a; Beghin et al., 2017) to predict food insecurity consequences of COVID-19 in 80 low- and middle-income countries.

2.2 | 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 detailed sectoral aggregation is available from the authors.

The IFSA model estimates the calorie intake per income decile in 80 low- and middle-income countries. The various food goods in the IFSA model are aggregated into four groups (major grain, other grains, roots and tubers, and 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, and income distribution data to derive projected consumptions over time (Beghin et al., 2017). The model looks at price impacts on food access from the consumer side and does not account directly for household production balances.

With the IFSA model in mind, we focus on grains and roots and tubers, which are the key staple foods of interest. The IFSA model incorporates real income, income distribution data (Theil's inequality index), and the real price of the main grain by country (processed rice, wheat crop price, other grain crop price including corn), a second grain price capturing grains other than the main grain, and the price of roots & tubers which is represented by the price of vegetables and fruits sector (v_f sector) in GTAP10. The price of other foods in IFSA is not mapped here as we only consider the price changes in these staple food items. The IFSA demand specification does not capture the substitution possibilities across the 4 food groupings. This simplification tends to overstate the impact of price changes which are typically correlated in the case of global shocks.

3 | AGRICULTURAL AND FOOD TRADE POLICY RESPONSES TO COVID-19

Early in the pandemic, IFPRI researchers raised concerns about the emergence of trade restrictions endangering food security but also noted that export restrictions were phased out rapidly (Glauber et al., 2021; Laborde et al., 2020). Price levels only moderately increased (Vos et al., 2020). The concern was to see another price spike in world grain prices induced by export restrictions as documented in Martin and Anderson (2012) and Ivanic and Martin (2008), in previous crises. Rice prices surged in 2007–2008, mostly through export restrictions. Such price increases exacerbate poverty in vulnerable households who spend a disproportionate share of their income on food.

Trade policy responses to COVID-19 focused mostly on export restrictions related to medical supplies (CRS, 2021). Agricultural and food trade was also targeted by some policies (ITC-MacMap, 2021). According to the database maintained by the ITC-MacMap, 54 agri-food trade restrictive policies were implemented affecting various goods

from onions to rice and wild animals. The composition is as follows: 23 export restrictions, four export quotas, three export licenses, and seven import bans, and 14 SPS restrictions on imports. The only potentially significant restrictions on commodity markets focus on rice from India (licensing), Vietnam (export quotas for 37 days), and Russia (temporary quotas and duties on grain exports) (USDA-FAS, 2021).

To counter these restrictions, 28 countries implemented trade facilitating measures to pre-empt price increases for food imports. There were twenty-three tariff reductions, eliminations and/or quota increases, and a few cases of easing some certifications requirements. Overall, these measures have had limited impact on availability and prices of major commodities such as rice given that most major producers showed some restraint in their policy reactions to the pandemic. Their impact on prices and availability of grains has been moderate. High stock-to-use ratios in early 2020 for most grains helped to stabilize prices.[5] The concerns of higher price levels and volatility created by potential trade restrictions had faded by end of 2020 (Baffes & Wu, 2020). Therefore, we do not attempt to model their impact and focus on trade cost increases created by logistic disruptions in transportation, trade, and warehousing sectors.

4 | SCENARIO RESULTS

4.1 | Impact on real income

The income shocks are shown in Table 4 for 2020. The impact on factor income combines the shock on effective supplies of factors and change in returns and cost of living. Table 4 shows the real income shocks derived using the local price index (the true-cost-of-living index for the representative agent), in many cases, the change in return (wage relative to the cost of living) mitigates the large shock imposed on unskilled labor. The resulting shock on factor income of unskilled labor is in many cases not as large as the skilled labor income impact or even GDP shock, such as in the Central and East Africa regions.

