CHAPTER 2

ONLINE ANNEX

Annex 2.1. Data Sources and Sample Coverage

The primary data sources for this chapter are the IMF *World Economic Outlook* database, the Penn World Table (PWT) 10.0 database, the World Input-Output Database (WIOD) Release 2013 and 2016, United Nations National Accounts Statistics, and EORA MRIO 26 sector database (see Annex Table 2.1.1 for all sources). The sample coverage for the different sections of the analysis, driven by data availability, is reported in Annex Table 2.2.2.

Annex Table 2.1.1. Data Sources

Indicator	Source
Real GDP per capita (at constant prices, in 2017 US dollars)	Penn World Table 10.0
Total factor productivity (at constant prices, 2017=1)	Penn World Table 10.0
Capital stock (at constant prices, in 2017 US dollars)	Penn World Table 10.0
Number of persons engaged	Penn World Table 10.0
Population	Penn World Table 10.0
Financial crisis	Laeven and Valencia (2018); Reinhart and others (2016)
Pandemic incidence	Furceri and others (2020); Cockburn, Delon, Ferreira (1969)
Disaster incidence	Emergency Events Database (EM-DAT), CRED / UCLouvain, Brussels, Belgium, www.emdat.be (D. Guha-Sapir)
Conflict incidence	Uppsala Conflict Data Program (UCDP) Georeferenced Event Dataset and Battle-Related Deaths Dataset; UCDP/PRIO Armed Conflict Dataset; Novta and Pugacheva (2021)
Inter-country Input-Output Tables	World Input-Output Database (WIOD) Releases 2013 and 2016
Sectoral real Gross Value Added (volume indices)	World Input-Output Database (WIOD) Releases 2013 and 2016
Sectoral TFP shocks components	World Input-Output Database (WIOD) Releases 2013 and 2016
Sectoral government spending shock components	World Input-Output Database (WIOD) Releases 2013 and 2016
COVID-19 shock components	ILOSTAT and OECD's Quarterly National Accounts
Tourism and Transportation Share of GDP	World Travel and Tourism Council
Service Sector Share of GDP	World Bank, World Development Indicators

Source: IMF staff compilation.

Annex Table 2.1.2. Economies Included in the Analysis

Exercise	List of Economies
Historical country-level analysis and medium-term losses exercise (* if data for medium-term losses exercise only)	Afghanistan*; Albania*; Algeria*; Angola; Antigua and Barbuda*; Argentina; Armenia; Aruba*; Australia; Austria; Azerbaijan*; Bahamas, The*; Bahrain; Bangladesh*; Barbados; Belarus*; Belgium; Belize*; Benin; Bhutan*; Bolivia; Bosnia and Herzegovina*; Botswana; Brazil; Brunei Darussalam*; Bulgaria; Burkina Faso; Burundi; Cabo Verde*; Cambodia*; Cameroon; Canada; Central African Republic; Chad*; Chile; China; Colombia; Comoros*; Congo, Democratic Republic of the*; Congo, Republic of*; Costa Rica; Croatia; Cyprus; Czech Republic; Côte d'Ivoire; Denmark; Djibouti*; Dominica*; Dominican Republic; Ecuador; Egypt; El Salvador*; Equatorial Guinea*; Eritrea*; Estonia; Eswatini; Ethiopia*; Fiji; Finland; France; Gabon; Gambia, The*; Georgia*; Germany; Ghana*; Greece; Grenada*; Guatemala; Guinea*; Guinea-Bissau*; Guyana*; Haiti*; Honduras; Hong Kong SAR; Hungary; Iceland; India; Indonesia; Iran; Iraq; Ireland; Israel; Italy; Jamaica; Japan; Jordan; Kazakhstan; Kenya; Kiribati*; Korea; Kosovo*; Kuwait; Kyrgyz Republic; Lao P.D.R.; Latvia*; Lesotho; Liberia*; Libya*; Lithuania*; Luxembourg; Macao SAR; Madagascar*; Malawi*; Malaysia; Maldives*; Mali*; Malta; Marshall Islands*; Mauritania; Mauritius; Mexico; Micronesia*; Moldova; Mongolia; Montenegro, Rep. of*; Morocco; Mozambique; Myanmar*; Namibia; Nauru*; Nepal*; Netherlands; New Zealand; Nicaragua; Niger; Nigeria; North Macedonia*; Norway; Oman*; Pakistan*; Palau*; Panama; Papua New Guinea*; Paraguay; Peru; Philippines; Poland; Portugal; Puerto Rico*; Qatar; Romania; Russia; Rwanda; Samoa*; San Marino*; Saudi Arabia; Senegal; Serbia; Seychelles*; Sierra Leone; Singapore; Slovak Republic; Slovenia; Solomon Islands*; Somalia*; South Africa; South Sudan*; Spain; Sri Lanka; St. Kitts and Nevis*; St. Lucia*; St. Vincent and the Grenadines*; Sudan; Suriname*; Sweden; Switzerland; São Tomé and Príncipe*; Taiwan Province of China*; Tajikistan; Tanzania; Thailand; Timor-Leste*; Togo; Tonga*; Trinidad and Tobago; Tunisia; Turkey; Turkmenistan*; Tuvalu*; Uganda*; Ukraine; United Arab Emirates*; United Kingdom; United States; Uruguay; Uzbekistan*; Vanuatu*; Venezuela; Vietnam*; Yemen*; Zambia; Zimbabwe
Historical sector-level analysis (* if data for government spending shocks only)	Australia; Austria; Belgium; Brazil; Bulgaria; Canada; China; Croatia*; Cyprus; Czech Republic; Denmark; Estonia; Finland; France; Germany; Greece; Hungary; India; Indonesia; Ireland; Italy; Japan; Korea; Latvia; Lithuania; Luxembourg; Malta; Mexico; Netherlands; Norway*; Poland; Portugal; Romania; Russia; Slovak Republic; Slovenia; Spain; Sweden; Switzerland*; Taiwan Province of China; Turkey; United Kingdom; United States
COVID-19 spillovers exercise	Australia; Austria; Belgium; Brazil; Canada; China; Czech Republic; Denmark; Finland; France; Germany; Greece; Hungary; India; Indonesia; Ireland; Italy; Japan; Korea; Mexico; Netherlands; Norway; Poland; Portugal; Romania; Russia; Slovak Republic; Spain; Sweden; Switzerland; Taiwan Province of China; Turkey; United Kingdom; United States

