

# An Updated Assessment of the Economic Impact of COVID-19—Online Appendix

## May 2020

### Appendix 1. Explanation of Shocks for the Simulations

#### Shock 1: Tourism

In the Global Trade Analysis Project (GTAP) dataset, travelers' expenditure is merged with the other cross-border trade flows in both goods and services, based on their shares<sup>a</sup> as described in the GTAP Data Base Documentation:<sup>b</sup>

*“Travelers’ expenditures” include spending abroad by tourists, people working overseas for short periods, and the like. The balance of payments statistics treat these expenditures as a single services commodity. But to fit in with the I-O [Input-Output] accounting framework in the GTAP Data Base, we need to resolve them into the standard GTAP commodities; so if a traveler abroad buys a T-shirt or a train ticket, we treat the expenditure as trade in apparel or in “other transport”, not in “travelers’ expenditures”.*

Therefore, we use the magnitude of tourism expenditure losses by country and divide each by the total production value of all sectors in GTAP. These shocks are then given to the output of this sector in every country. We introduced a new variable,  $qor(REG)$  in the model, which is the aggregate output across all sectors. This is endogenous by default, and therefore needs to be swapped by an exogenous variable of the same dimension. We choose the technological change or total factor productivity (TFP) variable  $aoreg(REG)$  for this swap, because this implies that the tourism shock happened due to factors that are neither policy-driven nor industry-driven, but totally outside the economic system.

The variable  $qor$  is simply a weighted aggregation of percent changes in output ( $qo$ ). The sequence of equations that connect  $qo$  with  $aoreg$  is as follows:

1. Market clearing equation ensures output equals domestic consumption  $qds$  and exports  $qxs$ :

$$\begin{aligned} qo(i,r) &= SHRDM(i,r) * qds(i,r) \\ &+ \mathbf{sum}(s,REG, SHRXMD(i,r,s) * qxs(i,r,s)) \\ &+ tradslack(i,r); \end{aligned}$$

2. Domestic consumption is a sum of consumption by firms ( $qfd$ ), households ( $qpd$ ), and government ( $qgd$ ):

$$\begin{aligned} qds(i,r) &= \mathbf{sum}(j,PROD\_COMM, SHRDFM(i,j,r) * qfd(i,j,r)) \\ &+ SHRDPM(i,r) * qpd(i,r) \\ &+ SHRDGM(i,r) * qgd(i,r); \end{aligned}$$

3. Each type of consumption above has a CES nest, with an elasticity of substitution between domestic and imports (Armington) dictating the extent of pass through from prices to demand for domestic consumption by each agent. The following is the example equation for domestic private consumption being a function of total private consumption ( $qp$ ), and private consumption prices—domestic ( $ppd$ ) and aggregated ( $pp$ ).

$$qp(i,s) = qp(i,s) + ESUBD(i) * [pp(i,s) - ppd(i,s)];$$

4. Each of the prices in the equations like the above are linked to the market prices ( $pm$ ) – the following shows the example of the private domestic consumption price:

$$ppd(i,r) = atpd(i,r) + pm(i,r);$$

5. The following equation links the market price with the supply price, the only difference being the output tax ( $to$ ), which remains unchanged in our simulations:

$$ps(i,r) = to(i,r) + pm(i,r);$$

6. The following equation links supply price with TFP, i.e. the variable  $ao$ , and other prices of intermediate inputs ( $pf$ ), their associated productivity changes ( $af$ ) as well as those of primary factors ( $pfe$ ) and their associated productivity changes ( $afe$  and  $ava$ ):

$$\begin{aligned} ps(j,r) + ao(j,r) &= \mathbf{sum}(i,ENDW\_COMM, STC(i,j,r) * [pfe(i,j,r) - afe(i,j,r) - \\ &ava(j,r)]) \\ &+ \mathbf{sum}(i,TRAD\_COMM, STC(i,j,r) * [pf(i,j,r) - af(i,j,r)]) \\ &+ profitslack(j,r); \end{aligned}$$

7. Finally, the equation below shows how the total change in TFP may come from the sector-specific TFP  $aosec$ , region-specific TFP  $aoreg$  and TFP that is specific to a sector and region  $aoall$ , which is our swap variable for  $qo$ :

$$ao(j,r) = aosec(j) + aoreg(r) + aoall(j,r);$$

<sup>a</sup> See this link for example: <https://www.gtap.agecon.purdue.edu/events/Conferences/2009/documents/SvcTrd.pdf>