Capital income takes the brunt of the economic impact of COVID-19, such as in Central and Southern Asia region and Pakistan. The impact of the economic contraction is widespread affecting both demand and available supply of effective labor and capital.[6] In some cases, the reduction in availability of labor or capital is stronger than the reduction in demand, leading to increase in nominal returns. In addition, the local cost of living falls in many countries relative to the BfC cost of living which contributes to higher real returns for factors. In any case the income shocks are very sizable, especially in Central and Southern Asia, Central Africa, India, and Latin America and Caribbean regions which leads to large exacerbations of food insecurity as later discussed.

4.2 | Impact on food prices

Food price changes are expressed in relative deviation from the BfC baseline in real terms. Nominal prices are deflated by the local cost-of-living index. They are shown in Table 5, in percent change. The majority of food prices decrease in both runs, except for the two perishable food sectors, affected by the greater loss of productivity and level of disruption in supply chains. For the other sectors, the dominant influence is the demand contraction brought about by reduced incomes in all markets. This leads to price decreases in most but not all cases for 2020.

Looking first at the two sectors experiencing mostly price increases, prices in the Vegetable, fruits, root and tubers sector increase the most, especially in Central Africa (5.86%), Central and Southern Asia (5.44%), Ethiopia (3.40%), and LAC (2.89%). Smaller increases of <2% take place in Pakistan (1.82%), India (1.45%), and East Africa (1.40%). Meat and Dairy product prices increase moderately, by 2.25% in Central and Southern Asia, 1.67% in India, 1.23% in Pakistan and 1.19% in South East Asia. Other Meat and Dairy price increases are even more limited, even though they are observed in most countries.

Grain prices increase in a few countries and decreases in many others. For example, in the Cereal grains N.E.C. sector, prices increase in Central Africa (4.60%), Central and Southern Asia (3.78%), and Ethiopia (1.78%) and LAC (.91%). Other countries and regions experience price decreases for the same grain category, notably a decrease of 1.45% in West Africa. Rice prices increase in Central Africa (1.98%), Ethiopia (1.78%), India (1.32%), and West Africa (.84%). Rice prices decrease in China (-.89%).

Wheat prices increase in Central and Southern Asia (2.74%) and Ethiopia (1.49%) but also decrease in many other countries, driven by the demand-income contractions. For example, wheat prices decrease by 1.64% in Central Africa and 1.23% in Nigeria. Oilseed prices increase as well, in Central Africa (4.96%), Central and Southern Asia (1.41%), Ethiopia (1.84%), and LAC (1.1%), and decreases in most other regions. Vegetable oil prices decrease in most countries. In summary, Central Africa, Central and Southern Asia, Ethiopia, and Latin America and Caribbean regions are the most affected by price increases and face large income contractions. These are the hotspot for increases in food insecurity under COVID.

[5] Supply shocks in 2021 contributed to higher staple prices, except for rice.
[6] The model adjusts factor productivity to match the macro shocks, decrease in demand and loss of sectoral TFP and resulting factor rewards.

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TABLE 4 Income shocks in percent deviation from the BfC scenario (2020 COVID-19 run)

Income category	Skilled labor	Unskilled labor	Capital	GDP
Central Africa	−11.41	−7.06	−11.22	−9.86
China	−2.84	−3.54	−3.91	−3.85
Commonwealth of Independent States	−1.54	−3.01	−3.66	−3.24
Central & Southern Asia + Other Asia	−15.94	−14.41	−16.16	−16.20
East Africa	−4.25	−1.76	−3.40	−3.24
Ethiopia	−11.89	−2.32	−7.84	−7.00
Europe including GBR and CHE	−2.39	−3.87	−2.83	−2.93
India	−11.78	−8.34	−13.94	−12.71
Latin America and the Caribbean	−13.62	−8.99	−13.16	−12.43
North Africa	−3.24	−1.82	−3.55	−3.24
Nigeria	−3.67	−1.92	−4.08	−3.24
Pakistan	−7.04	−4.99	−7.65	−7.33
Rest of World	−5.10	−5.27	−7.06	−6.22
Southern Africa	−4.93	−5.11	−6.85	−5.86
South East Asia	−9.31	−6.33	−8.86	−8.65
USA	−5.77	−6.00	−6.87	−6.44
West Africa	−.12	−5.52	−3.29	−3.24

