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Assessing the Impact of Supply Disruptions on the Global Pandemic Recovery

Prepared by Harri Kemp, Rafael Portillo, and Marika Santoro

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ABSTRACT: We estimate the role of (pre-Ukraine war) supply disruptions in constraining the Covid-19 pandemic recovery, for several advanced economies and emerging markets, and globally. We rely on two approaches. In the first approach, we use sign-restricted Vector Auto Regressions (SVAR) to identify supply and demand shocks in manufacturing, based on the co-movement of surveys on new orders and suppliers' delivery times. The effects of these shocks on industrial production and GDP are recovered through a combination of local projection methods and the input-output framework in Acemoglu et al. (2016). In the second approach, we use the IMF's G20 model to gauge the importance of supply shocks in jointly driving activity and inflation surprises. We find that supply disruptions subtracted between 0.5 and 1.2 percent from global value added during the global recovery in 2021, while also adding about 1 percent to global core inflation that same year.

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Introduction

Although it has become a trite observation, the Covid-19 pandemic period has been truly unique. Whereas recessions and recoveries usually reflect movements in aggregate demand, the sharp swings in activity since 2020 have come instead from a combination of supply and demand factors. This was particularly evident during the recovery from the Great Lockdown that started in mid-2020. As goods demand surged, unprecedented supply chain stresses soon emerged, with a high share of firms reporting shortages of intermediate inputs and labor (see e.g., Celasun (2022), Pitschner (2022)). Logistical bottlenecks also contributed to longer delivery times, with many key ports experiencing congestion levels well above pre-pandemic levels (Komaromi et al., 2022). Their emergence at a time when aggregate activity was well below its pre-Covid trend has underscored the impact of the pandemic on global productive capacity.

The drivers and implications of these supply-side disruptions have been the subject of much debate. Much of the recent work has been on the impact on inflation, understandably so given the unprecedented inflationary surge that has taken place over this period. In this paper our focus is on the impact on activity across a group of advanced economies (AEs) and emerging markets (EMs) and globally. We focus mainly on 2021: this was the year in which these disruptions were most visible and their effect on activity less likely to be polluted by other supply shocks, especially those stemming from the invasion of Ukraine.

Our main contribution is that we use two complementary approaches to disentangle the relative importance of demand and supply forces in driving activity over this period, while also taking a global perspective. Each approach emphasizes different dimensions of the global macro data, one centered around manufacturing surveys and input-output linkages, and the other centered around aggregate output and inflation surprises. Importantly, we do not take a stand on the precise mechanisms and drivers underlying supply and demand shocks. We apply simple identification strategies and let the data speak.

The first approach comprises three stages. In the first stage, we use a sign-restricted Bayesian vector autoregression (SVAR) to identify demand and supply shocks to manufacturing, drawing on the information contained in Purchasing Managers' Indices (PMIs) and following earlier work by Goldman Sachs (2020, 2021). Supply shocks are identified as shocks that reduce efficiency in the sector, lengthening delivery times faced by manufacturing firms for their supplies and at the same time reducing orders for firms' products (a measure of activity). In the second stage, we use the Jordà (2005) local projection method to determine the impact of the estimated supply shocks on manufacturing production, across countries and globally, and on global trade. Finally, in a third step, we use the input-output framework in Acemoglu et al (2016) to assess sectoral spillovers and the impact on aggregate value added (GDP), treating the underlying supply shock as a shock to productivity.

We then use an alternative approach that exploits the structure of the IMF's G20 model[1], a multi-country semi-structural model with new-Keynesian features, to assess the relative importance of demand and supply shocks in 2021 in explaining surprises in inflation and output outturns relative to the IMF's pre-Pandemic projections. In the model, supply shocks shift Phillips curves. Intuitively, if core inflation is higher than what is implied by the model's Phillips curve for a given level of output, the excess inflation interpreted as reflecting in part a supply

[1] Andrle et al. (2015).

shock. The approach produces estimates for both output and inflation since the recovered shock impacts both variables.

We find that supply shocks were an important factor constraining the pandemic recovery. According to the first approach, supply shocks had a sizable effect on the manufacturing recovery, spilling over to other sectors and lowering economy-wide value added. This approach estimates that supply shocks in 2021 subtracted around -3.4 percent from global manufacturing production, around -4 percent from global trade, and -1.2 percent from global GDP, once spillovers to other sectors are considered. This approach also shows that measures of supply disruptions generally eased in 2022 in lockstep with a cooling off in global demand. The second approach finds broadly similar effects on global GDP, although the impact is somewhat smaller at -0.5 percent. Additionally, it estimates that supply shocks added around 1 percentage point to global core inflation in 2021.

These estimates are sizable. The gap between the level of global GDP and the level implied by pre-Pandemic Projections from the IMF's January 2020 World Economic Outlook publication (WEO) stood at 3.7 percent in 2021, consistent with a rapid but incomplete global recovery. Our estimates imply that the gap would have been smaller, between 2.5 and 3.2 percent, in the absence of 2021 supply shocks. Relatedly, the WEO's global measure of core inflation was 3.5 percent in 2021, compared with an average of 2.9 percent over the 2010-2019 period and a projection of 3.1 percent in the January 2020 WEO. The G20 model estimates therefore imply that global core inflation in 2021 would have been below pre-Covid projections in the absence of supply shocks.

While both approaches yield broadly similar estimates at the global level, there is greater variation at the country level. The first approach typically finds larger effects on activity in advanced economies, for example in some European countries such as Germany, as these countries show greater signs of stress in manufacturing surveys. The second approach finds greater impact of supply shocks in countries with a larger inflation response earlier in the recovery. This is the case in several EMs, for example in Latin America, and in the US. There are several possible reasons for the differences. The first approach relies on the informational content of manufacturing surveys, which may be stronger in AEs, while the second approach relies on the accuracy of the pre-Covid projections, which may be biased in some countries. In addition, the second approach relies on a relation between supply disruptions and core inflation that may take time to materialize. It can be argued that in AEs some of the inflationary effects from the 2021 disruptions were felt in 2022 rather than in 2021. In all, the differences do not alter the main finding that supply disruptions were a sizable drag on the global pandemic recovery.

Our paper relates to the burgeoning literature on the macro effects of the Covid shock and the subsequent recovery. Some of the work recognized early on the dual demand/supply nature of the Covid shock and the role of production networks and supply chains in the propagation of sectoral developments (Baqaee and Farhi, 2022, Guerrieri et al., 2022 and 2021, among others). As inflation surged during the recovery, much of the focus has been on understanding why. Several papers have used network models to quantify sectoral supply and demand factors behind the inflation increase (Di Giovanni et al, 2022, Ferrante et al, 2022), while others have stressed sectoral drivers but in models with limited input output structure (Kindberg-Hanlon and Portillo, 2023, Gudmundsson et al, 2023). Other papers have looked at aggregate factors such as shocks to labor supply or limited slack in the labor market (Amiti et al, 2022, Ball et al, 2022, Crump et al, 2022) and possible non-linearities in the aggregate Phillips curve (Ball et al, 2022, Linde et al, 2022, Cerrato and Gitti, 2022, Gudmundsson et al, 2023). Overall, these papers find an important role for both supply and demand factors in accounting for the inflation surge, which is broadly consistent with the results from the application of the G20 model in this paper. The first approach in our paper is more closely related to papers that focus on the impact of supply disruptions on activity, especially Goldman Sachs (2021) but also Celasun et al (2022). Celasun et al (2022) follows a broadly similar empirical strategy but with a different set of variables and finds impacts that are in line with our own estimates but with an emphasis on Europe. The approaches used here are also consistent with the model in Alessandria et al (2022).

Background and Stylized Facts

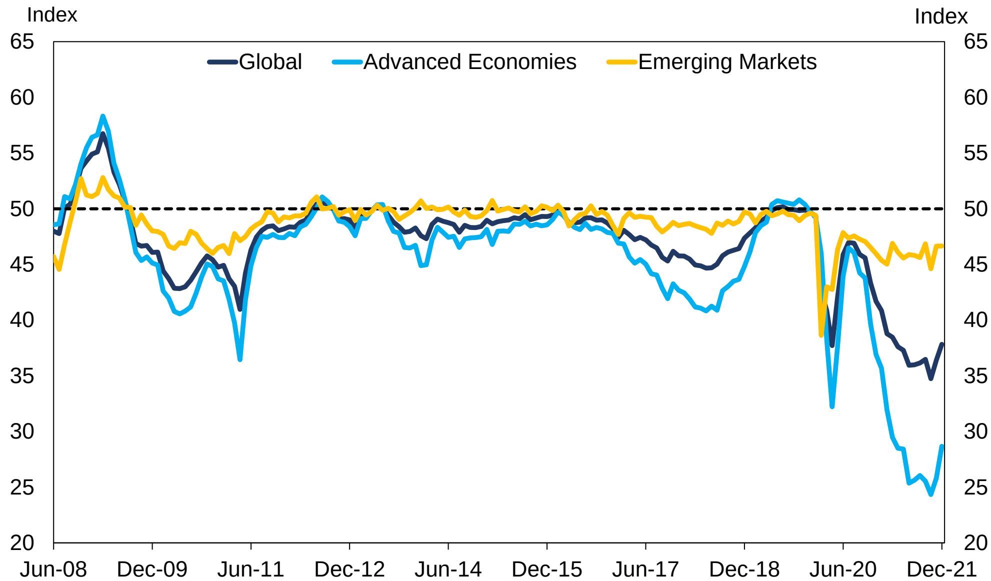
Supply bottlenecks emerged as a critical headwind to the economic recovery in 2021. Bottlenecks materialized in delivery times lengthening to well above their pre-pandemic levels (especially in AEs), scarcity of intermediate goods and, to a lesser extent, labor shortages. The key drivers behind these disruptions were a surge in demand for goods running against inelastic supply, shutdowns due to Covid restrictions, and softer labor force participation. Celasun et al. (2022) provides a detailed overview of the stylized facts related to the supply disruptions of 2021. In this section, we present a summary of the salient facts relevant for our empirical strategy.

A useful summary measure of global supply disruptions/constraints is provided by the manufacturing PMI suppliers' delivery times index, published monthly as part of the S&P Global manufacturing PMI (S&P Global, 2022). The global manufacturing purchasing managers index (PMI) is a survey-based indicator of business conditions in the sector, covering around 40 countries. It includes measures of changes in output, new orders, employment, input and output prices, export orders, purchasing activity, suppliers performance, backlogs of orders, and inventories. The surveys ask respondents to report the change in each variable compared to the previous month, indicating whether each has risen/improved, fallen/deteriorated, or remained unchanged. PMIs are considered a timely indicator of business conditions as they are released ahead of comparable official data. They are also reported as diffusion indices, with the value of the index varying between 0 and 100. A level of 50 signals no change relative to the previous, readings above 50 signals an improvement or increase, and readings below 50 signals a deterioration or decrease. The greater the divergence from the neutral level, i.e., 50, the greater the rate of change.[2]

In the case of the suppliers' delivery times (SDT) subindex, a value below 50 indicates that delivery times are lengthening for the average firm, relative to the previous month. Movements in the subindex are related to the state of the global business cycle, as can be seen in Figures 1 and 2. During expansions it takes time for upstream firms to adjust production in response to increased demand, firms must wait longer to get the inputs that they need, and the index declines. Inversely, delivery times tend to shorten (the index increases) when activity is slowing. The cyclicality is also reflected in the negative co-movement between the SDT index and measures of new orders (Figure 2, top panel).

[2] See https://www.spglobal.com/marketintelligence/en/mi/products/pmi.html for more information.

Figure 1. Manufacturing Suppliers' Delivery Times

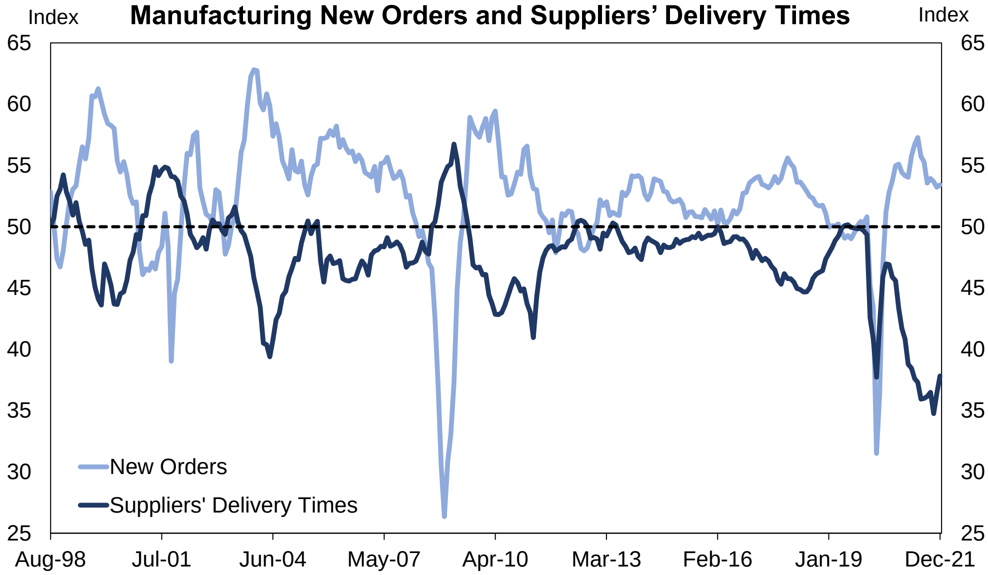


Sources: Haver Analytics, S&P Global, and authors' calculations.