Source: IMF staff compilation.

Annex 2.2. Country-Level Evidence on Scarring from Past Recessions

This annex provides technical details about the cross-country analysis presented in the chapter on historical evidence of the impact of economic recessions and the paths of subsequent recoveries. Recession episodes are identified using the Harding and Pagan (2002) algorithm on annual real GDP per capita, with a window of 1 year, minimum phase length of 1 year, and minimum cycle length of 2 years. While the standard approach for business cycle dating is tailored to quarterly data, the use of annual data allows for the identification of cycles for a larger sample of countries, in particular including developing economies for which quarterly data is often not available. Recessions identified using this approach for the United States match those reported by the NBER.

Recessions are classified by co-occurrence of a particular type of a crisis, namely: a financial crisis, an epidemic or pandemic, a disaster, or a conflict. Each recession can be associated with several types of crises, or with no crisis, in which case it is referred to as a "typical" recession. The incidence of financial crises follows Laeven and Valencia (2018) for the period going back to 1970 and Reinhart and others (2016) for years prior to 1970. In both cases, financial crises include banking crises, currency crises, and sovereign debt crises. Past modern epidemics and pandemics include the Hong Kong flu, SARS, H1N1, MERS, Ebola and Zika and are identified for countries in which cases have been reported. Disasters are identified using the Emergency Events Database (EM-DAT) when a country in a given year has experienced disasters that led to damages exceeding 1% of GDP or affected 5% of population (including deaths). Finally, a country is defined as being in conflict if in a given year there are battle-related deaths that exceed 100 people per one million population (Novta and Pugacheva 2021). A complete list of data sources is provided in Annex Table 2.1.1.

Each recession episode is further characterized by its depth (defined as the loss in real GDP per capita between the peak and the trough in percentage terms) and duration (defined as the number of years between the peak and the trough). Recession duration in the chapter's regression sample ranges between one and ten years, with 60 percent of recessions lasting one year and 90 percent of recessions lasting not more than three years for both advanced economies (AEs) and emerging market and developing economies (EMDEs). For comparability across recessions of different duration, the chapter focuses on recession depth defined as the loss between the peak and the first year of the recession. Under this definition, the median recession is associated with a 2.2% decline in per capita output in the first year.