TABLE 5 Impact on real food prices (deflated by local cost-of-living index) in deviation from baseline (2020 run)

Region	Fish	Grains other than wheat and rice	Meats and Dairy	Oilseeds	Rice	Sugar	Vegetables, fruits, root & tubers	Vegetable oil	Wheat
Central Africa	−1.02	4.60	.48	4.96	1.98	−.03	5.86	−1.10	−1.64
China	−1.14	−.67	.89	−.63	−.89	−.88	.78	−.76	−.68
Commonwealth of Independent States	−1.31	−.92	.75	−.87	.41	−.50	.52	−.35	−.49
Central and Southern Asia & Other Asia	−1.15	3.78	2.25	1.41	.86	−2.04	5.42	−1.88	2.74
East Africa	−1.23	−.11	.71	−.14	.28	.12	1.40	−.02	.31
Ethiopia	−5.10	1.76	.12	1.84	1.78	−3.49	3.40	.66	1.49
Europe including GBR and CHE	−1.59	−1.36	.10	−1.34	−.75	−1.30	.04	−1.04	−1.40
India	1.19	−.32	1.67	.14	1.32	−.13	1.45	−1.17	−.58
Latin America & the Caribbean	−2.59	.91	.86	1.10	−.26	−.33	2.89	−.81	.48
North Africa	−1.07	−.25	.83	−.37	−.44	−.28	.94	.07	−.13
Nigeria	−1.41	−.63	−.10	−.62	−.13	−1.16	.68	−.47	−1.23
Pakistan	−1.72	.13	1.23	.36	−.29	.12	1.82	−.08	.34
Rest of World	−1.78	−.95	.38	−1.26	−.69	−1.24	.58	−1.10	−.79
Southern Africa	−1.24	−.20	.73	−.33	.41	−.55	1.14	−.01	.10
South East Asia	−1.67	.09	1.19	.00	−.10	−.36	1.07	.00	−.77
USA	−2.50	−2.14	.31	−2.18	−.71	−.87	−.51	−1.18	−2.04
West Africa	−1.32	−1.45	.70	−1.35	.84	−.22	−.06	−.07	.04

TABLE 6 Agricultural and food trade impact in deviation from the BfC scenario 2020 COVID-19 runs (in percent)

Country/region	Exports	Imports
Central Africa	-18.28	−5.34
China	−12.77	−15.72
Commonwealth of Independent States	−12.05	−7.58
Central & Southern Asia + Other Asia	−30.54	−1.43
East Africa	−11.36	−3.63
Ethiopia	−19.16	3.11
Europe including GBR and CHE	−15.69	−17.42
India	−16.72	−11.96
Latin America and the Caribbean	−23.37	−5.63
North Africa	−11.48	−2.12
Nigeria	−14.21	−3.96
Pakistan	−13.06	−6.69
Rest of World	−15.06	−15.95
Southern Africa	−12.43	−11.57
South East Asia	−17.28	−6.68
USA	−12.43	−23.93
West Africa	−7.63	−12.52

Price impacts for 2021 are shown in Appendix Table A.3. Income recovery takes place in some countries and food prices exhibit some moderate changes either positive or negative depending on the shift of food demands induced by income variations. Still, income shocks dominate in 2021.

4.3 | Impact on trade

Aggregate agricultural and food trade effects are shown in Table 6 for 2020. Agricultural export values fall for all countries and the magnitudes of these contractions are large in absolute value.

Imports of agricultural and food goods also fall but often by smaller percentages than agri-food exports fell, except in the EU and the USA. Ethiopia increases its imports of food slightly, by 3.45%. With that exception, all countries decreased their reliance on foreign market to fulfill consumer demand. Export revenues for these agri-food sectors fell as well in all countries, contributing to the loss of income. These magnitudes are all computed using the global cost-of-living benchmark as the price of a "common global basket."[7]

At the agri-food sectoral level (detailed tables available upon request), there are large changes, positive and negative in imports, depending on the country. We find increases in wheat imports in Central and Southern Asia (30.71%) and Ethiopia (25.57%), oilseeds in Central Africa, meat and dairy in Central and Southern Africa (14.35%) vegetables, fruit, roots and tubers in Ethiopia (10.89%). However, there are many more large import decreases as well, especially in the USA, EU, and China.