<sup>b</sup> See this link: <https://www.gtap.agecon.purdue.edu/resources/download/2865.pdf>

## Shock 2: Consumption

We assume the aggregate private consumption, captured by the private consumption utility variable  $up$ , to be shocked at different extent (0.7% and 2% in low and mid/high scenarios, respectively), by swapping it with a technological shifter variable in the value-added part of the production “ $avareg$ ”. The link here is through the complex connections between consumption and production. Again, as in all our other shocks, we keep the consumption variable ‘ $up$ ’ endogenous and shock the variable  $avareg$  based on our pre-simulation.

1. The following equation links nominal private consumption expenditure ( $yp$ ) and private consumer price index ( $ppriv$ ) with our variable of interest,  $up$ :

$$yp(r) - pop(r) = ppriv(r) + UELASPRIV(r) * up(r);$$

2. The following equation connects  $ppriv$  with each of the different commodity prices:

$$ppriv(r) = \text{sum}(i, TRAD\_COMM, CONSHR(i,r) * pp(i,r));$$

3. The following expresses each of these prices as the weighted sum of domestic ( $ppd$ ) and imported prices ( $ppm$ ):

$$pp(i,s) = PMSHR(i,s) * ppm(i,s) + [1 - PMSHR(i,s)] * ppd(i,s);$$

4. The following equation links the market price with the supply price, the only difference being the output tax ( $to$ ), which remains unchanged in our simulations:

$$ps(i,r) = to(i,r) + pm(i,r);$$

5. The following equation links supply price with TFP, i.e. the variable  $ao$ , and other prices of intermediate inputs ( $pf$ ), their associated productivity changes ( $af$ ) as well as those of primary factors ( $pfe$ ) and their associated productivity changes ( $afe$  and  $ava$ ):

$$\begin{aligned} ps(j,r) + ao(j,r) &= \text{sum}(i, ENDW\_COMM, STC(i,j,r) * [pfe(i,j,r) - afe(i,j,r) - \\ &\quad ava(j,r)]) \\ &\quad + \text{sum}(i, TRAD\_COMM, STC(i,j,r) * [pf(i,j,r) - af(i,j,r)]) \\ &\quad + profitslack(j,r); \end{aligned}$$

6. Finally, the equation below shows how the total change in TFP may come from the sector-specific TFP  $avasec$ , TFP that is specific to a sector and region  $avaall$ , and the region-specific TFP  $avareg$ , which is our swap variable for  $up$ :

$$ava(j,r) = avasec(j) + avareg(r) + avaall(j,r);$$

## Shock 3: Investment

Investment slack ( $qcgdslack$ ) is exogenous in this model. We swap it with investment ( $qcgds$ ) and shock the latter in the long containment scenario by 6.25% for the People’s Republic of China. This means that there will be more or less investment, relative to savings.

## Shock 4: Fiscal Stimulus

We take all fiscal stimulus numbers and equally divide them as subsidies for consumption and those for labor (inputs to production).

## Appendix 2. ADB’s Economy and Regional Grouping in the GTAP Model

Asia	Central Asia	East Asia	Southeast Asia	South Asia
	Azerbaijan Georgia Kazakhstan Kyrgyz Republic Tajikistan Turkmenistan Uzbekistan	Hong Kong, China Korea, Republic of Mongolia People’s Republic of China Hubei Hunan, Henan, Guangzhou (HHGZ) RoChina	Brunei Darussalam Cambodia Indonesia Lao People’s Democratic Republic Malaysia Myanmar Philippines Singapore Thailand Timor-Leste Viet Nam	Afghanistan Bangladesh Bhutan India Maldives Nepal Pakistan Sri Lanka
G3	Oceania	Pacific <sup>a</sup>		
	Australia New Zealand	American Samoa Cook Islands Fiji French Polynesia Guam Kiribati Marshall Islands Micronesia, Federated States of Nauru New Caledonia Niue	Northern Mariana Islands Palau Papua New Guinea Pitcairn Samoa Solomon Islands Tokelau Tuvalu United States Minor Outlying Island Vanuatu Wallis and Futuna Islands	
Others	United States Japan European Union Austria Belgium Bulgaria Croatia Cyprus Czech Republic Denmark Estonia Finland United Kingdom	France Germany Greece Hungary Ireland Italy Latvia Lithuania Luxembourg	Malta Netherlands Poland Portugal Romania Slovakia Slovenia Spain Sweden	
	Rest of the World <sup>b</sup> Democratic People’s Republic of Korea Latin America <sup>c</sup> Russian Federation Turkey Africa (Sub-Saharan Africa) <sup>d</sup>			

GTAP = Global Trade Analysis Project.