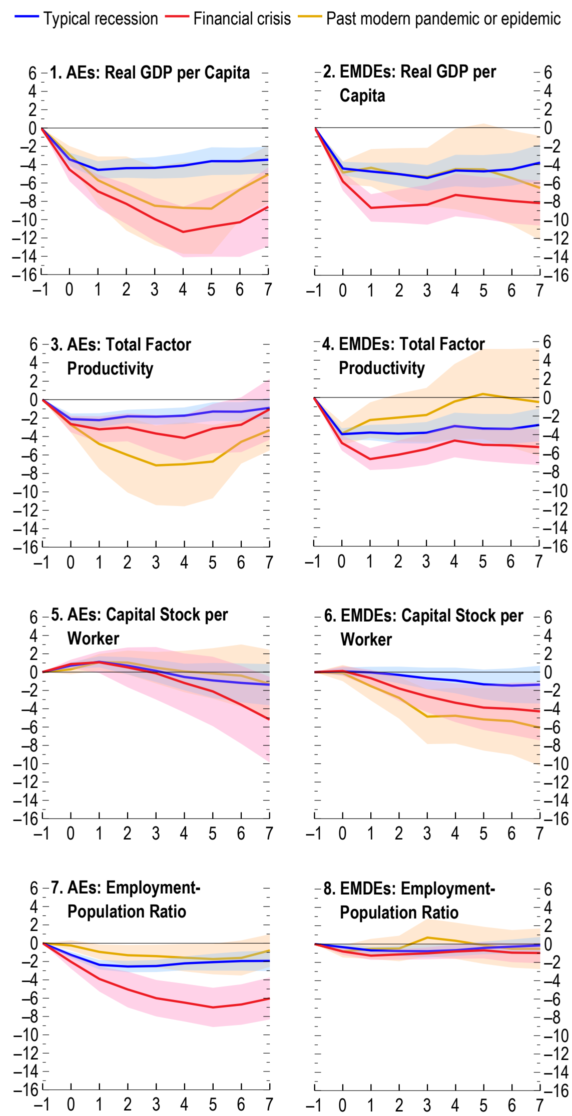
The analysis of the impact of a recession on GDP per capita, total factor productivity (TFP), capital per worker, and employment-to-population ratio relies on local projections (Jordà 2005) to trace out the impulse response functions based on the following equation:

$$y_{i,t+h} - y_{i,t-1} = \beta_1^h D_{i,t} + \sum_{E \in \{types\}} [\beta_2^{E,h} D_{i,t} * E_{i,t-2,t+2} + \beta_3^{E,h} E_{i,t}] + \varphi_1^h X_{i,t} + \mu_i^h + \theta_t^h + \varepsilon_{i,t}^h ,$$

in which $(y_{i,t+h} - y_{i,t-1})$ represents cumulative growth in log points in real GDP per capita (or another dependent variable) at different horizons (h=0,…7); $D_{i,t}$ is a dummy for recession onset (first year after the peak); $E_{i,t}$ is a dummy for occurrence of a financial crisis, an epidemic or pandemic, a disaster, or a conflict; the interaction terms $D_{i,t} * E_{i,t-2,t+2}$ capture different types of crisis events that happened within t-2 to t+2 of a given recession; $X_{i,t}$ is a vector of controls that includes two lags of the dependent variable's growth rate, one lag of log GDP in constant US dollars, and two lags of credit-to-GDP ratio; μ_i^h and θ_t^h are country and year fixed effects that control for all time-invariant country characteristics and time-specific common global shocks, respectively. The impact of a recession is given by $\beta_1^h + \beta_2^{E,h} + \beta_3^{E,h}$. Regressions are estimated separately for each horizon on a fixed sample. Thus, the number of observations, countries, and recession episodes is the same at all horizons and across all dependent variables. In all regressions, the left-hand-side variable has been winsorized at 0.5/99.5 percentiles to mitigate the effect of outliers.

The estimation results are presented in the chapter Figure 2.6. As the charts show the cumulative impact of a recession relative to the baseline, the return of the impulse response to zero signifies that the dependent variable has recovered. While the path of output differs by the type of recession, the estimates are negative and statistically significant across all horizons (Figure 2.6, panel 1), indicating that recessions are associated with permanent output losses, on average. Recessions associated with financial crises lead to more negative outcomes, as has been shown in the previous literature (Cerra and Saxena 2008; October 2009 *World Economic Outlook*). The path of output after past modern pandemic recessions has been in between that of regular recessions and financial crisis recessions. However, the COVID-19 crisis is global and more severe than those previous pandemics and with greater early signs of scarring.

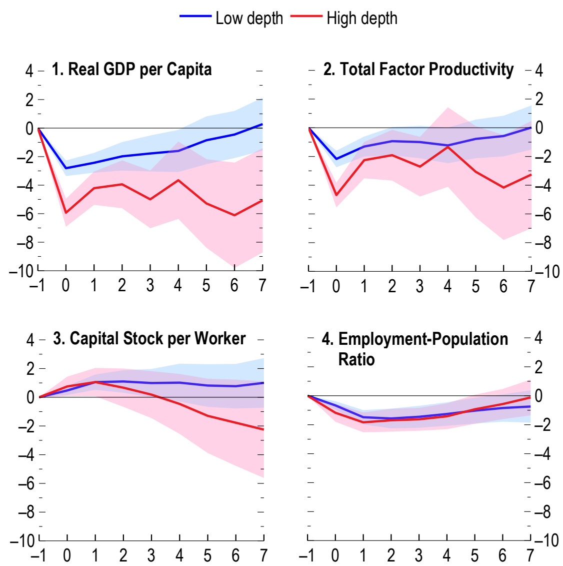
Annex Figure 2.2.1. Medium-Term Output Losses and Channels of Impact: Across Advanced Economies and Emerging Market and Developing Economies
(Percentage points)



Sources: Penn World Table 10.0; and IMF staff calculations.
Note: The solid lines represent the estimated cumulative IRFs, shaded areas represent 90 percent confidence intervals. Time since the shock (in years) on the *x*-axis. Past modern pandemics and epidemics include Hong Kong flu, SARS, H1N1, MERS, Ebola, and Zika. AEs = advanced economies; EMDEs = emerging market and developing economies.