For the 2020 COVID run, exports in most sectors in most countries fall by 10% or more. There are large decreases, exceeding 20% in rice exports in Central and Southern Asia, Central Africa, India, Latin America and Caribbean, Southern Africa, and South East Asia. We also observe large decreases in exports of roots and tubers from Central Africa, Central and Southern Asia, and LAC. Similar patterns are projected for wheat in the same countries and in Ethiopia. Exports of other grains N.E.C. fall by more than 20% in Central and Southern Asia, and LAC. Meat and dairy exports fall similarly in many of the same countries. In sum, Central and Southern Asia and then LAC exhibit the most accentuated changes in agri-food exports. These changes are behind the aggregate changes shown in Table 6.

Impacts on aggregate food trade for 2021 are shown in appendix tables A.4 with more muted contraction patterns than in 2020. Noticeable, are the increase in food imports in North Africa, Ethiopia, and Nigeria. Agricultural and food sectoral results for 2021 are available from the authors upon request.

4.4 | Impact on terms of trade

We have two aggregate measures of changes in purchasing power in the regions covered by the CGE model. First, we look at the true cost-of-living index over the benchmark weighted average of these indexes globally, which provides a gauge of the impact of local cost of living relative to the "global" benchmark cost of living (how well a country's cost of living is faring relative to what is happening globally). Second, we have a more traditional terms for trade measures (index of export prices over an index of import prices). They are shown in Table 7 for 2020 runs in percent change from BfC values.

First, we note that changes are small in absolute value for both indicators. Relative cost of living falls in many countries, except in Central and Southern Asia (+3.02%), and LAC (+1.05%). The largest price decreases are in West and Northern Africa regions (-1.34% and -1.11%). Elsewhere, relative changes in the cost of living are <1%. Terms of trade improve for India (+1.67%) and for Ethiopia (1.02%), and deteriorates for Nigeria (-1.92%), and to a lesser extent for Commonwealth of Independent States, Central and Southern Asia, and East Africa regions (<1% decrease).

[7] The global cost-of-living price index is computed as the benchmark-consumption weighted average of the local (regional) cost-of-living indexes, where the benchmark is the 2019 equilibrium.

TABLE 7 Terms of trade effects and change in relative cost of living in deviation from the BfC scenario 2020 (in percent)

Regions	Relative cost of living/ global benchmark	Terms of trade change
Central Africa	.46	-.60
China	−.90	−.12
Commonwealth of Independent States	−.82	−.88
Central & Southern Asia + Other Asia	3.02	.82
East Africa	−.99	−.74
Ethiopia	−.33	1.02
Europe including GBR and CHE	−.11	−.01
India	.41	1.67
Latin America and the Caribbean	1.05	.27
North Africa	−1.11	−.69
Nigeria	−.14	−1.92
Pakistan	−.15	.48
Rest of World	.08	−.08
Southern Africa	−.95	−.34
South East Asia	−.17	.03
USA	.12	.53
West Africa	−1.34	−.59

TABLE 8 Food insecurity evolution in the BfC and COVID baselines

	2019	2020	2021
	Number of food-insecure people (millions)		
But for COVID-19	779.6	869.3	866.2
COVID-19	779.6	1,042.5	954.3

Source: Estimates derived using USDA's International Food Security Assessment Model.

The two measures of relative purchase power are poorly correlated. One would expect a negative correlation if all goods were tradable—improvements in terms of trade would lead to a reduction of the local cost of living. This is not the case, however, as import dependency varies across regions. For example, terms of trade improve in India but its relative cost of living also increases. Conversely, Nigeria experiences a deterioration of its terms of trade but its relative cost of living falls. Results for 2021 are available upon request from the authors. They are qualitatively comparable with small magnitudes and imperfect correlation between the two measures.