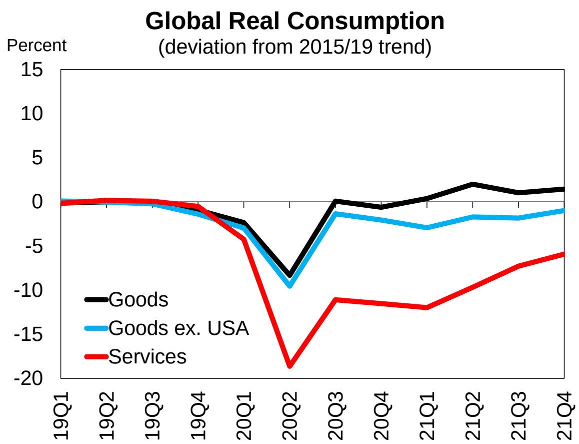
The Covid period stands out by the magnitude of the lengthening of delivery times, with the SDT index falling well below historical levels, especially in advanced economies, first during the lockdowns and then starting in 2021. This coincided with a recovery in demand for manufactured goods, as seen in the improvement in output and new orders indices (Figure 2, top panel). However, the relation between new orders and SDTs breaks down in the more recent period, indicating that while firms were facing increased demand, they were also being constrained in their ability to secure the inputs they needed to increase production. These constraints can be thought of as a decrease in the productive capacity of the entire sector. A more extreme version of this dynamic was visible during the 2020 lockdown period, as supply delivery times lengthened while activity plummeted.

During 2021 we therefore observe a combination of strong demand and a decrease in productive capacity, resulting in large disruptions. Global goods demand surged in 2021, led by the US, as consumers shifted spending from contact-intensive services to goods, and durable goods in particular (see Figure 2, bottom panels). By end-2021, goods consumption in the US reached levels 9 percent above levels implied by pre-Covid trend. As mentioned in Celasun et al. (2022), multiple factors were behind the shift from services to goods spending, including higher demand for products that helped people work, learn, and play at home. Goods demand was also supported by strong income-support measures during the pandemic.

Figure 2. New Orders, Suppliers' Delivery Times, and Real Consumption

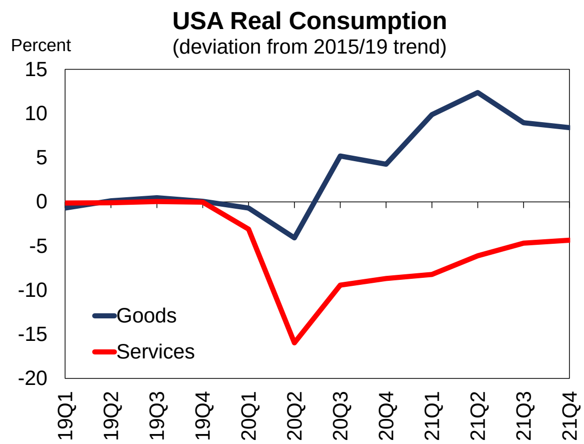


Sources: Haver Analytics, S&P Global, and authors' calculations.



Sources: Haver Analytics and authors' calculations.

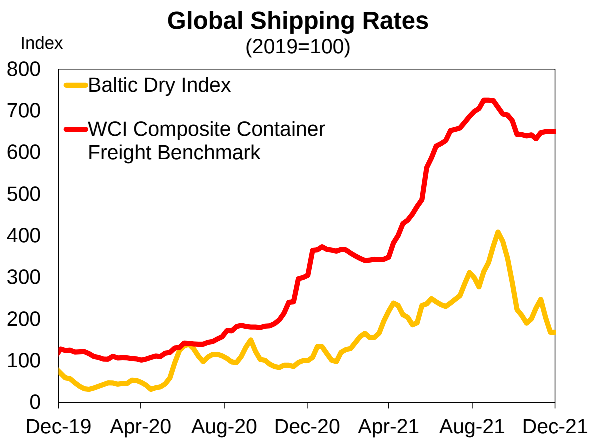
Notes: Australia, Austria, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hong Kong, Iceland, Indonesia, Ireland, Israel, Italy, Japan, Korea, Latvia, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Romania, South Africa, Sweden, Taiwan, Thailand, Turkey, United Kingdom, and the USA.



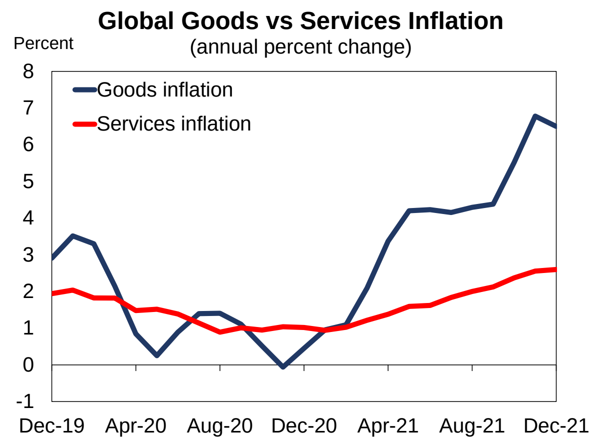
Sources: Haver Analytics and authors' calculations.

At the same time, specific supply-side distortions, including jammed logistical systems and shortages of intermediate inputs and labor, constrained productive capacity. Many ports saw severe congestion with shipping volumes running above pre-pandemic levels on the back of surging demand for goods, while pandemic restrictions interrupted activity. As a result, international shipping costs soared as transportation systems came under strain (Figure 3, top left).

Figure 3. Supply Bottlenecks and Inflation

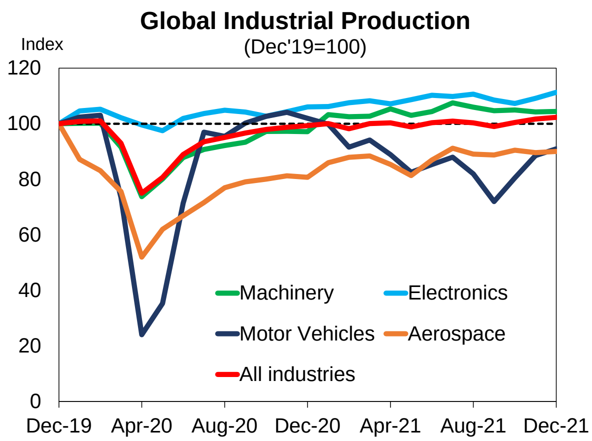


Sources: Bloomberg and authors' calculations.



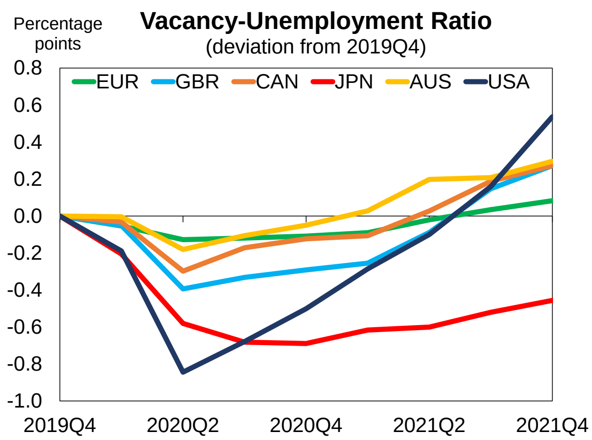
Sources: Haver Analytics and authors' calculations.

Notes: Brazil, Canada, Chile, China, Colombia, Czech Republic, Denmark, Euro Area, Hungary, Japan, Korea, Malaysia, Mexico, Norway, Poland, South Africa, Sweden, Switzerland, United Kingdom, and the USA.



Sources: Haver Analytics and authors' calculations.

Notes: Global includes Brazil, France, Germany, India, Italy, Japan, Korea, Mexico, Poland, Russia, Singapore, South Africa, Spain, Taiwan, Thailand, Turkey, United Kingdom, and the USA.



Sources: Haver Analytics, National Sources, and authors' calculations.

Notes: EUR includes Austria, Belgium, Finland, Germany, Ireland, Greece, Luxemburg, The Netherlands, Norway, Portugal, Spain, and Sweden.

Rising goods demand and supply bottlenecks led to a sharp acceleration in global goods inflation (Figure 3, top right). While services inflation also trended higher as economies gradually reopened, intermittent pandemic-related restrictions and voluntary movement restrictions (disproportionately impacting services spending) contributed to keeping services demand and inflation contained through 2021.

Shortages of intermediate inputs weighed on some manufacturing sectors more than others. Global motor vehicle production was constrained by a scarcity of microchips, with global production bottoming out in September 2021 at close to 30 percent below the pre-pandemic level (Figure 3, bottom left). More broadly, labor market developments were also a likely contributor to the bottlenecks. Labor markets tightened across many regions, with labor force participation lagging pre-pandemic levels even as the recovery gathered steam, possibly reflecting a surge in early retirements during the pandemic and a reluctance to return to the labor force due to uncertain health conditions. As a result, vacancy-to-unemployment ratios increased substantially across several regions (Figure 3, bottom right), with firms reporting considerable difficulties in finding workers and further constraining the economy-wide supply response.

Methodology and Estimation Results

The methodology entails two complementary approaches. The first approach employs an empirical strategy to estimate the impact of the 2021 supply-side disruptions on global macroeconomic outcomes, which consists of three steps. In the first step, we use a Bayesian VAR framework and global PMI indexes to identify structural supply and demand shocks. In a second step, we calculate the impact of the estimated supply shocks on global manufacturing production using a local projection model (Jordà, 2005), while in a final third step the structure of global input-output tables is employed to estimate the impact on G20 countries and global GDP. The second approach draws on the structure of a global macro model with new Keynesian features, the IMF's G20 model, to interpret data on output and core inflation and estimate the impact of supply shocks.

Sign restricted VAR

Identification of supply and demand shocks

As a first step in estimating the impact of supply disruptions on activity, we use a sign-restricted Vector Auto Regression (SVAR). The SVAR uses data on new orders (NO_t) and suppliers' delivery times (SDT_t) from manufacturing PMIs (S&P Global, 2022) to estimate:

$$\boldsymbol{Y}_t = \mu_0 + C(L)\boldsymbol{Y}_{t-1} + \boldsymbol{\varepsilon_t}$$

where the index t is time in months, $\boldsymbol{Y}_t = [NO_t \,;\, SDT_t]$, $C(L)$ is the polynomial lag operator, and ε_t is the vector of reduced form residuals. The reduced form VAR contains four lags and a constant (μ_0). Both new orders and suppliers' delivery times are demeaned, while suppliers' delivery times are inverted (an increase in the index implies lengthening delivery times). All variables are in monthly frequency and seasonally adjusted, with the sample period varying according to data availability (all samples have December 2021 as the endpoint). The sample includes the US, Germany, France, Italy, Spain, United Kingdom, Japan, Korea, Canada, China, India, Brazil, Mexico, Russia, Turkey, and a global measure.

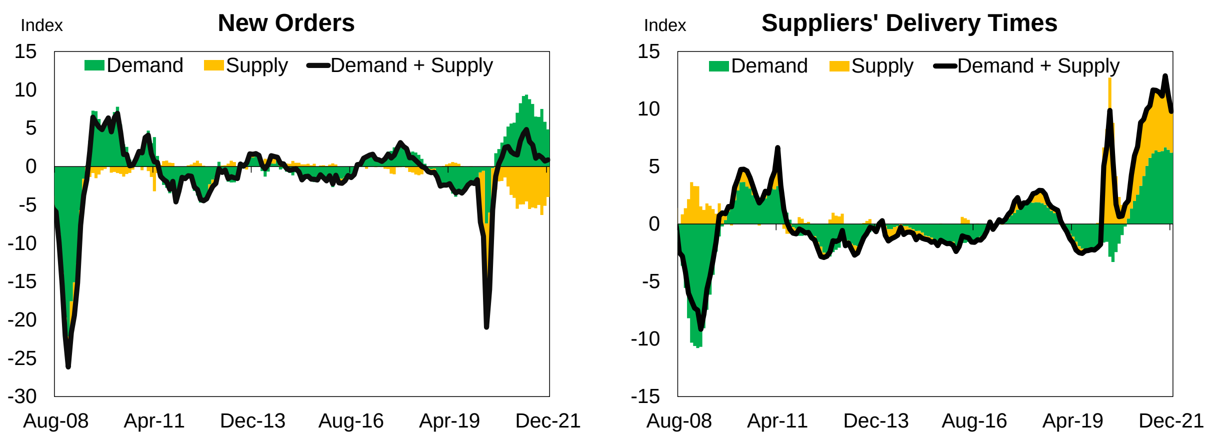
The identification assumption is that demand shocks (ε_t^D) induce new orders and suppliers' delivery times to move in the same direction, whereas supply shocks (ε_t^S) lead them to move in opposite directions. This identification strategy follows Goldman Sachs (2020, 2021) and is similar to Celasun et al. (2022) but applied to a different set of variables:[3]

$$\begin{pmatrix} NO_t \\ SDT_t \end{pmatrix} = \begin{pmatrix} + & - \\ + & + \end{pmatrix} \times \begin{pmatrix} \varepsilon_t^D \\ \varepsilon_t^S \end{pmatrix} \tag{1}$$

[3] Goldman Sachs (2021) and Celasun et al. (2022) estimate sign-restricted VAR models to identify supply and demand shocks. Goldman Sachs applies the model to PMI output and delivery times, while Celasun et al. (2022) estimate a sign-restrcited VAR in manufacturing output and manufacturing producer prices.