Focusing on the channels of impact, the analysis shows that medium-term losses in GDP per capita for regular recessions can be primarily attributed to losses in TFP and there are is also a persistent decline in employment per capita. For financial crisis recessions, TFP, capital-to-worker ratios, and employment losses all play a role. Annex Figure 2.2.1 further shows impulse response functions for advanced economies and emerging market and developing economies separately. The comparison shows that TFP is damaged in all countries, for both typical and financial crisis recessions. Employment per capita losses are more important in advanced economies, while declines in the capital-per-worker ratio occur in financial crises recessions in emerging and developing market economies.

Annex Figure 2.2.2. Recovery Paths Following Deep and Shallow Recessions
(Percentage points)



Sources: Penn World Table 10.0; and IMF staff calculations.
Note: The solid lines represent the estimated cumulative IRFs, shaded areas represent 90 percent confidence interval. Time since the shock (in years) on the x-axis. High and low-depth recessions are split based on the median per-capita output loss. The figure includes only recessions that last one year and does not include recessions related to financial crises, past modern pandemics and epidemics, disasters, or conflicts. IRF = impulse response function.

The analysis of past recession episodes is further nuanced by classification of recessions into those with high and low depth (based on the median loss in the first year of the recession), drawing on the observation that the current COVID-19 crisis is characterized by its unparalleled depth. To perform this analysis, the regression equation is modified to include interaction terms for recessions of 1) high depth and one year duration, 2) low depth and one year duration, 3) high depth and more than a year duration, 4) low depth and more than a year duration. The interaction terms are included for all recession types. For conciseness, results presented in the chapter are for recessions of one-year duration. As Annex Figure 2.2.2 shows, GDP per capita growth is stronger immediately after deep recessions, as the economy bounces back, with the red line increasing more sharply after the initial downturn. But this initial bounce back is not enough to make up for the downturn itself and there are still permanent output losses, unlike for shallower recessions. This is primarily driven by reduction in total factor productivity and capital per worker ratios.

Annex 2.3. Historical Importance of Sectoral Spillovers

This annex describes the methodology used in the chapter to assess the impact of spillovers from sectoral shocks to sectoral outcomes. The analysis expands the framework based on input-output tables laid out in Acemoglu, Akcigit, and Kerr (2016) and Acemoglu and others (2016) by considering multiple countries and by encompassing spillovers not only from domestic sectors, but also from sectors in foreign countries. In particular, the following set of local projections (Jordà 2005) is estimated:

$$\Delta^h Y_{s,c,t} = \sum_{J=O\quad ,UpD,UpF,DnD,DnF} \beta^{J,h} Shock^{J}_{s,c,t} + \gamma\Gamma_{s,c,t} + \varepsilon_{s,c,t}\ , \qquad (A.1)$$

where $\Delta^h Y_{s,c,t}$ is the cumulative growth in real Gross Value Added (GVA) in sector s, country c between time $t-1$ and $t+h$, unless differently specified; $Shock^{J}_{s,c,t}$ are shocks hitting sector s in country c at time t coming from different parts of the production and distribution network, indexed by J, and described in more detail shortly; $\Gamma_{s,c,t}$ is a set of control variables; and finally $\varepsilon_{s,c,t}$ is the error term. In all regressions, values of cumulative growth in real GVA larger than 0.5h (smaller than -0.5h) have been capped at 0.5h (-0.5h), to mitigate the effect of outliers. The effects of interest—namely, the relative impact that shocks originating in different parts of the network have on GVA—are given by the $\beta^{J,h}$. In order to make meaningful comparisons across those coefficients, the various $Shock^{J}_{s,c,t}$ variables are divided by their standard deviations.

In light of the standardization of the shocks, the following modification of (A.1) is estimated to correctly quantify the size of the effects of the *own* versus *total* network shocks:

$$\Delta^h Y_{s,c,t} = \sum_{J=Own,TotNwk} \beta^{J,h} Shock^{J}_{s,c,t} + \gamma\Gamma_{s,c,t} + \varepsilon_{s,c,t}\ , \qquad (A.2)$$

where $Shock^{TotNwk}_{s,c,t} = \sum_{J=UpD,UpF,DnD,DnF} Shock^{J}_{s,c,t}$ again is divided by its standard deviation.