5 | COVID-19'S IMPACT ON FOOD INSECURITY TRENDS

Our analysis builds on previous findings of Baquedano, Zereyesus, Christensen et al. (2021a) and Baquedano, Zereyesus, Valdes et al. (2021b) on the effects of COVID-19 on food security in two ways. First, as discussed above the shocks to income, as proxied by GDP changes, and price are more robust and take into account the influence of trade shocks as well as distinguishing the effects on skilled and unskilled labor. This is important, as the IFSA model, directly uses the GDP and price shocks to derive the estimates of food insecurity from COVID-19. Second, unlike the previous studies, we evaluate the increase in food insecurity from 2019 on to our BfC baseline and then under COVID-19 in 2020 and 2021. This allows us to decompose the deterioration of food security over time into its two components (one created by the pandemic, the other reflecting underlying trends observed in recent years). The previous studies only compared a 2020 scenario without COVID-19 to a 2020 scenario with COVID-19. Moreover, at the time of these studies, the effects on GDP and food prices for 2020 were unknown and were based on early projections. Our estimates for 2020 are now more definitive as the effects on GDP and prices are known.

The food security results highlighted below are for a subset of the GTAP results presented above, as the expanded IFSA database only covers 80 low- and middle-income countries. A much lower number than the GTAP database which covers the world. All macroeconomic shocks to GDP and prices are based on 2019 price levels for the two scenarios (BfC and COVID-19). The USDA's IFSA defines food insecurity as the inability of a person to consume 2100 kcal per person per day (Baquedano, Zereyesus, Christensen et al., 2021a). Using this definition our discussion on food security focuses on the number of food-insecure people. The first major finding is consistent with FAO et al. (2021); food insecurity had been increasing even before the COVID-19 pandemic, driven mainly by regions and countries with protracted conflicts or protracted economic crises.

The number of food-insecure people under the BfC scenario was estimated to have increased on average 31.9% from 2019 to 2020 as implied by figures in Table 8. This increase represents the baseline metric to separate the effects from COVID-19 and long-term trends. When the GDP estimates that incorporate the global effects of COVID-19 are considered, the number of food-insecure people is estimated to have increased by 42.3% (see Table 8). Hence, about 34.1% of the increase in food insecurity

between 2019 and 2020 is caused by long-term trends and 65.9% by COVID.

For 2021, the food security trends tapers under the BfC scenario with a small decrease in food insecurity of -.4% with respect to its 2020 level. Under the COVID scenario in 2021, the food security situation improves with the number of food insecure declining 8.5% with respect to the high COVID levels in 2020. Still COVID is estimated to have a strongly negative impact on food insecurity, responsible for 50.4% of the estimated increase in food insecurity relative to its level in 2019. The other 49.6% comes from underlying longer trends driven by conflicts and economic crises.[8]

The number of food insecure in 2021 remains nearly 22.4% higher than in 2019 (Table 8). The higher number of food insecure in 2021 relative to pre-pandemic levels, implies that about half of the change in the number of food-insecure people reflect long-term dynamics and not COVID-19 trends. All the modeled regions saw a sharp increase in the number of food-insecure people because of the pandemic as shown in Table 9. The five most affected countries and regions by the pandemic are: India, Central and Southern Asia, Pakistan Latin America and the Caribbean, and South East Asia. India is estimated to have seen the largest increase in the number of food insecure in 2020 because of the COVID-19 pandemic of any region. The increase in the number of food-insecure people in India from the pandemic is 63 million (see Table 9). The decline of India's food security metrics is mainly explained by an increase in the number of people in lower-income deciles considered food insecure because of the pandemic. For example, prior to the pandemic, the third income decile was estimated to be food secure, after the pandemic, the decile is considered food insecure. In 2021, India, Central and Southern Asia, South East Asia, and East Africa, and Latin America and the Caribbean are the most affected countries by the pandemic in terms of increased food insecurity. These geographical results are broadly consistent with the new analysis of Laborde et al. (2022) revisiting the impact of COVID "2 years later." They estimate that hunger in South-Asia was the most exacerbated in 2020 and to a lesser extent still in 2021. Our relatively low estimates of food-insecure people in West Africa due to COVID is also consistent with estimates of Laborde et al. (2022). Our estimated increase in food-insecure populations is higher than the mid-range estimate in SOFI (2021) (118 million) and close to the upper bound of the projected range in SOFI (161 million). Our 2020 estimate of 163.2 million is higher than the estimate of Laborde et al. (2022) of 123.7 million. Our 2021 estimate of 86.5 million is lower than IFPRI's estimate of 99.4 (Laborde et al. 2022). These differences originates in the difference in modeling assumptions, and macro projections done at different times and assumed caloric requirements. Broadly, various estimates are in agreement that South Asia has been most impacted and more than Africa, and that 2020 was the worst exacerbation of food insecurity relative to 2021.