Figure 4 plots the two main variables, new orders (NO_t) and suppliers' delivery times (SDT_t) for the global measure of the PMIs, and a decomposition of the structural shocks ε_t^D and ε_t^S.[4] Estimates for the global aggregate show that supply shocks (yellow area) were generally small in the years leading up to the pandemic, with demand shocks (green area) playing a more significant role in driving both global new orders and changes in suppliers' delivery times**.** In contrast, large negative supply shocks amid the pandemic-related shutdowns contributed to the decline in new orders in the first half of 2020 and drove the significant lengthening in delivery times in the same period. In 2021, the boost to new orders from higher demand was offset by negative supply shocks, while both supply and demand shocks contributed meaningfully to the lengthening of delivery times. In all, demand shocks accounted for around 2/3rd of the deterioration in global delivery times through the peak in October 2021, with supply shocks accounting for the remaining 1/3rd (right panel in Figure 4).

Figure 4. Supply-Demand Decomposition of Global New Orders and Suppliers' Delivery Times



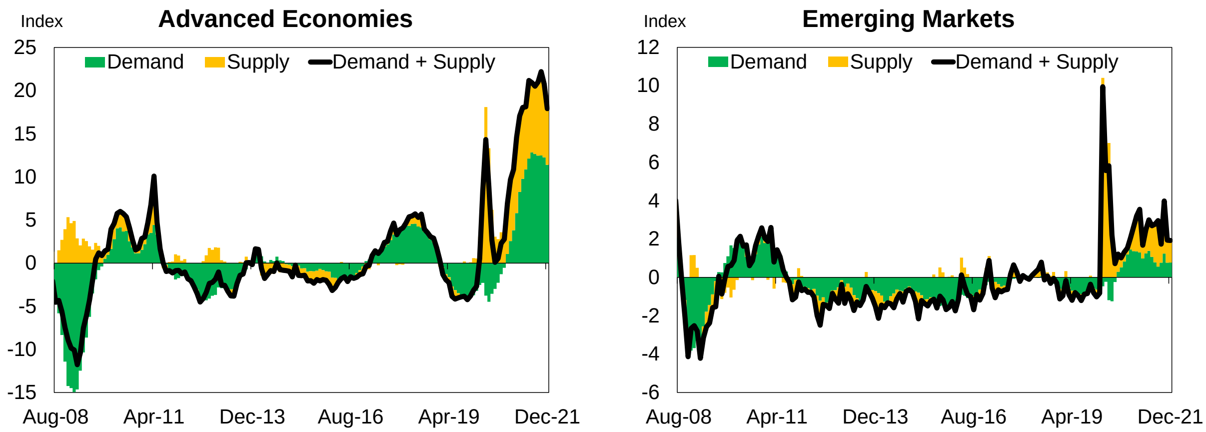
Sources: Haver Analytics, S&P Global, and authors' calculations.

For AEs, demand shocks accounted for close to 80 percent of the deterioration in delivery times through the peak in October 2021 (Figure 5, left panel). In contrast, in EMs, demand and supply shocks weighed equally on the lengthening in suppliers' delivery times (Figure 5, right panel). This corresponds to the observation that supply constraints were more binding in AEs, in part due to the stronger demand. A similar pattern emerges when looking at individual country-level decompositions.[5]

[4] Indices are deviation from mean; suppliers' delivery times are inverted.

[5] See Annex I for individual country-level results.

Figure 5. Supply-Demand Decomposition of Suppliers' Delivery Times: AEs vs EMs



Sources: Haver Analytics, S&P Global, and authors' calculations.

Impact of 2021 supply shocks on industrial production

In the second step of our empirical strategy, we determine the impact of the estimated supply shocks on manufacturing output (the manufacturing component of the Industrial Production index) by estimating a local-projection model (Jordà, 2005) for each country in the sample using the following specification:

$$IP_{t+h} = \beta_s^h * \varepsilon_t^S + \beta_d^h * \varepsilon_t^D + \delta^h X_t + \epsilon_t^h \quad (2)$$

where IP_{t+h} is the log-level of manufacturing output *h* periods ahead and ε_t^D and ε_t^S are the demand and supply shocks derived from the bivariate SVAR estimated in the first step. X_t is a matrix of control variables and includes lags of the shocks and manufacturing output, as well as a linear and quadratic trend. The estimated values of $\{\beta_s^h\}$ and $\{\beta_d^h\}$ underpin the impulse response functions (IRFs) of interest and are used in conjunction with the estimated supply shocks to measure the impact on manufacturing output.[6] The measure of global industrial production from the CPB Netherlands Bureau for Economic Policy Analysis World Trade Monitor (WTM) was used to assess the global impact (CPB, 2022).[7] Additionally, no breakdown is available for China. As such, data on total industrial production was used.

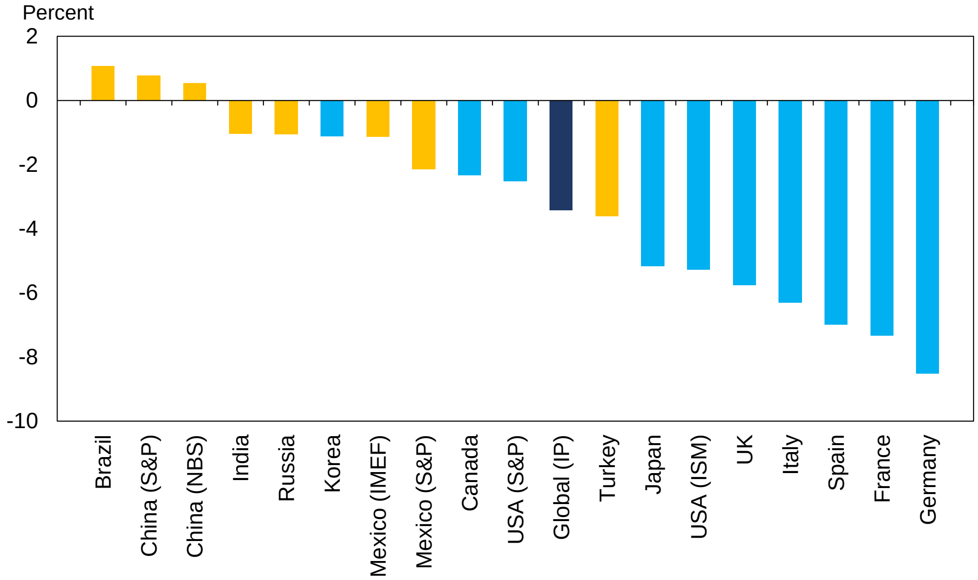
Figure 6 shows the impact of the estimated 2021 supply shocks on manufacturing output.[8] Global industrial output would have been about 3.4 percent higher in 2021 in the absence of supply shocks.

[6] Estimated IRFs displayed in Annex II.

[7] The WTM brings together, aggregates, and summarizes monthly data on global trade and industrial production. See https://www.cpb.nl/sites/default/files/omnidownload/CPB-Background-Document-April2020-The-CPB-World-Trade-Monitor-technical-description-update_31.pdf for a technical discussion on the construction of global trade and production indices.

[8] For the US, two measures of new orders and suppliers' delivery times were used in the bivariate SVAR to estimate supply and demand shocks to be used in the local-projection model - one set as published by S&P Global and another as published by the Institute for Supply Management (ISM). Results are shown for both measures. Similarly, for Mexico, results based on survey data published by both S&P Global and the Instituto Mexicano de Ejecutivos de Finanzas (IMEF) are shown, while for China results based on the S&P Global and National Bureau of Statistics of China (NBS) surveys are shown.

Figure 6. Impact of 2021 Supply Shocks on 2021 Manufacturing IP



Sources: Authors' calculations.

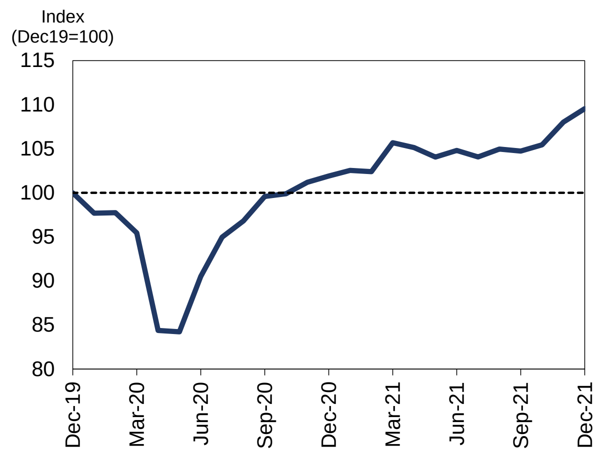
The hit to manufacturing output was generally larger in AEs, confirming the observation that supply constraints were more binding in these regions as reflected in the surveys. Consistent with a deepening of supply disruptions in the automotive and aircraft industries due to chip shortages during 2021, supply shocks are estimated to have had a sizable negative impact on manufacturing output in Germany and France. Similar to the findings in Celasun et al. (2022), the US manufacturing sector is among the less affected AEs despite seemingly more severe bottlenecks. This possibly reflects the more moderate exposure of US manufacturers to imported intermediate inputs. The estimates are broadly in line with results from Celasun et al. (2022) for the Euro Area, which are based on an alternative identification scheme.

For most countries the estimated impact of supply shocks on manufacturing output is negative, with two important outliers in Brazil and China. This potentially highlights a limitation of the current method in that it relies on the information content of PMI indices, which may vary across countries. For example, in Brazil, suppliers' delivery times steadily improved between October 2020 and September 2021, implying a series of positive supply shocks. Only toward the end of 2021 did suppliers' delivery times start deteriorating again.[9] In the case of China, industrial production had been expanding steadily over most of the period, including through 2020 and 2021 following the initial dip at the onset of the pandemic.[10] Combined with relatively modest estimated supply shocks, this results in a *positive* impact of supply shocks on industrial output. Alternatively, the nature of the global supply shock might imply that the net effect on Chinese industrial output was positive despite domestic supply restrictions, as exports benefited from above-trend demand for durable and intermediate goods.

[9] See left panel of Figure A1 in Annex III.
[10] See right panel of Figure A1 in Annex III.

Impact of 2021 supply shocks on global trade

Figure 7: Global Trade Volumes



Source: CPB Netherlands Bureau for Economic Policy Analysis and author's calculations

Another feature of the post-Covid experience was the strong recovery in global trade following the initial sharp contraction. Data on global trade volumes (an average between global export and import volumes) are sourced from the CPB Netherlands Bureau for Economic Policy Analysis WTM (CPB, 2022). According to this index global trade volumes contracted by 15 percent between December 2019 and May 2020, before rebounding by close to 20 percent between May and September 2020 and ending the year above pre-Covid levels. The recovery in global trade volumes can partly be ascribed to the significant increase in global goods demand over this period (discussed in Section II). Despite the rapid recovery the level of global trade remained broadly flat over much of 2021, increasing by around 2 percent between January and September 2021 (see Figure 7). Global shipping rates increased markedly over this period, while logistical issues at ports (especially in the US) led to significant shipping delays as goods demand outstripped shipping and port capacity. While global trade recovered significantly following the 2020 lockdowns, it is highly likely that trade volumes would have recovered even more in the absence of these supply shocks.

We use two approaches to assess the impact on trade. First, we estimate a local-projection model as before (equation (2)) with the left-hand side variable replaced by the measure for global trade volumes. Additionally, we estimate a sign-restricted SVAR with three variables: new orders, suppliers' delivery times, and global trade volumes. The identification strategy assumes that demand shocks (ρ_t^D) increase new orders, suppliers' delivery times, and global trade, whereas supply shocks (ρ_t^S) lower new orders and trade but lengthen suppliers' delivery times:

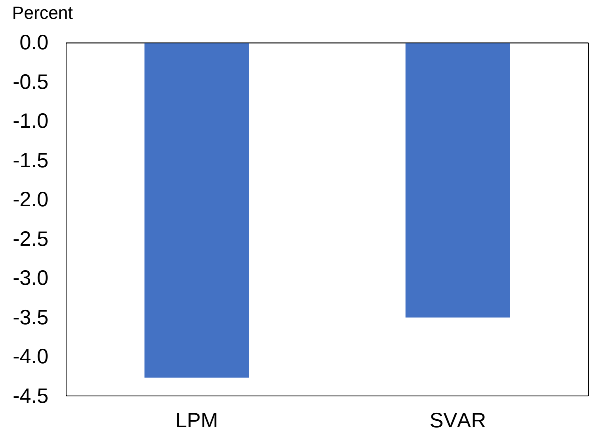
$$\begin{pmatrix} NO_t \\ SDT_t \\ T_t \end{pmatrix} = \begin{pmatrix} + & - \\ + & + \dots \\ + & - \end{pmatrix} \times \begin{pmatrix} \rho_t^D \\ \rho_t^S \\ \dots \end{pmatrix} \quad (3)$$

The sample period employed for the estimation is January 2001 to December 2021.

The decomposition from the SVAR shows that demand shocks account for most of the variation in trade in the pre-Covid period. However, supply shocks related to the Covid-19 pandemic and associated disruptions during the recovery made a sizable negative contribution to global trade volumes during 2020 and 2021.

Results from the two complementary methods imply that global trade would have been between 3.5 percent and 4.3 percent higher (on average) in 2021 in the absence of supply shocks (Figure 8).[11]

Figure 8: Impact of Supply Shocks on 2021 Global Trade Volumes



Source: Author's calculations

Impact of 2021 supply shocks on GDP

The third and final step of the empirical exercise consists in mapping estimates of the changes in manufacturing production onto changes in national and global GDP. In order to do that, we need to estimate the impact of the decline in manufacturing output on the non-manufacturing sectors in each country and at the global level.