Construction of the Network Shocks

Shocks hitting sector s in country c at time t originating in the same sector-country-year are what are called *own shocks* in the chapter, $Shock^{Own}_{s,c,t}$. Shocks originated in other sectors and/or countries are what are called *network shocks* in the chapter. They are denoted by DnD (downstream domestic), UpD (upstream domestic), DnF (downstream foreign), and UpF (upstream foreign). They are built from input-output tables based on the following formulas:

$$Shock^{DnD}_{s,c,t} = \sum_{j\neq s} a_{s,c,j,c,0}\, Shock^{Own}_{j,c,t}\ , \qquad (A.3)$$

$$Shock^{UpD}_{s,c,t} = \sum_{j\neq s} \hat{a}_{s,c,j,c,0}\, Shock^{Own}_{j,c,t}\ , \qquad (A.4)$$

$$Shock^{DnF}_{s,c,t} = \sum_{j}\sum_{g\neq c} a_{s,c,j,g,0}\, Shock^{Own}_{j,g,t}\ , \qquad (A.5)$$

$$Shock_{s,c,t}^{UpF} = \sum_{j} \sum_{g \neq c} \hat{a}_{s,c,j,g,0} \, Shock_{j,g,t}^{Own} \ , \qquad (A.6)$$

where $a_{s,c,j,g,t} = \left[\frac{sales_{(j,g)\to(s,c),t}}{sales_{s,c,t}}\right]$ are the sales going from sectors j in countries g to the focal sector s in country c at time t, as a share of total sales of the focal sector; and $\hat{a}_{s,c,j,g,t} = \left[\frac{sales_{(s,c)\to(j,g),t}}{sales_{s,c,t}}\right]$ are the sales the focal sector s in country c to other sectors j in countries g.

Therefore, downstream shocks—domestic and foreign—are the sum of shocks originating in supplier sectors that travel *downstream* to the focal sector, weighted by the importance of each supplier sector for the focal sector; whereas upstream shocks—domestic and foreign—are the sum of shocks originating in costumer sectors that travel *upstream* to the focal sector, again weighted by the importance of each costumer sector for the focal sector. To mitigate concerns about endogenous changes in the input-output structure in response to the shocks, sales shares a and $\hat{a}$ are held fixed at the initial $t = 0$ period.

Supply and Demand Shocks

The chapter analyzes one supply-side and one demand-side shock. The *supply-side shock* is the year-on-year percentage change in TFP in each sector:

$$\Delta \log TFP_{s,c,t} = \Delta \log rGVA_{s,c,t} - \alpha_{s,c,t} \Delta log L_{s,c,t} - \left(1 - \alpha_{s,c,t}\right) \Delta log K_{s,c,t} \ ,$$

where $rGVA_{s,c,t}$ is real GVA; $L_{s,c,t}$ is total hours worked; $K_{s,c,t}$ is real fixed capital stock; and $\alpha_{s,c,t}$ is the sectoral labor share of value added, which is calculated as a 2-year moving average.

The *demand-side shock* is the year-on-year percentage change in government spending directed to each sector. In analogy to Acemoglu, Akcigit, and Kerr (2016), this shock is built by weighting the change in real total government spending in country c at year t by the sales of each sector s in country c and year $t - 1$ going to either the public administration sector or government consumption in final demand, as a share of sectoral output in $t - 1$. Total real government spending in country c at time t is the sum of government consumption and total inputs of the public administration sector in country c at time t.[1]

Regression Results for Sectoral Spillovers

Results for the estimation of the regressions (A.1) and (A.2) in the case of TFP shocks are reported in Annex Table 2.3.1. The controls included are a set of country, sector, and time fixed effects. The definition of the dependent variable for the local projections for TFP is slightly modified so that $\Delta^h Y_{s,c,t}$ is the percent change between time t and $t + h$, which excludes the large and almost mechanical contemporaneous effect of own TFP shocks on sectoral GVA. The

[1] The government spending shock is not derived for the public administration, education, and health sectors, given that changes in government spending directed to those sectors reflect institutional factors more than economic choices.

coefficients reported in Annex Table 2.3.1 are the ones shown in Figure 2.9, panel 1 in the chapter, to which the reader is referred for a discussion of their economic meaning.