<sup>a</sup> Aggregated as *Fijietc* in the GTAP Model.

<sup>b</sup> Rest of the World includes Canada, Mexico, Rest of North America, Switzerland, Norway, Rest of European Free Trade Association, Albania, Belarus, Ukraine, Rest of Eastern Europe, Rest of Europe, Armenia, Bahrain, Iran, Israel, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, Rest of Western Asia, Egypt, Morocco, Tunisia, and Rest of North Africa.

<sup>c</sup> Latin American includes Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela, Rest of South America, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, El Salvador, Rest of Central America, Dominican Republic, Jamaica, Puerto Rico, Trinidad and Tobago, and Rest of Caribbean.

<sup>d</sup> Africa (Sub-Saharan Africa) includes Benin, Burkina Faso, Cameroon, Côte d’Ivoire, Ghana, Guinea, Nigeria, Senegal, Togo, Rest of Western Africa, Rest of Central Africa, South Central Africa, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, United Republic of Tanzania, Uganda, Zambia, Zimbabwe, Rest of Eastern Africa, Botswana, Namibia, South Africa, and Rest of South African Customs Union.

Source: Global Trade Analysis Project. 2020.GTAP 10 Data Base Final Release 1 Release Candidate 1 Regions. <https://www.gtap.agecon.purdue.edu/databases/regions.aspx?version=10.211>.

### Appendix 3. GDP Impact of COVID-19, by Economy (Without Policy Responses)

Economy	\$ million		% of GDP	
	Short containment	Long containment	Short containment	Long containment
People's Republic of China	-1,083,078	-1,623,381	-7.5	-11.2
Bangladesh	-10,354	-15,938	-4.3	-6.6
Brunei Darussalam	-655	-1,157	-2.7	-4.8
Cambodia	-1,152	-1,740	-4.9	-7.4
Hong Kong, China	-18,412	-32,033	-4.5	-7.9
India	-111,732	-170,849	-3.9	-6.0
Indonesia	-57,195	-87,912	-4.6	-7.1
Kazakhstan	-5,193	-9,432	-1.6	-3.0
Kyrgyz Republic	-259	-480	-2.5	-4.6
Lao PDR	-804	-1,233	-4.9	-7.5
Malaysia	-19,000	-29,773	-4.0	-6.3
Mongolia	-673	-1,130	-3.9	-6.6
Nepal	-2,183	-3,752	-7.9	-13.6
Pakistan	-11,268	-17,220	-3.3	-5.1
Philippines	-15,701	-23,941	-3.9	-6.0
Republic of Korea	-130,170	-198,535	-7.7	-11.7
Singapore	-28,914	-45,147	-6.7	-10.5
Sri Lanka	-4,301	-6,731	-3.8	-6.0
Taipei, China	-14,830	-25,043	-2.3	-3.9
Thailand	-30,412	-45,778	-5.4	-8.1
Viet Nam	-7,516	-12,926	-2.9	-5.0

% = percentage, COVID-19 = Coronavirus 2019, GDP = gross domestic product, Lao PDR = Lao People's Democratic Republic.

Note: Computed based on Global Trade Analysis Project (GTAP) model. In the short containment scenario, the assumption is that it takes 3 months (from when the outbreak intensifies in each economy) for economies to get their domestic outbreaks under control and to start normalizing economic activity; and in the long containment scenario, this process takes 6 months.

Source: Asian Development Bank estimates.