We follow the input output approach in Acemoglu et al. (2016). To calibrate input-output network in each country and at the global level we use information from the World Input-Output Database (WIOD).[12] The 2016 WIOD provides annual time-series of world input-output tables from 1995 to 2014. For our application we use the latest available data in the 2016 release, which is based on 2014 data. The tables are constructed using information from national accounts, published input-output tables, and international trade statistics. Products can be used as intermediates by other industries, or as final products by households/firms and governments. The data covers 43 major countries, including the European Union (28 countries) and 15 other major economies.

In the current application, we focus on G20 countries and the global aggregate. For each country, we assume that output is produced by two sectors, namely manufacturing *m* and non-manufacturing *n*. We aggregate all sectors and generate a measure of the input-output matrix for the manufacturing and non-manufacturing sectors, as well as a corresponding measure for value added. At the global level, we generate the same sectoral aggregates and derive a world aggregate input-output matrix. Table 1 reports aggregate cost shares for the global manufacturing and non-manufacturing sectors.[13] The manufacturing sector produces output mainly by using manufactured intermediate inputs (42 percent), although non-manufacturing inputs also make up a sizable share (32 percent).

Table 1: Global Cost Shares

	Manufaturing	Non-manufacturing
Manufacturing inputs	0.42	0.12
Non-manufacturing inputs	0.32	0.32
Taxes and transportation	0.01	0.01
Value added (VA)	0.25	0.55
Gross output	1	1
Share of VA in World GDP (%)	17	83
Share of Output in World Output (%)	31	69

Source: WIOD2016 and authors' calculations

[11] See Appendix II for IRFs.
[12] For more details on the World Input-Output Tables see https://www.rug.nl/ggdc/valuechain/wiod/wiod-2016-release
[13] For simplicity, we lump taxes and transportation costs in value added.

Global output (y) is the sum of global manufacturing (y_m) and non-manufacturing (y_n) output. Both sectors use a Cobb-Douglas production technology, and it is assumed that in a static economy, all global value added (global GDP) is consumed ($VA = consumption = C$). The output of the global manufacturing sector (y_m) is:

$$y_m = e^{\pi_m} l_m^{\alpha} (x_{mn}^{a_{mn}} x_{mm}^{a_{mm}}) \quad (4)$$

where π_m is a shock affecting productivity in the manufacturing sector, l is labor, x_{mm} and x_{mn} are the quantities of manufacturing and non-manufacturing inputs used by the manufacturing sector to produce its output, and α, a_{mm} and a_{mn} are the intensity or cost shares of the respective inputs. Similarly, the production function of the non-manufacturing sector is:

$$y_n = e^{\pi_n} l_n^{\alpha} (x_{nm}^{a_{nm}} x_{nn}^{a_{nn}}) \quad (5)$$

As Acemoglu et al. (2016) show, a supply shock affecting manufacturing production propagates downstream to other sectors, i.e., to sectors that use the manufacturing production output as an input in the production function. Assuming that the labor input remains constant, this can be expressed in matrix form as:

$$\boldsymbol{d}ln\begin{pmatrix} y_m \\ y_n \end{pmatrix} = (\boldsymbol{I} - \boldsymbol{A})^{-\mathbf{1}} \boldsymbol{d}ln\begin{pmatrix} \pi_m \\ \pi_n \end{pmatrix}, A = \begin{pmatrix} a_{mm} & a_{mn} \\ a_{nm} & a_{nn} \end{pmatrix} = \begin{pmatrix} 0.42 & 0.32 \\ 0.12 & 0.32 \end{pmatrix} \quad (6)$$

where $\boldsymbol{I}$ is the identity matrix and $\boldsymbol{A}$ is the matrix of the respective cost shares in the global manufacturing and non-manufacturing sectors, which are calibrated using the shares in Table 1. Assuming that supply shocks affect the economy mostly through shocks to the global manufacturing chain, implies that $\boldsymbol{d}ln\pi_n = 0$. Then equation (6) simplifies to:

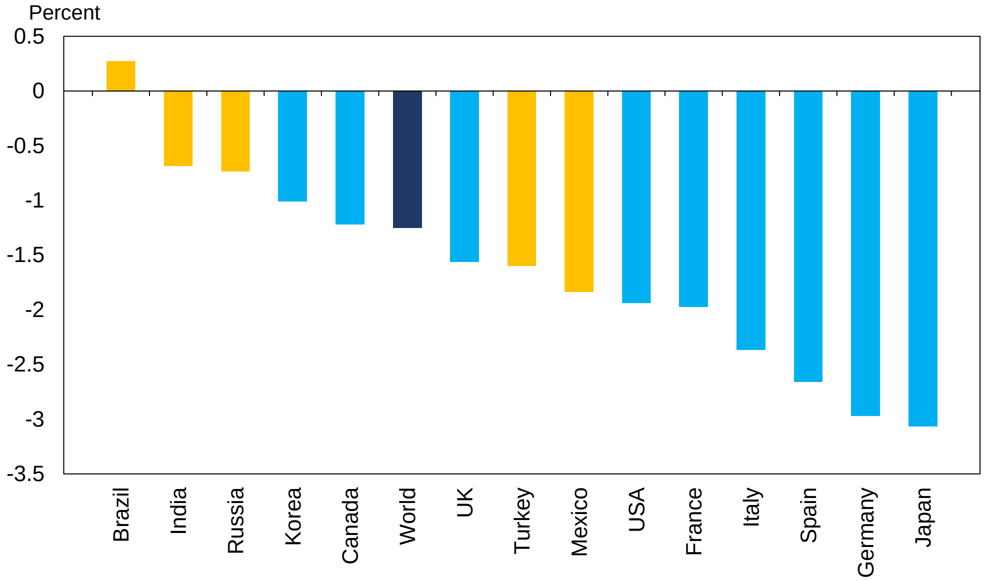
$$\boldsymbol{d}lny_n = \frac{a_{nm}}{1 - a_{mm}} \boldsymbol{d}lny_m \quad (7)$$

i.e., the impact of supply shocks on manufacturing production propagates downstream to sectors that utilize manufacturing output as an input (with a share a_{nm}). In the previous section, we estimated that supply shocks generated a contraction in global (gross) manufacturing output of 3.4 percent in 2021, i.e., $\boldsymbol{d}lny_m = -3.4$. It is straightforward to show that the value added of the manufacturing sector also falls proportionally. Applying the share of manufacturing value added in world GDP (17 percent) from Table 1, we can translate the fall in world manufacturing output into a drop in global value added in the manufacturing sector. This generates a direct effect on global GDP of around -0.6 percent.

Using (7), we can then calculate the propagation of the shock affecting manufacturing output to the global non-manufacturing sector using the cost shares in matrix $\boldsymbol{A}$ and $\boldsymbol{d}lny_m = -3.4$.The decline in manufacturing output generates a contraction of -0.7 percent in the non-manufacturing sector ($\boldsymbol{d}lny_n = -0.7$), which, using the share of value added of the non-manufacturing sector on world GDP from Table 1 (83 percent), subtracts another 0.6 percentage points from world GDP. In all, the total impact of the supply shocks in 2021 is a reduction in global GDP of about 1.2 percent relative to the counterfactual of no supply shocks (see Figure 9).

We repeat the same exercise for individual countries in the G20. Figure 9 reports the impact of the 2021 supply shocks on GDP. Similar to the estimated impact on manufacturing output, the impact on GDP is unevenly distributed. Countries more directly exposed to supply disruptions (such as Germany) faced the largest declines in GDP.

Figure 9. Impact of 2021 Supply Shocks on GDP

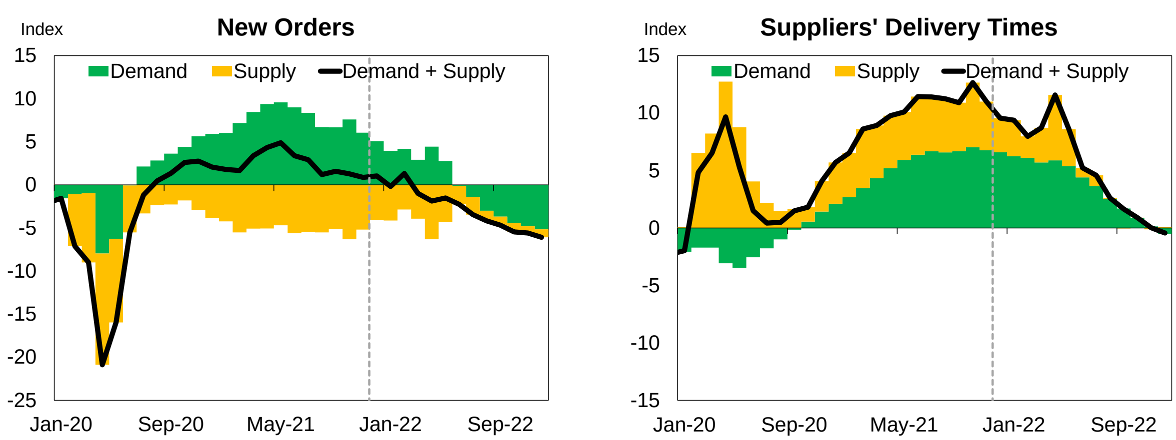


Sources: Authors' calculations.

Extending the empirical analysis to 2022

The empirical analysis can also be extended to 2022. Figure 10 shows the SVAR-based decomposition through December 2022. Global new orders have trended lower since end-2021, with fading supply shocks offset by weaker global demand (evidenced by the lower contribution of demand shocks). Suppliers' delivery times have also improved despite a spike in April/May 2022 when China implemented strict containment measures. Applying the framework to the 2022 data corroborates the observation that global demand shocks have slowed while supply shocks have eased, likely reflecting a combination of slowing recovery and rotation away from goods on the demand side and easing logistical pressures on the supply side.

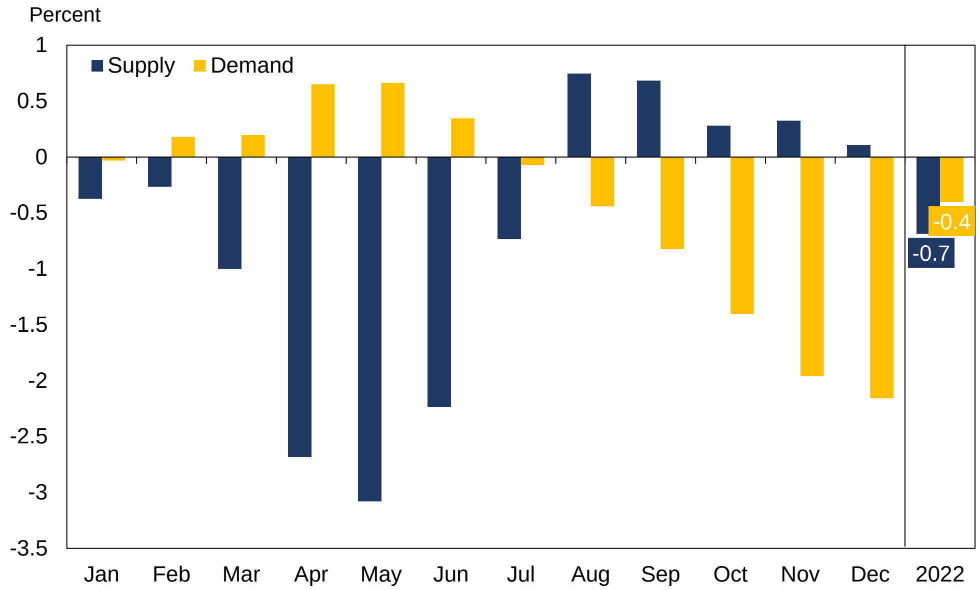
Figure 10. Supply-Demand Decomposition of Global New Orders and Suppliers' Delivery Times



Sources: Haver Analytics, S&P Global, and authors' calculations.

Figure 11 shows the impact of 2022 shocks on 2022 global industrial production.[14] In all, the level of global industrial output would be about 0.7 percent higher in 2022 in the absence of supply shocks. Most of the annual impact can be ascribed to the large declines in March through June when the lockdowns in China impacted global supply delivery times: in the latter part of the sample, easing supply disruptions contribute *positively* to industrial output. Demand shocks also contribute negatively to IP: they subtract around 0.4 percent from global industrial output in 2022, with most of the impact materializing in the second half of the year.

Figure 11. Impact of 2022 Supply and Demand Shocks on Global IP



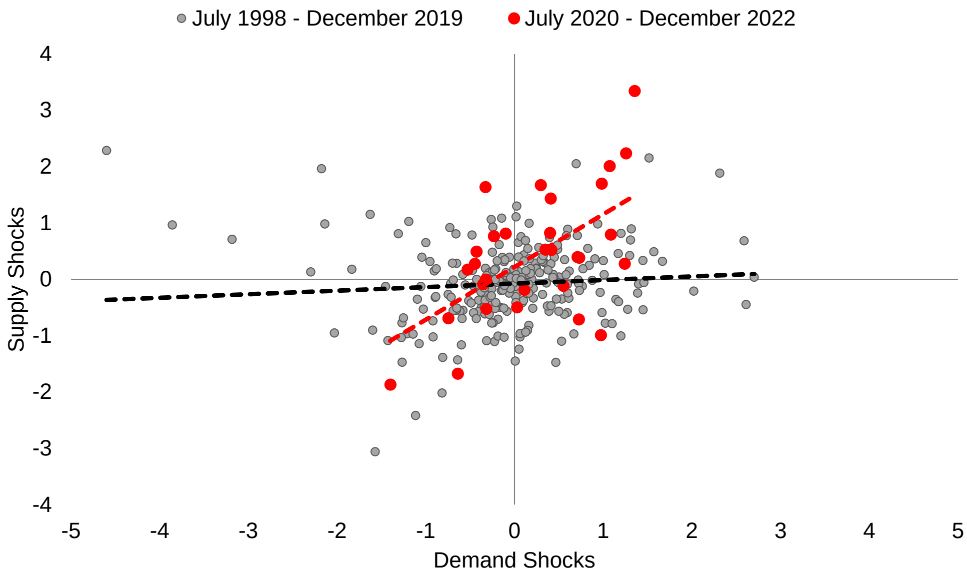
Sources: Authors' calculations.