Annex Table 2.3.1. Spillovers from Supply-Side TFP Shock

	h=1 (1)	h=2 (2)	h=3 (3)	h=4 (4)	h=5 (5)
Panel A. Own and Spillover Effects					
Own Shock	0.003*	0.006**	0.006	0.008	0.007
	(0.002)	(0.003)	(0.004)	(0.005)	(0.006)
Upstream Domestic Shock	0.003**	0.003	0.004	0.003	0.004
	(0.001)	(0.002)	(0.003)	(0.004)	(0.005)
Upstream Foreign Shock	0.000	–0.001	0.000	0.001	0.000
	(0.002)	(0.003)	(0.003)	(0.005)	(0.005)
Downstream Domestic Shock	0.006***	0.005**	0.008***	0.011***	0.010**
	(0.001)	(0.002)	(0.003)	(0.004)	(0.005)
Downstream Foreign Shock	0.005***	0.004	0.003	0.008*	0.010*
	(0.002)	(0.003)	(0.003)	(0.005)	(0.006)
Number of Observations	16,438	16,438	16,438	16,438	16,438
R^2	0.114	0.154	0.183	0.208	0.229
Panel B. Own and Total Spillover Effects					
Own Shock	0.003*	0.006**	0.006	0.008	0.007
	(0.002)	(0.003)	(0.004)	(0.005)	(0.006)
Total Network Shock	0.008***	0.008***	0.010***	0.014***	0.014***
	(0.001)	(0.002)	(0.003)	(0.004)	(0.005)
Number of Observations	16,438	16,438	16,438	16,438	16,438
R^2	0.113	0.154	0.183	0.208	0.228

Source: IMF staff calculations.
Note: The dependent variables are cumulative growth of real GVA at horizon *h* after a shock. Shocks are changes in sectoral TFP originated in Own sector or in other sectors in the production network, as described in the text. Total Network Shock is the sum of the four types of network shocks. Every shock is divided by its standard deviation. Regressions are estimated separately for each horizon. The sample covers 29 advanced and 11 emerging economies over 1995–2009 (see Annex Table 2.1.2). All regressions include country, sector, and year fixed effects. Standard errors are clustered at the country-sector level. * p<0.1; ** p<0.05; *** p<0.01.

Annex Table 2.3.2. Spillovers from Demand-Side Government Spending Shock

	h=0 (1)	h=1 (2)	h=2 (3)	h=3 (4)	h=4 (5)
Panel A. Own and Spillover Effects					
Own Shock	0.001	0.002	–0.001	–0.001	–0.001
	(0.001)	(0.001)	(0.002)	(0.003)	(0.005)
Upstream Domestic Shock	0.000	0.001	0.004	0.004	0.005
	(0.001)	(0.003)	(0.005)	(0.008)	(0.010)
Upstream Foreign Shock	–0.001	0.000	0.000	0.001	0.001
	(0.002)	(0.002)	(0.003)	(0.004)	(0.005)
Downstream Domestic Shock	0.002	0.006**	0.006	0.008	0.004
	(0.002)	(0.003)	(0.005)	(0.007)	(0.010)
Downstream Foreign Shock	0.004**	0.004*	0.006**	0.005	0.002
	(0.001)	(0.002)	(0.003)	(0.004)	(0.006)
Number of Observations	22,972	21,738	20,504	19,270	18,036
R^2	0.110	0.173	0.187	0.208	0.230
Panel B. Own and Total Spillover Effects					
Own Shock	0.001	0.003*	0.001	–0.001	–0.001
	(0.001)	(0.001)	(0.002)	(0.003)	(0.005)
Total Network Shock	0.002	0.006***	0.009***	0.010**	0.009
	(0.001)	(0.002)	(0.003)	(0.004)	(0.006)
Number of Observations	22,972	21,738	20,504	19,270	18,036
R^2	0.109	0.172	0.187	0.208	0.230

Source: IMF staff calculations.
Note: The dependent variables are cumulative growth of real GVA at horizon *h* after a shock. Shocks are changes in sectoral government spending originated in Own sector or in other sectors in the production network, as described in the text. Total Network Shock is the sum of the four types of network shocks. Every shock is divided by its standard deviation. Regressions are estimated separately for each horizon. The sample covers 31 advanced and 12 emerging economies over 1995–2014 (see Annex Table 2.1.2). All regressions include country, sector, and year fixed effects. Standard errors are clustered at the country-sector level. * p<0.1; ** p<0.05; *** p<0.01.

Annex Table 2.3.2 shows the results of the analysis of the government spending shock. The coefficients in the table are the ones displayed in Figure 2.9, panel 2 in the chapter. Note that the labels for the horizons h in that figure have been shifted by one period, to ease the comparison with TFP results.

Sector Recovery after Negative Shocks

This section presents the methodology used in the chapter to analyze the performance of sectors after being hit by negative shocks. When considering sectoral dynamics after a shock, it is important to recognize that the sectoral shocks analyzed in the chapter (TFP and government spending) are frequent shocks whose autocorrelation structure can potentially impact the cumulative change of outcomes after a shock experienced at any given period. In order to account for this feature of the data, results are derived with a two-step approach. First, equations of the following type are estimated:

$$\Delta Y_{s,c,t} = \sum_{h=0}^{H} \beta^h Shock_{s,c,t-h}^J + \gamma_{s,c,t} + \varepsilon_{s,c,t} ,$$

where $\Delta Y_{s,c,t}$ is the percent change in the share of sector s GVA in total GVA in country c from time $t-1$ to t; $Shock_{s,c,t-h}^J$ is a negative TFP or government spending shock, derived as described in previous sections, with $J = Own, TotNwk$; $\gamma_{s,c,t}$ is a set of country-time, sector-time, and country-sector fixed effects; and finally $\varepsilon_{s,c,t}$ is the error term. Changes in GVA shares larger than 0.5h (smaller than -0.5h) are capped at 0.5h (-0.5h), to mitigate the effect of outliers.