[8] The decomposition comes from comparing food insecurity in 2020 under the BfC and COVID scenarios and their evolution from 2019, and similarly in 2021.

6 | CONCLUSION

We analyzed the impact of the COVID-19 pandemic and associated policy responses on the global economy and food security in 80 low- and middle-income countries. We used a global economy-wide model with added detailed disaggregation of agricultural and food sectors and a BfC baseline for 2020. We incorporate aggregate income shocks, sectoral losses in productivity, rising transaction costs, and decreases in demand induced by distancing. We compute changes in income and food prices from the pandemic shocks in 2020 with and without the effects of COVID-19. To compare and contrast trends in 2020 and potential paths of economic recovery in 2021 we use GDP growth estimates from the IMF as explained previously.

The resulting shocks in prices and incomes from the CGE model simulations were incorporated into USDA ERS' IFSA model to analyze the deterioration in food security in these 80 countries. Negative income shocks dominate the impact of lower cost of food. Food insecurity increases in 2020 considerably in countries in Asia and Latin America and the Caribbean through income shocks rather than prices as aggregate income and income of unskilled labor falls considerably in many countries. Few sectors exhibit price increases as income contractions reduce demand in most sectors and most countries.

Our findings confirm that food insecurity had been deteriorating prior to the COVID-19 pandemic, as food insecurity was found to be on an upward trajectory when considering a scenario without the effects of COVID-19 on the global economy. The main effect of the pandemic was to sharply increase the deteriorating trend in food security in the 80 low- and middle-income countries covered in this study. Most of the increase in the number of food insecure people from COVID-19 in 2020 is driven by large Asian countries, particularly India, Bangladesh (not shown in the table), and Pakistan. Sub-Saharan African and Latin America and the Caribbean countries also saw a sharp increase in their food insecurity levels. Moreover, the increase in the number of food-insecure people in 2020 was driven by the effects of the COVID-19 pandemic. By contrast in 2021 relative to 2019, roughly half of the deterioration of food security is caused by long-term

TABLE 9 Food insecurity in number of food-insecure people in 2020 and 2021 in levels (millions) and share of population (%)

			But for COVID-19				COVID-19			
	2019		2020		2021		2020		2021	
Region	Number of food Insecure (million)	Share of the population food insecure (%)	Number of food Insecure (million)	Share of the population food insecure (%)	Number of food Insecure (million)	Share of the population food insecure (%)	Number of food Insecure (million)	Share of the population food insecure (%)	Number of food Insecure (million)	Share of the population food insecure (%)
TOTAL	779.6	18.3	869.3	20.1	866.2	19.8	1,042.5	24.1	954.3	21.8
Commonwealth of Independent States	6.1	8.5	6.9	9.5	6.8	9.3	7.9	10.9	7.2	9.9
Central and Southern Asia	96.3	31.3	101.9	32.7	93.0	29.5	127.0	40.8	112.6	35.8
India	129.4	9.9	153.7	11.6	158.7	11.8	216.7	16.3	188.2	14.0
Pakistan	80.8	35.3	83.3	35.7	75.6	31.7	96.5	41.3	79.7	33.4
South East Asia	50.2	10.2	58.5	11.7	59.4	11.8	69.0	13.8	68.0	13.5
Latin America and the Caribbean	45.4	8.2	55.0	9.8	48.0	8.5	77.4	13.9	54.2	9.6
North Africa	10.9	5.7	12.9	6.6	21.9	11.1	14.3	7.4	25.6	13.0
Central Africa	66.5	48.7	81.4	57.8	89.2	61.5	91.3	64.9	91.6	63.1
East Africa	103.7	40.3	100.1	37.9	105.1	38.7	106.4	40.2	110.0	40.5
Ethiopia	22.7	21.6	22.9	21.2	33.8	30.5	28.1	25.9	38.1	34.3
Southern Africa	86.7	43.3	96.2	46.9	90.4	43.1	103.8	50.7	92.7	44.2
West Africa	32.7	17.6	33.0	17.4	33.0	16.9	35.4	18.6	32.4	16.6
Nigeria	48.2	23.1	63.6	29.7	51.5	23.5	68.6	32.0	54.1	24.6