Correlation between supply and demand shocks

Another feature of the estimates is the strong co-movement between supply and demand shocks over 2021 and 2022, as shown in Figure 12. The correlation between the two shocks increased from 0.1 in the pre-Covid period (July 1998 through December 2019) to around 0.6 for the period July 2020 to December 2022. A possible interpretation is a non-linearity in the underlying supply curve: demand pushed up against a supply curve that was more inelastic than during normal times, due to the constraints described above.

[14] As before, a measure of global industrial production is used since no consistent measure for manufacturing output is available. The LPM is estimated with data through October 2022, the last available datapoint for the measure of global industrial production. Impulse response functions from the local projection model estimated through October 2022 are used to estimate the impact on production for the entire year.

Figure 12. Relationship between Global Supply and Demand Shocks



Sources: Authors' calculations.

Structural simulations using the IMF G20 Model

The second approach to estimating the impact of 2021 supply shocks on economic activity employs the structure of the IMF's Flexible System of Global Models (FSGM) and its G20 version. FSGM is a group of models developed at the IMF for policy analysis.[15] A typical module of FSGM is a multi-region, forward-looking, semi-structural global model consisting of 24 regions. The model features standard New-Keynesian nominal and real rigidities, two types of households (optimizing overlapping generations (OLG) and liquidity constrained households), a linear Phillips curve, and monetary policy reaction functions, among other features.[16] For the purpose of our exercise, we present the model's specification of the Phillips curve:

$$\pi_t = \varphi_1 E_t \pi_{t+j} + (1-\varphi_1)\pi_{t-j} + \varphi_2 \log y_t^{gap} + \varphi_3 \pi_t^{comm} + \varepsilon_t \quad (8)$$

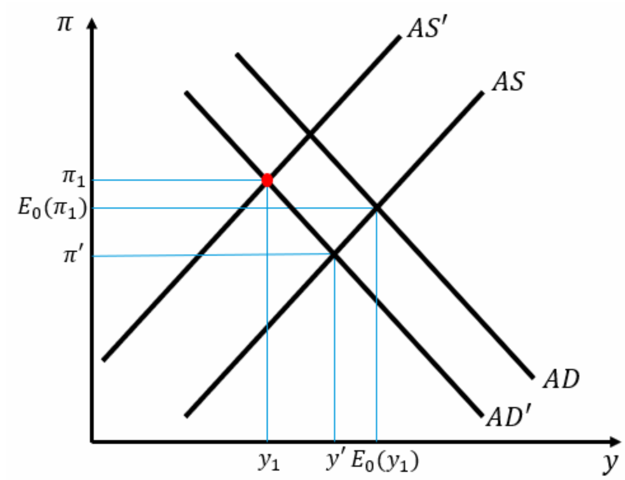
where π_t is the inflation rate, y_t^{gap} is the output gap or degree of slack in the economy, π_t^{comm} is the change in commodity prices (food and energy), and ε_t is a shock to the Phillips curve (interpreted here as a supply shock, i.e. a shock that pushes up inflation for a given level of activity). The calibrated parameters for this exercise are taken from Andrle et al. (2015). For reference, we note that the calibration of the slope of the Phillips curve (i.e., φ_2) is set at 0.1 for AEs (including for the US) and 0.2 for EMs. We use the G20 version of the model, which has an individual block for each G20 country and four other blocks for the rest of the world.

[15] Andrle et al. (2015).

[16] For this exercise, monetary policy is constrained in AEs as they were at or close to the zero-lower bound. In contrast, we allow monetary policy to respond endogenously to shocks in EMs given the larger degree of policy space.

As mentioned, we use the structure of the model to interpret deviations in output and inflation from pre-Covid forecasts. **Error! Reference source not found.** presents a stylized representation of the approach. Point $(y_1; \pi_1)$ on the chart presents a hypothetical 2021 output and inflation outcome, with lower output and higher inflation than the pre-Covid forecast $(E_0(y_1); E_0(\pi_1))$. Matching the output inflation surprise $(y_1 - E_0(y_1); \pi_1 - (\pi_1))$ requires a combination of shocks to supply and shocks to demand. Negative shocks to demand $(AD \rightarrow AD')$ lower activity $(E_0(y_1) \rightarrow y')$ and reduce inflation $(E_0(\pi_1) \rightarrow \pi')$. Since demand shocks imply lower inflation, matching the data also requires a negative shock to aggregate supply, which contributes to further lowering output and raising inflation $(y' \rightarrow y_1$ and $\pi' \rightarrow \pi_1)$. The model structure, and importantly the Phillips curve specification, plays a role in the estimation of both the demand shocks $(y' - E_0(y_1) < 0;\ \pi' - E_0(\pi_1) < 0)$ and supply shocks $(y_1 - y' < 0;\ \pi_1 - \pi' > 0)$.

Figure 13: Stylized Representation



Source: Author's calculations

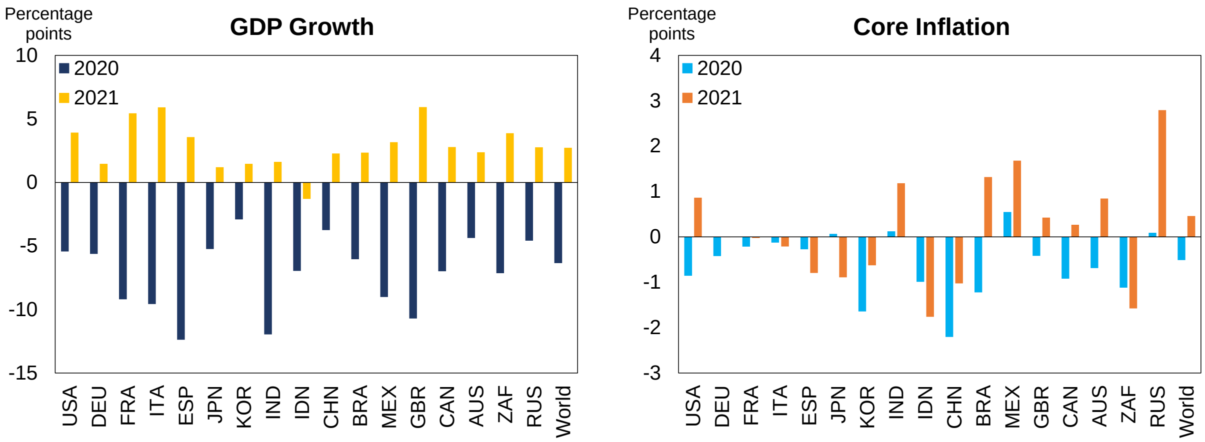
Impact of supply shocks on GDP and core inflation

To estimate the impact of supply shocks on GDP and core inflation, we first calculate deviations of output and core inflation from pre-Covid projections for 2020 and 2021 (where the pre-Covid projection is the January 2020 WEO forecast),[17,18] shown in Figure 14. GDP growth came in much lower than expected in 2020 and was above pre-Covid projections in 2021 as economies reopened. The inflation experience shows considerable cross-country variation, but in general core inflation came in below expectations in 2020 as demand contracted (especially in the first half of 2020) and energy prices declined. Core inflation rebounded somewhat in 2021, coming in above pre-Covid expectations in several regions, notably in the US and some large EMs, but came in below forecast in other countries, for example Spain, Japan, and China.

[17] IMF (2020).

[18] We make some additional assumptions as well as marginal adjustments to pre-Covid projections and outcomes: i) we include an oil price shock equal to deviations in historical data from pre-Covid projections to account for the impact of energy prices on inflation; ii) we adjust core inflation data for Germany to account for the effect of the changes in value added tax (VAT) in early 2021; iii) we adjust the pre-Covid inflation projections for several other countries using historic consensus forecasts; and iv) pre-Covid core inflation forecasts for India and Argentina are internal EMD forecasts as these are not available in the WEO database.

Figure 14. Growth and Inflation Deviation from pre-Covid Baseline

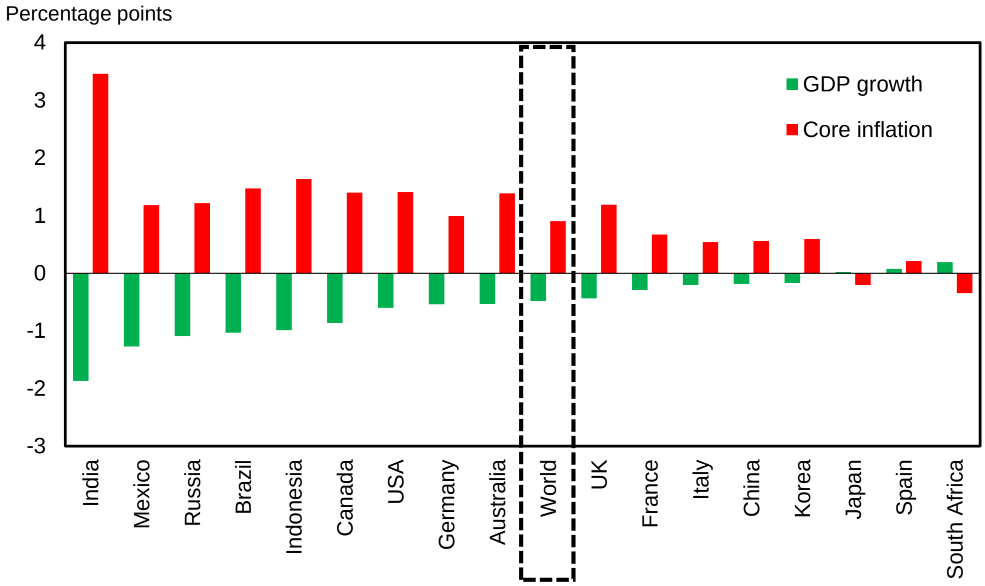


Sources: January 2020 WEO, July 2022 WEO, and authors' calculations.

Figure 15 shows the impact of the 2021 supply shocks, estimated using the decomposition described above, on GDP growth and core inflation. Like the previous section, supply shocks are estimated to have been a significant drag on activity in 2021. The aggregate impact is somewhat smaller than under the empirical exercise: global growth would have been an estimated 0.5 percentage points higher in the absence of supply shocks. As before, we see heterogeneous impacts across regions. However, impacts are generally larger for EMs and smaller for AEs than under the empirical methodology. Apart from the obvious difference in methodologies (static/partial equilibrium versus dynamic general equilibrium), part of the difference could lie in the use of deviations from a pre-Covid baseline to back out demand and supply shocks. Inflation deviations from baseline were generally larger for EMs than for AEs (see Figure 14), requiring larger supply shocks to match the data. In contrast, while growth deviations were sizable for many AEs, inflation outcomes were broadly in line or in some cases somewhat lower than projected in the pre-Covid baseline (with a notable exception in the US). As a result, smaller supply shocks are required to match the inflation data, resulting in less drag on growth.

Finally, the simulation results show that supply shocks added around 0.9 percentage points to global core inflation. As with the growth estimates, there is substantial heterogeneity across regions with the impacts generally larger in EMs, albeit with sizable effects in some AEs – notably the US, Canada, Germany, Australia, and the UK (see Figure 15).

Figure 15. Impact of 2021 Supply Shocks GDP Growth and Core Inflation



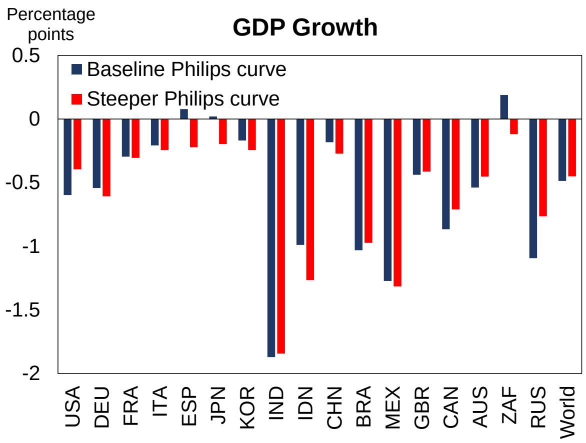
Sources: Authors' calculations.

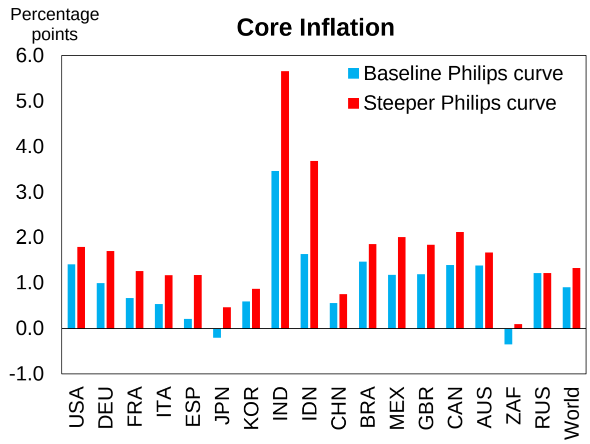
Sensitivity Analysis: The slope of the Phillips curve

The results described above depend crucially on the shape of the Phillips curve. Recent literature has shown evidence for a nonlinear (state-dependent) Phillips curve that has a flat slope when inflationary pressures are subdued and steepens when inflationary pressures are elevated. Recent literature suggest that a steeper Phillips curve could account for the surge in inflation during the post-Covid era, particularly in the US (Harding et al., 2022; Gudmundsson et al., 2022). We therefore conduct a sensitivity analysis where we increase the slope of the Phillips curve, i.e., the parameter which governs the relationship of inflation with the output gap (φ_2 in equation (8)).