Then, the following dynamic panel model is estimated, to recover the autocorrelation structure for the shocks:

$$Shock_{s,c,t}^J = \sum_{h=1}^{H} \theta^h Shock_{s,c,t-h}^J + \gamma_{s,c,t} + \varepsilon_{s,c,t} ,$$

where again $Shock_{s,c,t}^J$ is a negative shock with $J = Own, TotNwk$; $\gamma_{s,c,t}$ is a set of country-time, sector-time, and country-sector fixed effects; and $\varepsilon_{s,c,t}$ is an error term.

Finally, the two equations are combined. A unitary shock hitting sector s in country c at time t has an effect at horizon $h = 0$ equal to β^0; at $h = 1$, the effect is $\beta^0\theta^1 + \beta^1$; at $h = 2$, it is $\beta^0((\theta^1)^2 + \theta^2) + \beta^1\theta^1 + \beta^2$; and so on. Adding up those period-by-period effects gives the impulse response functions for the cumulative growth rate in GVA shares shown in Figure 2.10.

Sectoral Spillovers for COVID-19

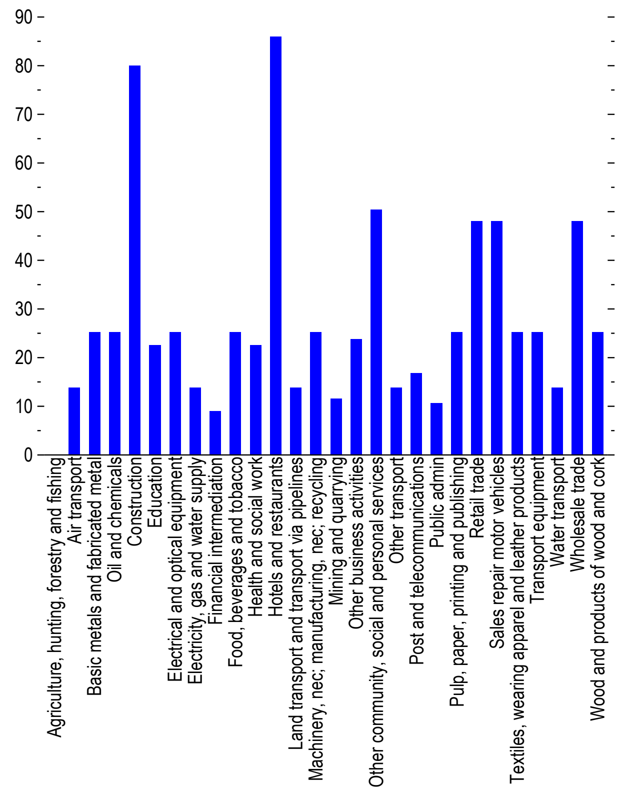
This section describes the methodology used in the exercise that assesses the spillovers from the COVID-19 shock to sectoral real GVA in historical terms.

The starting point of the analysis are COVID-19 shocks to TFP, $\Delta \log TFP_{s,c}$, and total hours worked, $\Delta \log L_{s,c}$, calibrated for each sector s in country c by considering changes between 2019Q4 and 2020H1 data. Changes in total sectoral hours worked are derived from mean weekly hours worked and employment levels from ILOSTAT. Changes in TFP are proxied by changes in labor productivity calculated as $\Delta \log TFP_{s,c} = \Delta \log GVA_{s,c} - \Delta \log L_{s,c}$. This effectively assumes unchanged capital. Changes in sectoral GVA are from the OECD's Quarterly National

Accounts statistics. Missing data are extrapolated using sector and country income group averages.

The TFP shock is assumed to be a supply-side shock, whereas the labor demand shock is divided into a supply component and a demand component according to the share of activities that are expected to be affected by COVID-19 containment measures. The demand component is derived according to the share of activities in a sector that can be performed through telework and are essential to the economy. The rationale is that the less activity in a sector is expected to be impacted by COVID-19 (because essential and/or potentially conducted remotely), the more any observed drop in labor utilization in that sector can be attributed to demand rather than supply factors. The opposite is true for sectors whose activity is largely affected by lockdowns, for which the decline in employment is then more linked to supply-side factors. In particular, the share of activity affected by COVID-19 in each sector is defined as:

Annex Figure 2.3.1. Share of Activity Impacted by COVID-19
(Percent)



Sources: Shibata (2020); and IMF staff calculations.
Note: The shares reflect the degree of teleworkability and essentiality of each sector's activity. They are assumed to be the same across countries.

$$\alpha_{s,c} = \left(1 - \text{share of telework}_{s,c}\right) \times (1 - \text{share of essential}_{s,c})$$

based on the classification of sectors in the United States in Shibata (2020). These shares are assumed to be constant across countries. Annex Figure 2.3.1 shows the values of α_s. Essential sectors (such as Agriculture) or sectors with a high degree of teleworkability (such as Finance) show very low values of α_s, whereas non-essential sectors with a low degree of teleworkability —such as Hospitality or Construction—display high α_s Values.