Source: Estimates derived using USDA's International Food Security Assessment Model.

trends and the other half by the continued pandemic. The projected uneven recovery in 2021 means that the pandemic is not quite as debilitating as it was in 2020, and as a result continued long-term trends account for a larger share of the food insecurity.

We also noted that most countries of interest experience moderate terms-of-trade deteriorations and losses of purchase power on world markets; these countries also experience more dramatic decreases in exports and often as well in imports, except Ethiopia. The fall in agricultural export revenues was considerable in many countries. The decreased reliance on trade was not induced by restrictive trade policies, but rather by the generalized demand contractions, as a result of lower incomes, damping agri-food export demands and by general equilibrium export supplies. Income derived from export sales fell. Similarly, imports contracted because of lower income in importing countries.

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APPENDIX

See Appendix Table. A.1., Appendix Table. A.2., Appendix Table. A.3., Appendix Table. A.4.

TABLE A.1 Shocks (COVID-BfC baseline) in percent deviation 2021 run

Variable shock	GDP target	Balance of payments	Government expenditures	Investment	Capital	Skilled labor	Unskilled labor
Central Africa	−.354	−3.352	−5.386	.739	−1.169	−1.169	−5.244
China	.636	−.146	7.966	4.471	−14.616	−14.616	−13.206
Commonwealth of Independent States	−1.625	−1.614	4.821	−12.302	−6.547	−6.547	−7.687
Central & Southern Asia + Other Asia	−15.703	−15.691	1.927	−6.280	−22.123	−22.123	−41.034
East Africa	−3.433	−3.344	−5.508	−8.868	−13.827	−13.827	−16.986
Ethiopia	−8.602	−8.576	−8.829	−20.541	−13.292	−13.292	−20.760
Europe including GBR and CHE	3.161	1.613	19.133	.590	−3.790	−3.790	2.416
India	−10.079	−9.946	−.147	−11.253	−21.419	−21.419	−32.770
Latin America & the Caribbean	−9.524	−9.418	−3.431	−16.014	−12.151	−12.151	−24.391
North Africa	−1.073	−.558	−7.360	−27.825	−10.491	−10.491	−10.736
Nigeria	1.307	1.399	−4.893	−6.302	−12.292	−12.292	−9.560
Pakistan	−3.583	−3.511	2.097	−3.180	−11.044	−11.044	−15.019
Rest of World	−1.741	−4.211	6.699	.541	−5.376	−5.376	−6.565
Southern Africa	−4.336	−4.315	−2.059	−2.596	−7.947	−7.947	−12.261
South East Asia	−9.289	−9.143	1.851	−16.139	−18.901	−18.901	−29.305
USA	−4.410	−.904	24.231	−.783	−12.182	−12.182	−16.681
West Africa	.549	.617	20.471	1.614	−16.028	−16.028	−14.550