Figure 16 compares the baseline results from the previous section to results obtained when doubling the slope of the Phillips curve for all regions. The decline in global output due to the estimated supply shocks is broadly similar to the baseline specification (around -0.5 percentage points in 2021), but with some variation across regions. On the other hand, supply shocks now add around 1.3 percentage points to global core inflation under the steeper Phillips curve specification, compared to 0.9 percentage points under the baseline. This is to be expected given the change in the calibration of the Phillips curve – under the alternative specification we expect more inflationary pressure for a given level of activity.

Figure 16. Growth and Inflation Deviations: Phillips Curve Comparison





Sources: Authors' calculations.

Looking at regional differences, the impact of supply shocks on activity under the alternative specification of a steeper Phillips curve is smaller in the US but larger in Europe than under the baseline specification, while the inflation impact is larger in both regions – an outcome that is in line with the stylized facts and the recent literature.

Conclusion

We used two novel approaches to estimating the impact of supply disruptions in 2021 on global output and inflation. In all, we estimate that supply shocks weighted negatively on the global recovery and contributed positively to global core inflation. The impact on the level of global GDP ranges from between 0.5 percent and 1.2 percent, while supply shocks are estimated to have added around 1 percentage point to global core inflation. There is significant variation across regions, with those regions more directly exposed to supply disruption (particularly in the auto sector) suffering more severe output losses. Both methods employed in the paper have their limitations. Importantly, the empirical approach relies on the informativeness of industrial production and PMI data across countries. On the other hand, the structural approach depends crucially on the structure of the model, the plausibility of the pre-Covid projections, and the behavior of core inflation.

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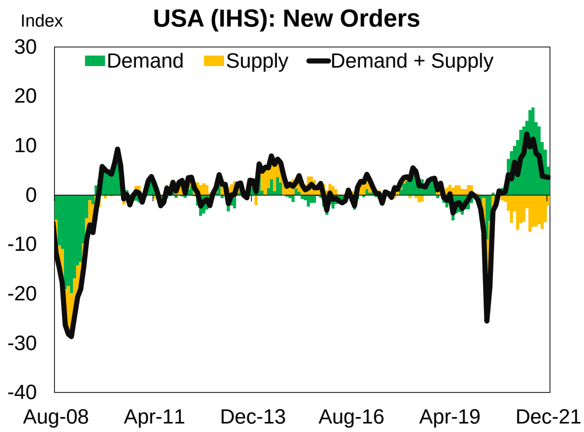
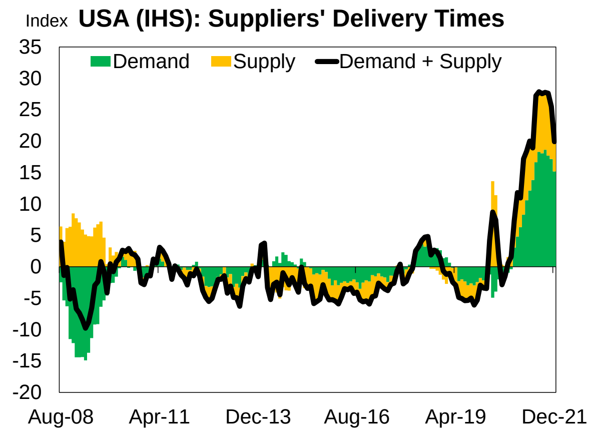
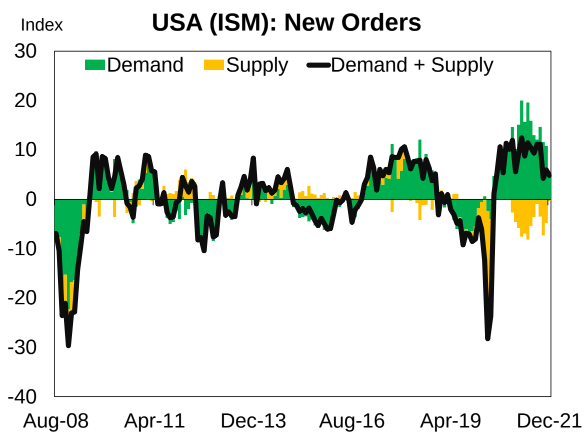
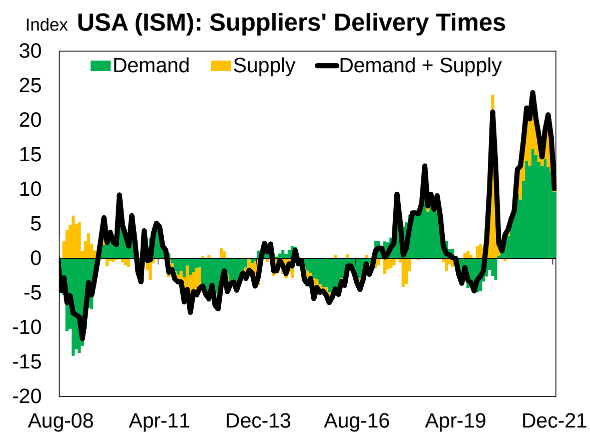
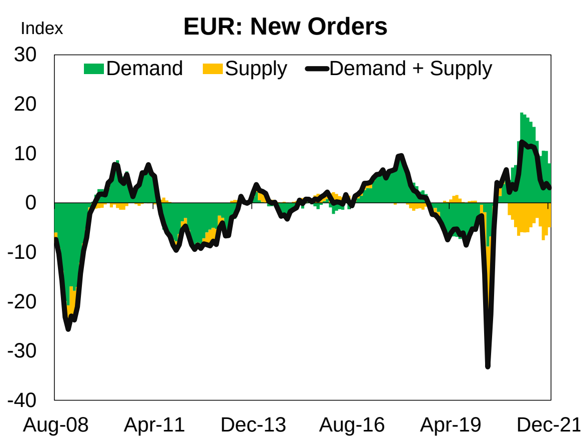
Annex I. Additional SVAR Results