The final step in the exercise is then to recover the effects of own and network shocks on sectoral real GVA at horizon h as

$$Effect_{s,c}^{J,h} = \beta^{SUP,J,h}(\Delta \log TFP_{s,c}^{J} + \alpha_s \Delta \log L_{s,c}^{J}) + \beta^{DEM,J,h}(1 - \alpha_s)\Delta \log L_{s,c}^{J} \ ,$$

where $\beta^{SUP,J,h}$ are the supply-side coefficients estimated for historical TFP shocks (see Figure 2.9 panel 1 and Annex Table 2.3.1) and $\beta^{DEM,J,h}$ are the demand-side coefficients estimated for historical government spending shocks (see Figure 2.9 panel 2 and Annex Table 2.3.2) for shocks of type $J = Own, UpD, UpF, DnD, DnF$. The network shocks to productivity and labor,

$\Delta \log TFP_{s,c}^{J}$ and $\Delta \log L_{s,c}^{J}$, $J = UpD, UpF, DnD, DnF$, are built based on formulas (A.3)-(A.6) using input-output tables for the year 2014 (the last available period in the WIOD dataset).

Figure 2.11 in the chapter shows the average effects across country-sectors for each type-J shock. The fact that $\beta^{SUP,J,h}$ and $\beta^{DEM,J,h}$ are estimated from regressions in which the shocks are standardized implies that the average effects reported in Figure 2.11 are relative contributions to the total GVA drop. Moreover, the timing convention adopted in the estimation of historical spillovers from supply-side shocks implies that results in the figure can be interpreted as those occurring in the immediate aftermath of the initial COVID-19 shock.

Annex 2.4. Evidence of Scarring from Output Forecast Revisions

This annex describes the general framework used in the chapter to provide evidence for possible medium-term economic damage from the COVID-19 crisis based on revisions of output forecasts. The analysis is conducted relying on regressions of the following type:

$$\Delta\hat{Y}_i^t = \alpha + \beta X_i + \gamma \Gamma_i + \varepsilon_i \ ,$$

where $\Delta\hat{Y}_i^t$ is the percentage change in forecasts for output in year t in country i between two forecast vintages; X_i is a country-specific regressor of interest; Γ_i is a country-specific vector of control variables; and ε_i is an error term.

The main comparison is between forecasts reported in the current April 2021 *World Economic Outlook* (WEO) and forecasts reported in the January 2020 *WEO Update*, thus spanning the full duration of the crisis up to the time of writing. For some specifications, the comparison between forecasts in the October 2020 *WEO* and forecasts in the January 2020 *WEO Update* is also considered, which captures the first phases of the crisis—notably before news on vaccines and the stronger-than-expected economic performance in many countries in the second half of 2020. The years t for which output forecast revisions are considered are 2022–2024.

The main effect of interest, β, corresponds to the percentage change in output forecast revisions associated with a (unit) change in X_i. The evolution of β in the regressions at different forecast horizons t provides evidence on the expected effects of the COVID-19 crisis on future economic activity and their heterogeneity according to X_i. In particular, the effects for the outer years can be interpreted as estimates of the degree of expected medium-term scarring.

Several regressors of interest X_i are considered: (*i*) indicators for income group based on the WEO country classification into advanced, emerging, or low-income economies (Figure 2.13 in the chapter, panel 2); (*ii*) share of GDP coming from tourism and transportation in 2019; (*iii*) share of GDP coming from services in 2019; (*iv*) fiscal support during COVID-19 crisis up to December 2020 (all Figure 2.13, panel 1).[1]

Regressions that look at the difference across income groups do not include any additional controls. Regressions that consider independent variables as in *ii-iv* include income-group and region fixed effects. Regressors described in *ii-iv* are standardized to have zero mean and unitary standard deviation. As a result, the estimates for the effects of interest, β, reported in Figure 2.13 are given in terms of percent change in output per standard deviation of the regressor. In all regressions, standard errors are clustered at the region level.

[1] Fiscal support data are from *Fiscal Monitor Database of Country Fiscal Measures in Response to the COVID-19 Pandemic* and include both additional spending and forgone revenue in response to the COVID-19 pandemic. They are available at https://www.imf.org/en/Topics/imf-and-covid19/Fiscal-Policies-Database-in-Response-to-COVID-19.