TABLE A.2 Income shocks in 2021

Income shocks in deviation from BfC scenario for 2021				
Income category	**Capital**	**Skilled labor**	**Unskilled labor**	**GDP**
Central Africa	−3.653	−3.504	−2.548	−3.354
China	.799	1.529	−.189	.636
Commonwealth of Independent States	−1.720	−1.142	−1.151	−1.625
Central & Southern Asia + Other Asia	−14.080	−12.374	−13.682	−15.703
East Africa	−3.370	−4.323	−1.831	−3.433
Ethiopia	−9.814	−14.294	−2.951	−8.602
Europe including GBR and CHE	3.587	3.997	.087	3.161
India	−10.275	−8.481	−6.081	−10.079
Latin America and the Caribbean	−9.445	−10.026	−6.558	−9.524
North Africa	−.868	−3.585	1.433	−1.073
Nigeria	−.071	−.474	3.937	1.307
Pakistan	−3.502	−2.893	−2.586	−3.583
Rest of World	−1.953	−.824	−1.708	−1.741
Southern Africa	−4.657	−4.013	−3.415	−4.336
South East Asia	−8.664	−9.326	−6.437	−9.289
USA	−4.459	−3.495	−4.166	−4.410
West Africa	.462	2.978	−2.128	.549

TABLE A.3 Impact on real food prices (deflated by local cost-of-living index) in % deviation from baseline (2021 run)

Region	**Fish**	**Grains other than wheat and rice**	**Meats and Dairy**	**Oilseeds**	**Rice**	**Sugar**	**Vegetables, fruits, root & tubers**	**Vegetable oil**	**Wheat**
Central Africa	−.56	.97	.23	1.13	.41	−.19	1.57	−.03	−1.63
China	−.52	−.86	.26	−.59	−.43	−.47	−.05	−.29	−.89
Commonwealth of Independent States	−.52	−.31	.38	−.37	.20	−.44	.45	−.44	−.36
Central and Southern Asia & Other Asia	−.49	3.63	1.75	1.65	1.19	−1.85	4.60	−1.39	2.53
East Africa	−.71	.55	.40	.52	.20	.22	1.44	.15	−.73
Ethiopia	−6.20	3.09	−1.05	3.24	.44	−4.12	4.24	.70	2.63
Europe including GBR and CHE	−.48	−1.69	−.41	−1.25	−.16	−.56	−1.27	−.45	−2.07
India	1.10	−.02	1.03	.31	1.17	.04	.91	−.66	−.21
Latin America & the Caribbean	−1.48	.96	.63	1.16	.11	.12	2.10	−.35	.38
North Africa	−.34	.16	.38	.24	.32	.00	.96	.39	−.46
Nigeria	−.60	−.36	−.12	−.36	.25	−.51	.29	.76	−.50
Pakistan	−.87	−.10	.45	−.09	−.31	−.14	.71	.47	−.07
Rest of World	−.84	−.71	.10	−.71	−.42	−.62	.00	−.42	−.80
Southern Africa	−.65	.11	.40	.20	.49	−.21	.83	.13	−.48
South East Asia	−.92	.68	.95	.86	.77	.18	.91	.49	−1.36
USA	−1.52	−1.22	.13	−1.29	−.44	−.43	−.50	−.69	−1.32
West Africa	−.83	−2.11	.47	−1.86	.87	−.07	−1.44	.31	−.83

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TABLE A.4 Agricultural and food trade impact in deviation from the BfC scenario 2021 COVID-19 runs (in percent)

Country/region	Exports	Imports
Central Africa	−8.26	−2.95
China	−6.22	−9.59
Commonwealth of Independent States	−7.98	−.12
Central & Southern Asia + Other Asia	−25.93	−2.36
East Africa	−9.25	−1.73
Ethiopia	−20.96	9.36
Europe including GBR and CHE	−7.92	−11.11
India	−11.65	−8.85
Latin America and the Caribbean	−17.69	−2.73
North Africa	−6.07	19.57
Nigeria	−7.94	3.78
Pakistan	−7.35	−5.29
Rest of World	−7.78	−7.59
Southern Africa	−8.15	−4.82
South East Asia	−14.95	−3.96
USA	−7.90	−19.20
West Africa	−.28	−8.07