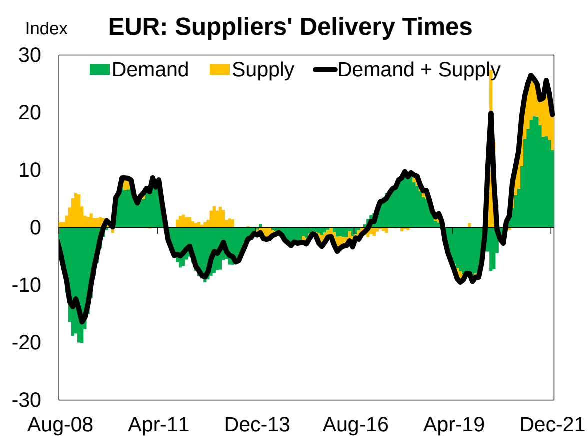


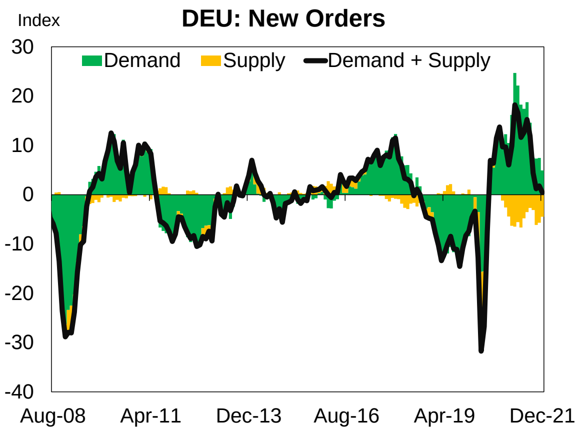








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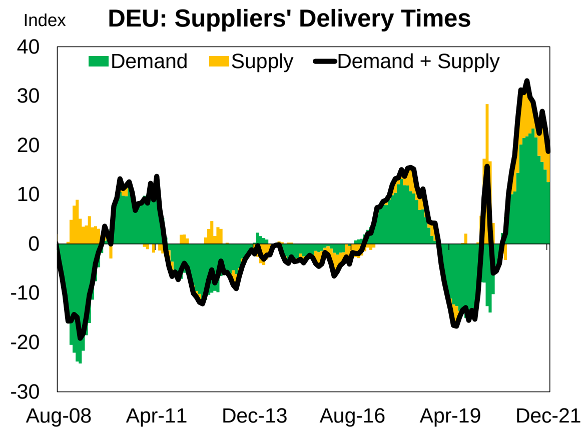
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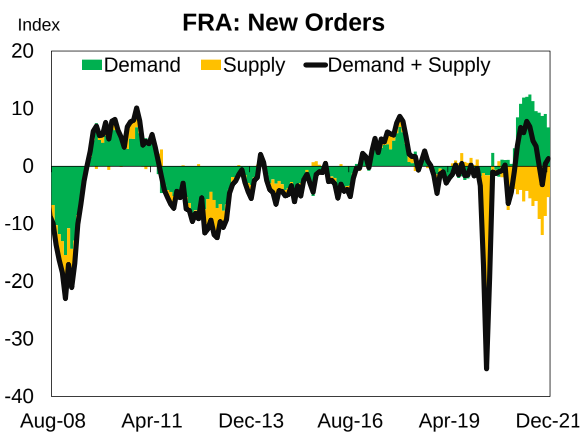
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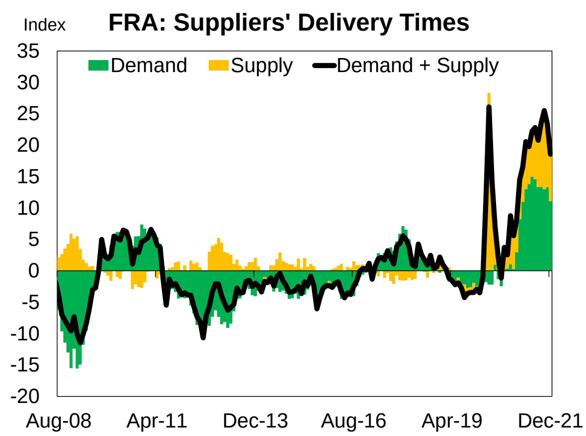
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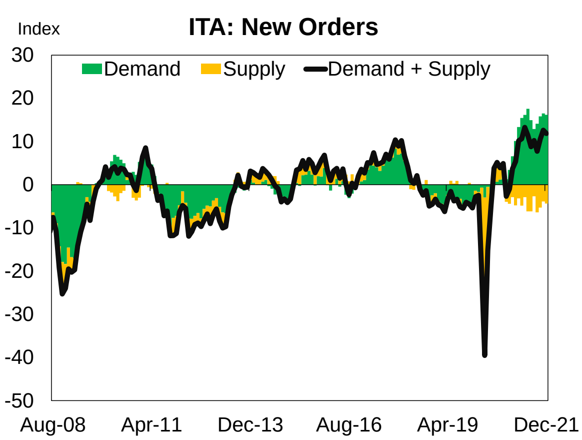
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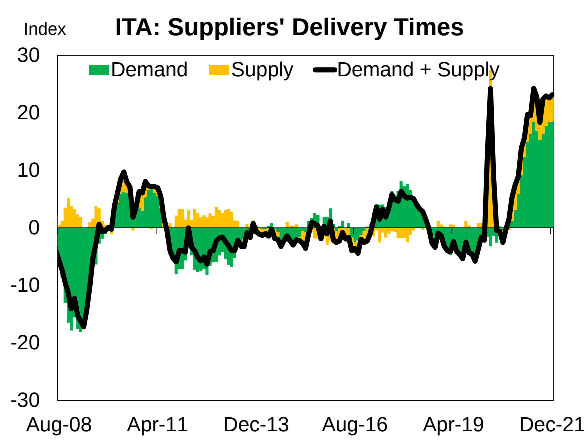
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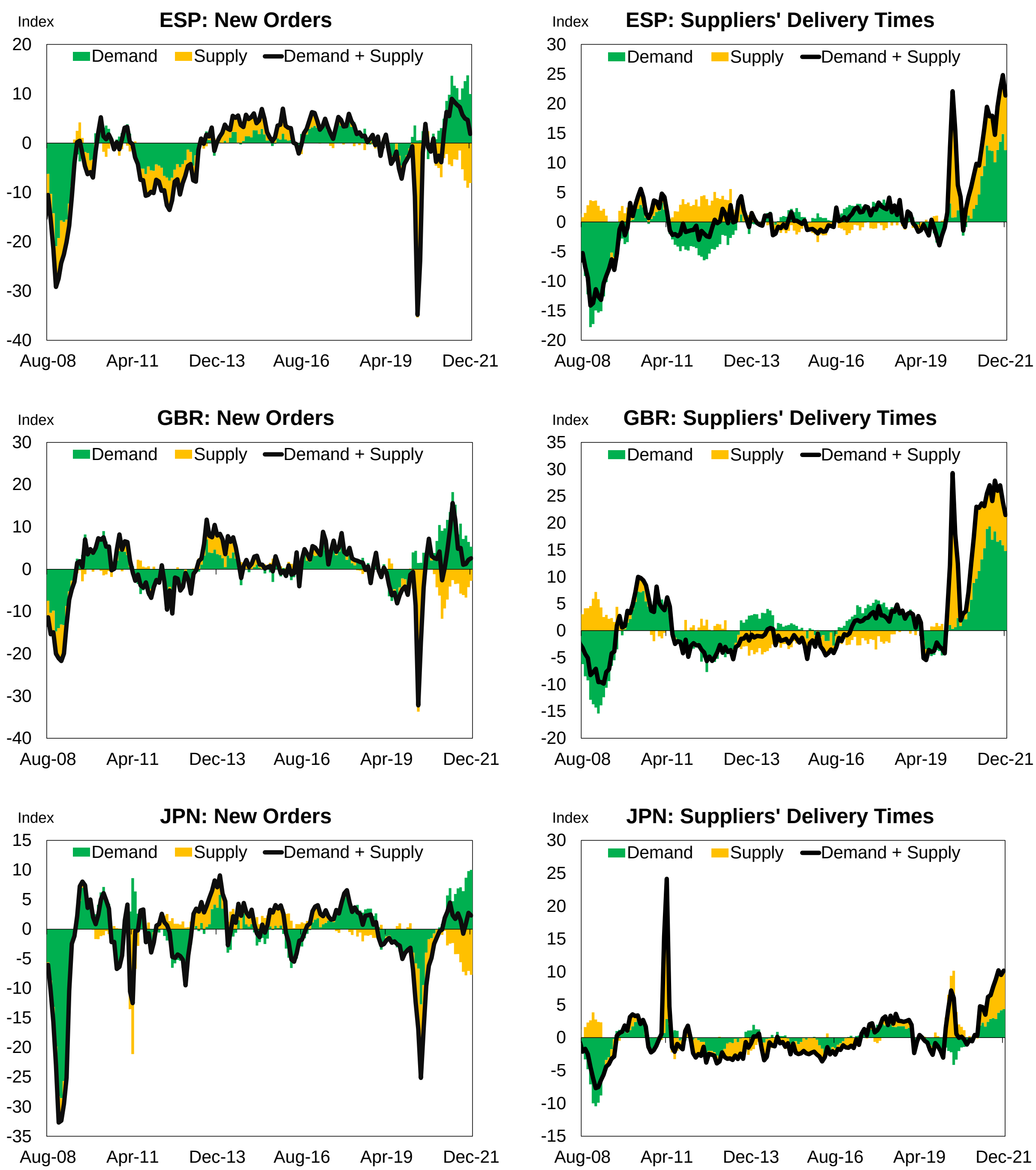
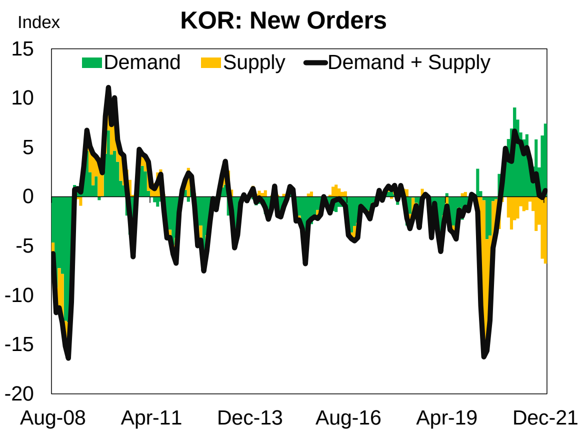
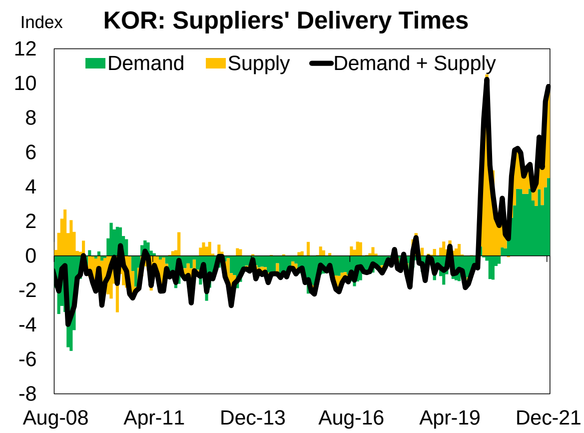
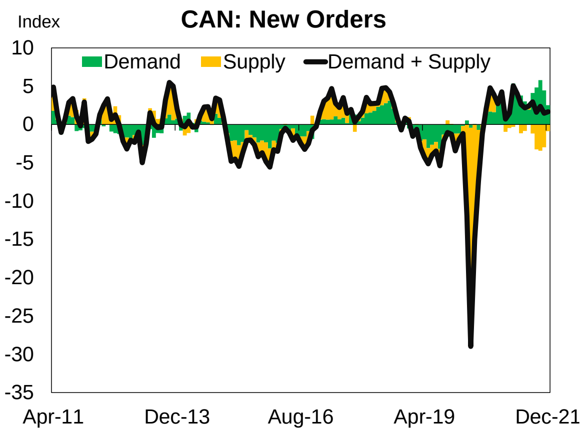
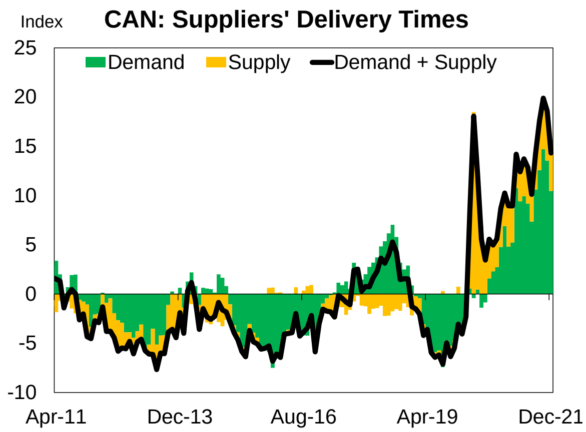
Apr-19
Dec-21

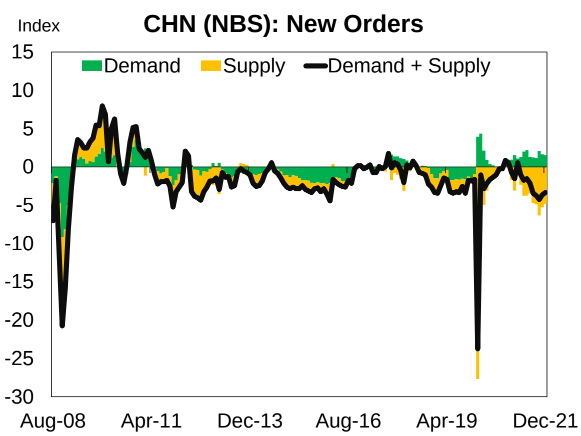

Index
ESP: New Orders
Demand
Supply
Demand + Supply
20
10
0
-10
-20
-30
-40
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21
Index
ESP: Suppliers' Delivery Times
Demand
Supply
Demand + Supply
30
25
20
15
10
5
0
-5
-10
-15
-20
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21
Index
GBR: New Orders
Demand
Supply
Demand + Supply
30
20
10
0
-10
-20
-30
-40
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21
Index
GBR: Suppliers' Delivery Times
Demand
Supply
Demand + Supply
35
30
25
20
15
10
5
0
-5
-10
-15
-20
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21
Index
JPN: New Orders
Demand
Supply
Demand + Supply
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21
Index
JPN: Suppliers' Delivery Times
Demand
Supply
Demand + Supply
30
25
20
15
10
5
0
-5
-10
-15
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21

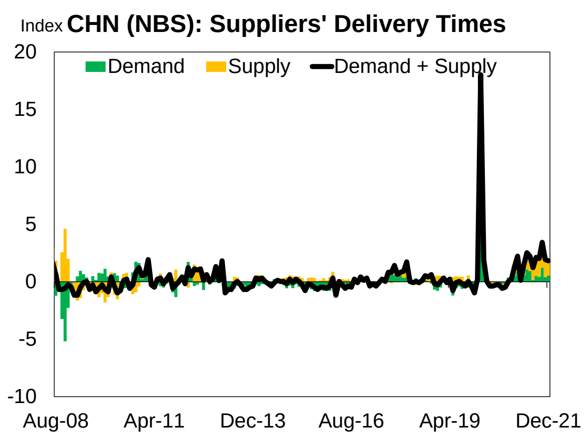

KOR: New Orders
Index
Demand
Supply
Demand + Supply
15
10
5
0
-5
-10
-15
-20
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21

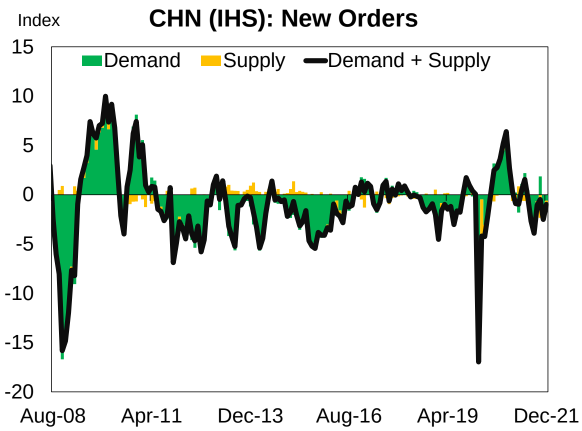

KOR: Suppliers' Delivery Times
Index
Demand
Supply
Demand + Supply
12
10
8
6
4
2
0
-2
-4
-6
-8
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21

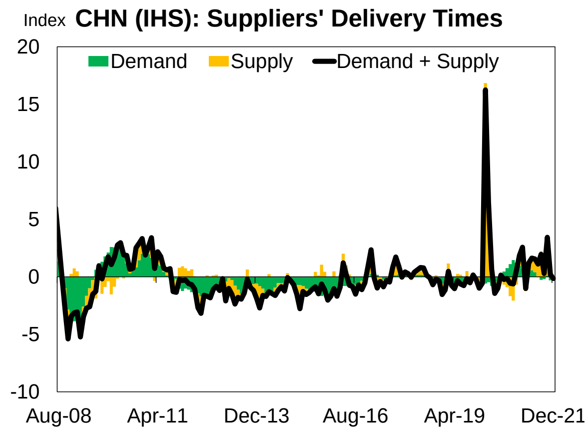

CAN: New Orders
Index
Demand
Supply
Demand + Supply
10
5
0
-5
-10
-15
-20
-25
-30
-35
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21

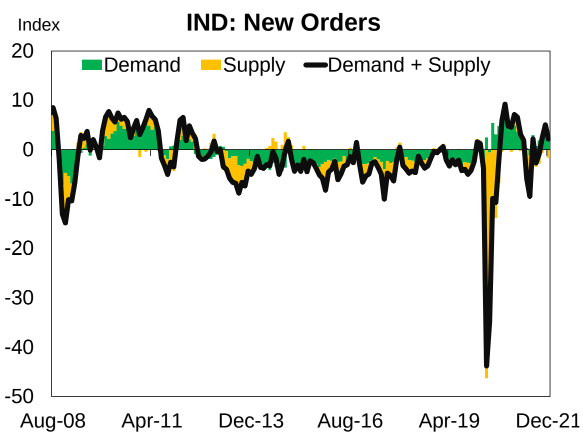

CAN: Suppliers' Delivery Times
Index
Demand
Supply
Demand + Supply
25
20
15
10
5
0
-5
-10
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21

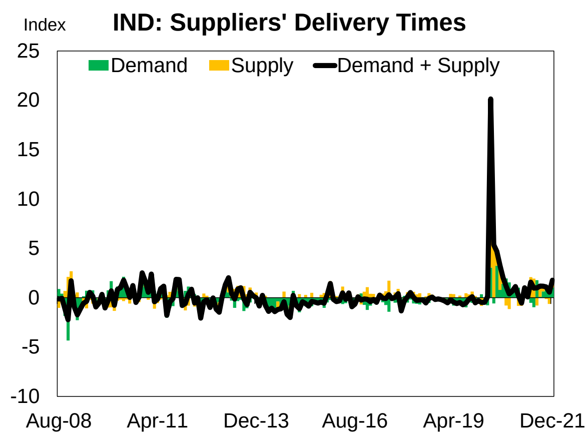

CHN (NBS): New Orders
Index
Demand
Supply
Demand + Supply
15
10
5
0
-5
-10
-15
-20
-25
-30
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21

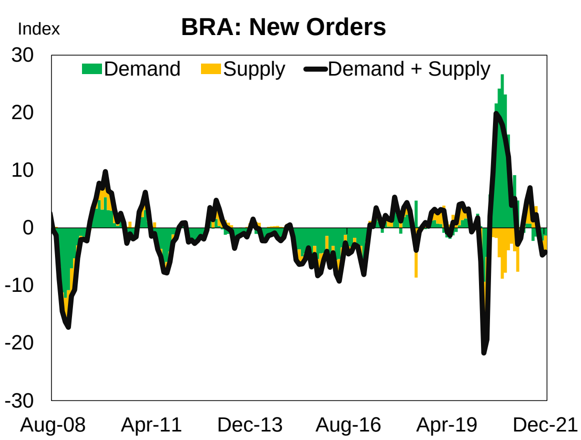

CHN (NBS): Suppliers' Delivery Times
Index
Demand
Supply
Demand + Supply
20
15
10
5
0
-5
-10
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21