## Appendix 4. Comparison between the Analysis in April 2020 ADO and the GTAP Model

	Analysis in April 2020	Global Trade Analysis Project (GTAP) v.10 Model
<b>Type of model</b>	Multiregional input-output analysis, based on ADB's Multiregional Input Output Table (MRIOT)	Multiregional, comparative-static, computable general equilibrium (CGE) model of world trade and investment.
<b>Countries/sector</b>	Aggregated to 62 economies (covering 95% of global GDP) and 35 sectors	Aggregated to 42 countries and regions and 52 subsectors.
<b>Model features</b>	<ul style="list-style-type: none"> <li>Shocks to final demand—in this case, tourism demand and domestic consumption and investment—are transmitted across sectors and borders via trade and production linkages</li> </ul>	<ul style="list-style-type: none"> <li>Standard features of the model such as the behavior of private individuals, firms, and governments, along with their responses to changing resource and market conditions.</li> <li>Consumers maximize welfare, subject to their budget limitations, with a relatively sophisticated representation of consumer demand, allowing for regional differences in the price and income elasticities of demand.</li> <li>Firms maximize profits using the limited resources available in the economy. Five primary factors of production (land, natural resources, physical capital, and skilled and unskilled labor) are combined with intermediate inputs, including imports, to produce the final output.</li> </ul>
<b>Impacts being measured</b>	<ul style="list-style-type: none"> <li>Impact on domestic consumption and investment in the People's Republic of China (PRC) and 38 other outbreak-affected economies</li> <li>Decline in tourism arrivals and receipts (also business travel)</li> <li>Spillovers via trade and production linkages</li> </ul>	<ul style="list-style-type: none"> <li>Impact on in domestic consumption and investment in the PRC and 95 other outbreak-affected economies</li> <li>Impact on trade: production/supply chain disruptions due to forced closures (decline in imports/exports)</li> <li>Decline in tourism receipts (global)</li> <li>Impact on employment and wage Income (millions)</li> <li>Impact of fiscal stimulus via income support (% GDP)</li> </ul>
<b>Scenario Settings</b>		
<b>Consumption</b>	<p><b>Short containment, smaller demand shocks:</b> Growth in domestic consumption in the PRC slows by: - 5 pp</p> <p>growth in domestic consumption in outbreak-affected economies excluding the People's Republic of China (PRC) declines by -2 pp</p>	<p><b>Short containment:</b> Decrease in productivity cuts consumption growth by: -6.7 pp in PRC -8.1 pp in the US -7.1 pp in EU -6.6 pp in Japan -6.5 pp in other outbreak-affected advanced economies -3.5 pp in other outbreak-affected economies</p>
	<p><b>Long containment, higher demand shocks:</b> Growth in domestic consumption in outbreak-affected economies decline by 5 pp;</p>	<p><b>Long containment, higher demand shocks:</b> Decrease in productivity cuts consumption growth by: -10.1 pp in PRC -12.2 pp in the US -10.7 pp in EU -9.9 pp in Japan -9.75 pp in other outbreak-affected advanced economies -5.3 pp in other outbreak-affected DMCs</p>

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	Analysis in April 2020	Global Trade Analysis Project (GTAP) v.10 Model
Investment	<p><b>Short containment, smaller demand shocks:</b> Growth in domestic investment in the PRC declines by 6.25 pp; Growth in domestic investment in outbreak-affected economies excluding the PRC declines by 2 pp.</p>	<p><b>Short containment:</b> Decrease productivity cuts investment growth by: -5.4 pp in PRC -8.2 pp in the US -10.0 pp in EU -7.3 pp in Japan -9.2 pp in other outbreak-affected advanced economies -4.4 pp in other outbreak-affected DMCs</p>
	<p><b>Long containment, higher demand shocks:</b> Growth in domestic investment in outbreak-affected economies declines by 6.25 pp.</p>	<p><b>Long containment:</b> Decrease productivity cuts investment growth by: -8.1 pp in PRC -12.3 pp in the US -15 pp in EU -10.95 pp in Japan -13.8 pp in other outbreak-affected advanced economies -6.6 pp in other outbreak-affected DMCs</p>
Tourism	<p><b>Short containment, smaller demand shocks:</b> Outbound PRC tourism drops by 55% for 3 months (WTO 2019); Economies that impose travel bans on visitors from outbreak-affected economies earn no tourism receipts from these countries for 3 months.</p> <p>Inbound tourism to outbreak-affected economies falls by 80% for 3 months; Inbound tourism to Asia excluding the PRC, the ROK, and Japan falls by 40% for 3 months; Inbound tourism to Europe excluding the European Union, Norway, Switzerland, and the United Kingdom falls by 30% for 3 months.</p>	<p><b>Short containment, smaller demand shocks:</b> Decline in international tourism receipts of 56%</p>
	<p><b>Long containment, higher demand shocks:</b> Outbound PRC tourism drops by 55% for 6 months; Economies that impose travel bans on visitors from outbreak-affected economies earn no tourism receipts from these countries for 6 months;</p> <p>Inbound tourism to outbreak-affected economies falls by 80% for 6 months; Inbound tourism to Asia excluding the PRC, the ROK, Japan falls by 40% for 6 months; Inbound tourism to Europe excluding the European Union, Norway, Switzerland, and the United Kingdom falls by 30% for 6 months.</p>	<p><b>Long containment, higher demand shocks:</b> Decline in international tourism receipts of 81%</p>
Trade costs for global supply chains	None	<p>Trade costs for industries linked to global supply chain:</p> <p><b>Short containment:</b> Increases by 1% <b>Long containment:</b> Increases by 2%</p>
Macroeconomic stimulus	None	<p><b>Short containment:</b> Half of the announced direct intervention to income and revenues enter as subsidy to consumers and producers</p> <p><b>Long containment:</b> The full amount of the announced direct intervention to income and revenues enter as subsidy to consumers and producers</p>

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	Analysis in April 2020	Global Trade Analysis Project (GTAP) v.10 Model
<b>Data Sources</b>		
<b>Main database</b>	ADB Multiregional Input-Output Table	The latest GTAP v.10 database was used and calibrated using 2018 data from the International Monetary Fund and the ADB Multiregional Input-Output Table.
<b>Employment effects</b>	MRIOT	GTAP database
<b>Fiscal stimulus</b>	n/a	Felipe, J. et al. 2020. ADB COVID-19 Policy Database (Version 1, 20 April 2020). Manila: ADB.
<b>Tourism</b>	<p>Al Jazeera. 2020. Coronavirus: Travel Restrictions, Border Shutdowns by Country. <a href="https://www.aljazeera.com/news/2020/03/coronavirus-travel-restrictionsborder-shutdowns-country-200318091505922.html">https://www.aljazeera.com/news/2020/03/coronavirus-travel-restrictionsborder-shutdowns-country-200318091505922.html</a> (accessed 26 March 2020).</p> <p>IATA. 2020. COVID-19 Updated Impact Assessment of the Novel Coronavirus. 5 March. <a href="https://www.iata.org/en/iata-repository/publications/economic-reports/coronavirus-updated-impact-assessment/">https://www.iata.org/en/iata-repository/publications/economic-reports/coronavirus-updated-impact-assessment/</a></p> <p>IATA. 2020. COVID-19 Assessing Prospects for Domestic Markets. 21 April. <a href="https://www.iata.org/en/iata-repository/publications/economic-reports/covid-19-assessing-prospects-for-domestic-markets/">https://www.iata.org/en/iata-repository/publications/economic-reports/covid-19-assessing-prospects-for-domestic-markets/</a></p> <p>New York Times. 2020. Coronavirus Travel Restrictions across the Globe. <a href="https://www.nytimes.com/article/coronavirus-travelrestrictions.html">https://www.nytimes.com/article/coronavirus-travelrestrictions.html</a> (accessed 26 March 2020).</p> <p>World Tourism Organization (WTO). 2020. Impact Assessment of the COVID-19 Outbreak on International Tourism. 5 March. <a href="https://webunwto.s3.eu-west-1.amazonaws.com/s3fs-public/2020-03/UNWTO-Impact-Assessment-COVID19.pdf">https://webunwto.s3.eu-west-1.amazonaws.com/s3fs-public/2020-03/UNWTO-Impact-Assessment-COVID19.pdf</a></p> <p>WTO. 2019. <i>Guidelines for the Success in the Chinese Outbound Tourism Market</i>. Madrid: International Air Transport Association. <a href="https://doi.org/10.18111/9789284421138">https://doi.org/10.18111/9789284421138</a>.</p>	

% = percentage, \$ = US dollars, n/a = not applicable, ADB = Asian Development Bank, DMC = developing member countries, EU = European Union, GDP = gross domestic product, IATA = International Air Transport Association, IMF = International Monetary Fund, pp = percentage points, PRC = People's Republic of China, ROK = Republic of Korea, SARS = Severe Acute Respiratory Syndrome, WTO = World Tourism Organization.

Source: ADB.