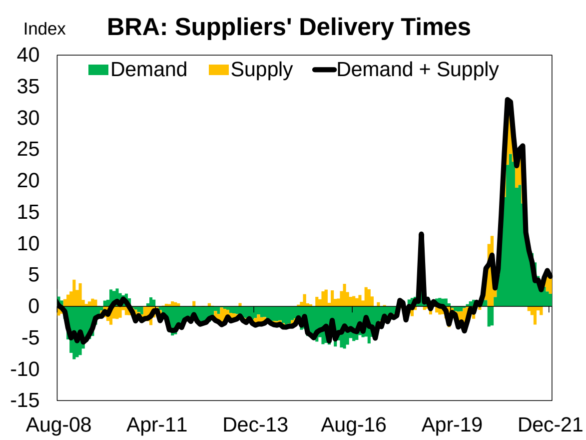

Index
CHN (IHS): New Orders
Demand
Supply
Demand + Supply
15
10
5
0
-5
-10
-15
-20
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21


Index
CHN (IHS): Suppliers' Delivery Times
Demand
Supply
Demand + Supply
20
15
10
5
0
-5
-10
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21

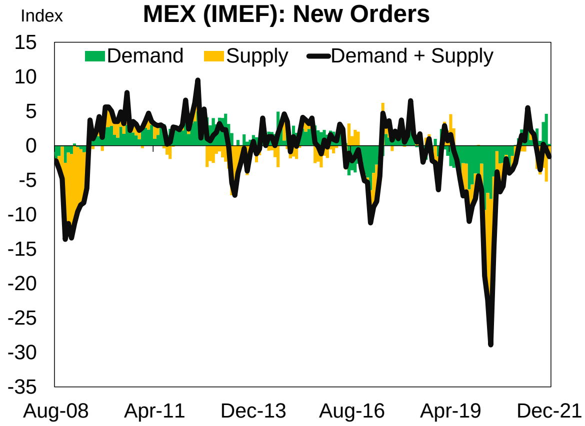

Index
IND: New Orders
Demand
Supply
Demand + Supply
20
10
0
-10
-20
-30
-40
-50
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21


Index
IND: Suppliers' Delivery Times
Demand
Supply
Demand + Supply
25
20
15
10
5
0
-5
-10
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21

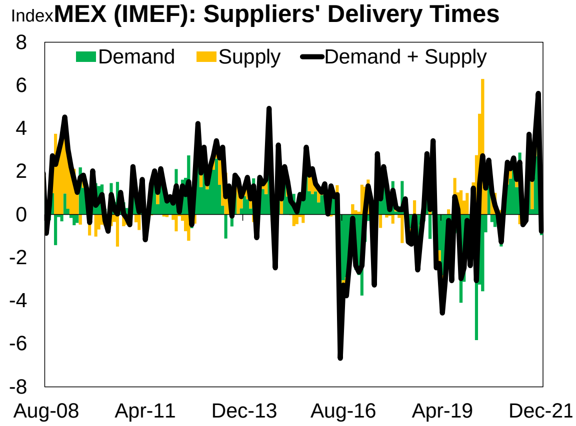

Index
BRA: New Orders
Demand
Supply
Demand + Supply
30
20
10
0
-10
-20
-30
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21


Index
BRA: Suppliers' Delivery Times
Demand
Supply
Demand + Supply
40
35
30
25
20
15
10
5
0
-5
-10
-15
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21

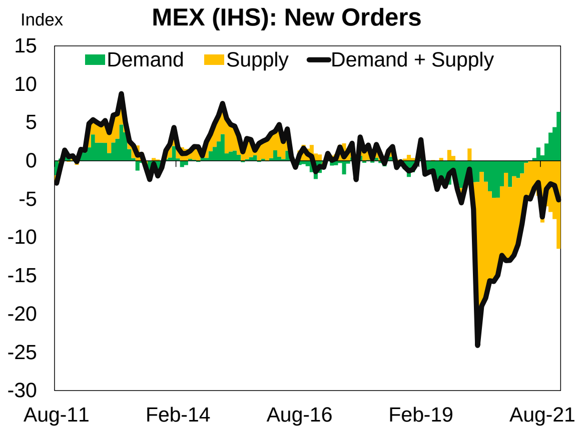
MEX (IMEF): New Orders



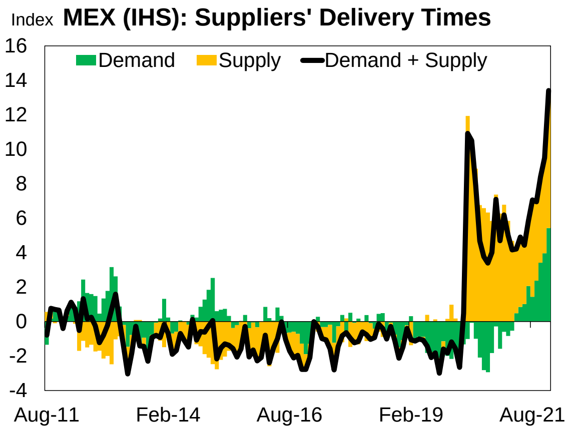
MEX (IMEF): Suppliers' Delivery Times



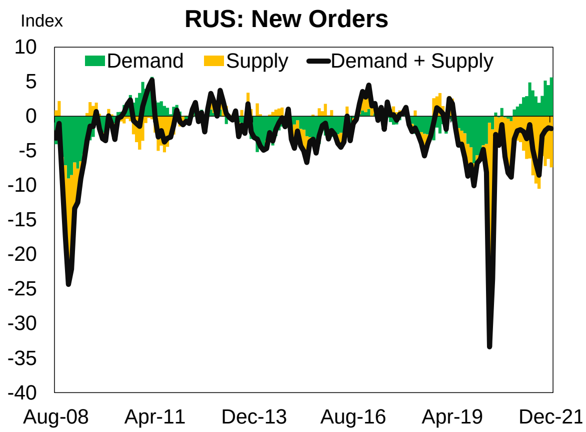
MEX (IHS): New Orders



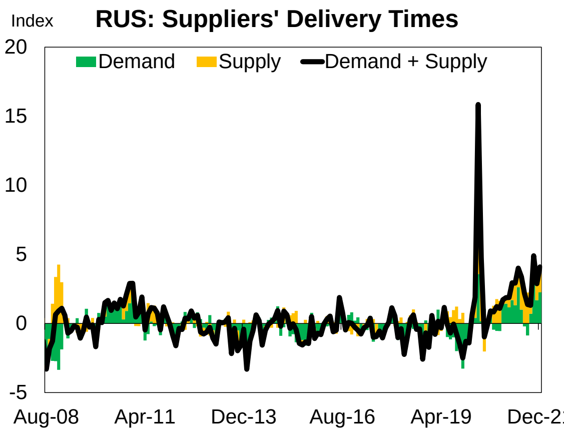
MEX (IHS): Suppliers' Delivery Times

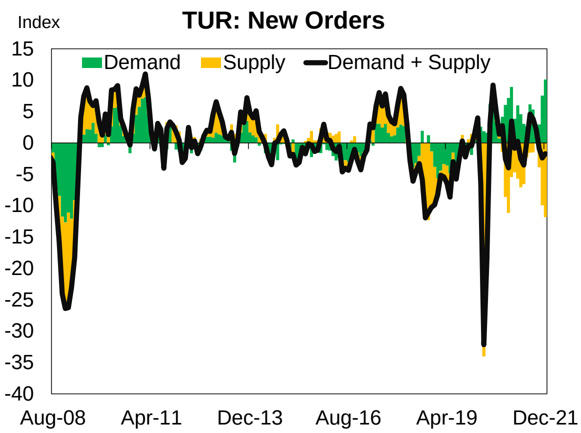


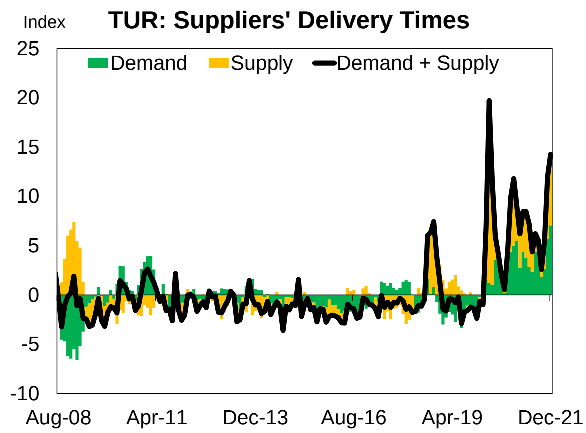
RUS: New Orders



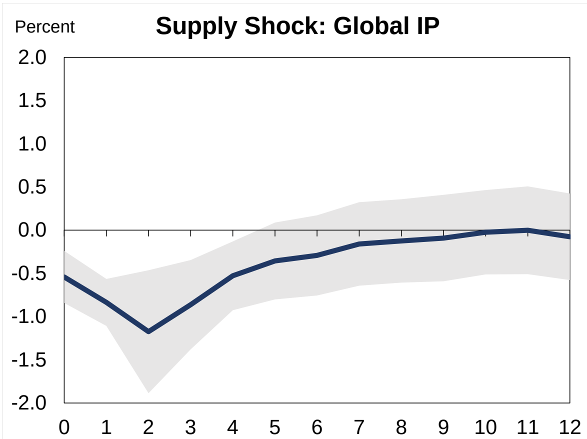
RUS: Suppliers' Delivery Times

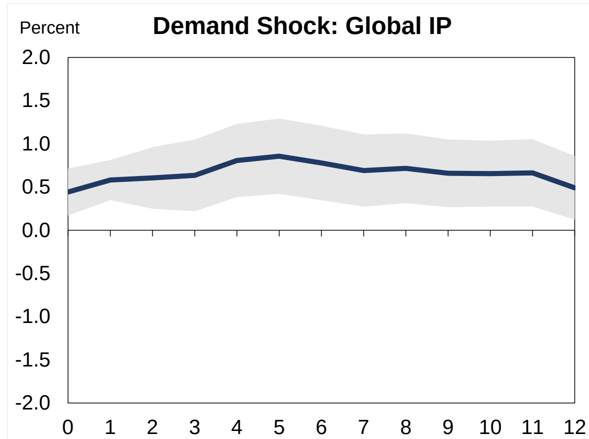


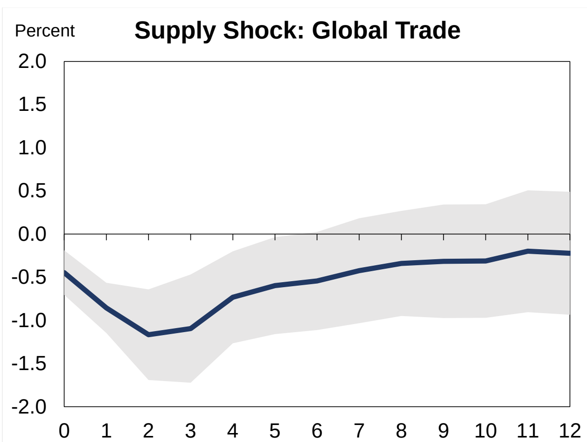

Index
TUR: New Orders
Demand
Supply
Demand + Supply
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21

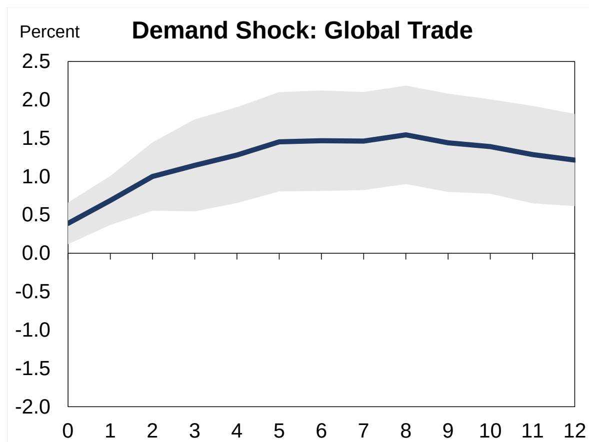

Index
TUR: Suppliers' Delivery Times
Demand
Supply
Demand + Supply
25
20
15
10
5
0
-5
-10
Aug-08
Apr-11
Dec-13
Aug-16
Apr-19
Dec-21

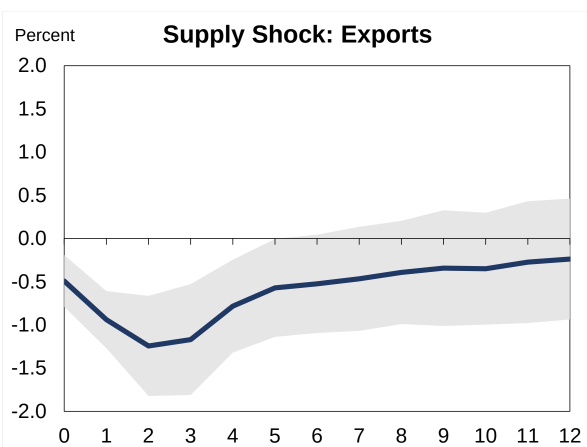
Annex II. Impulse Response Functions (IRFs)

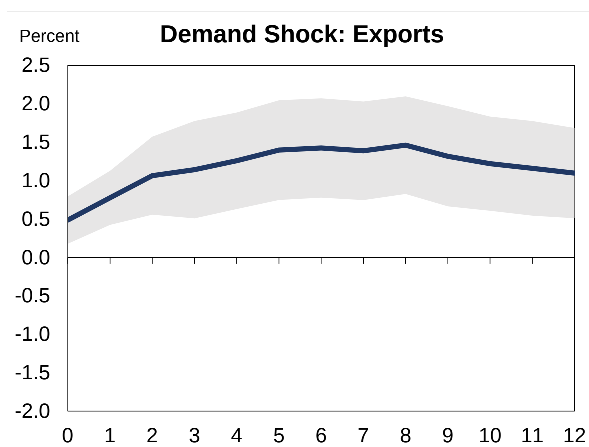


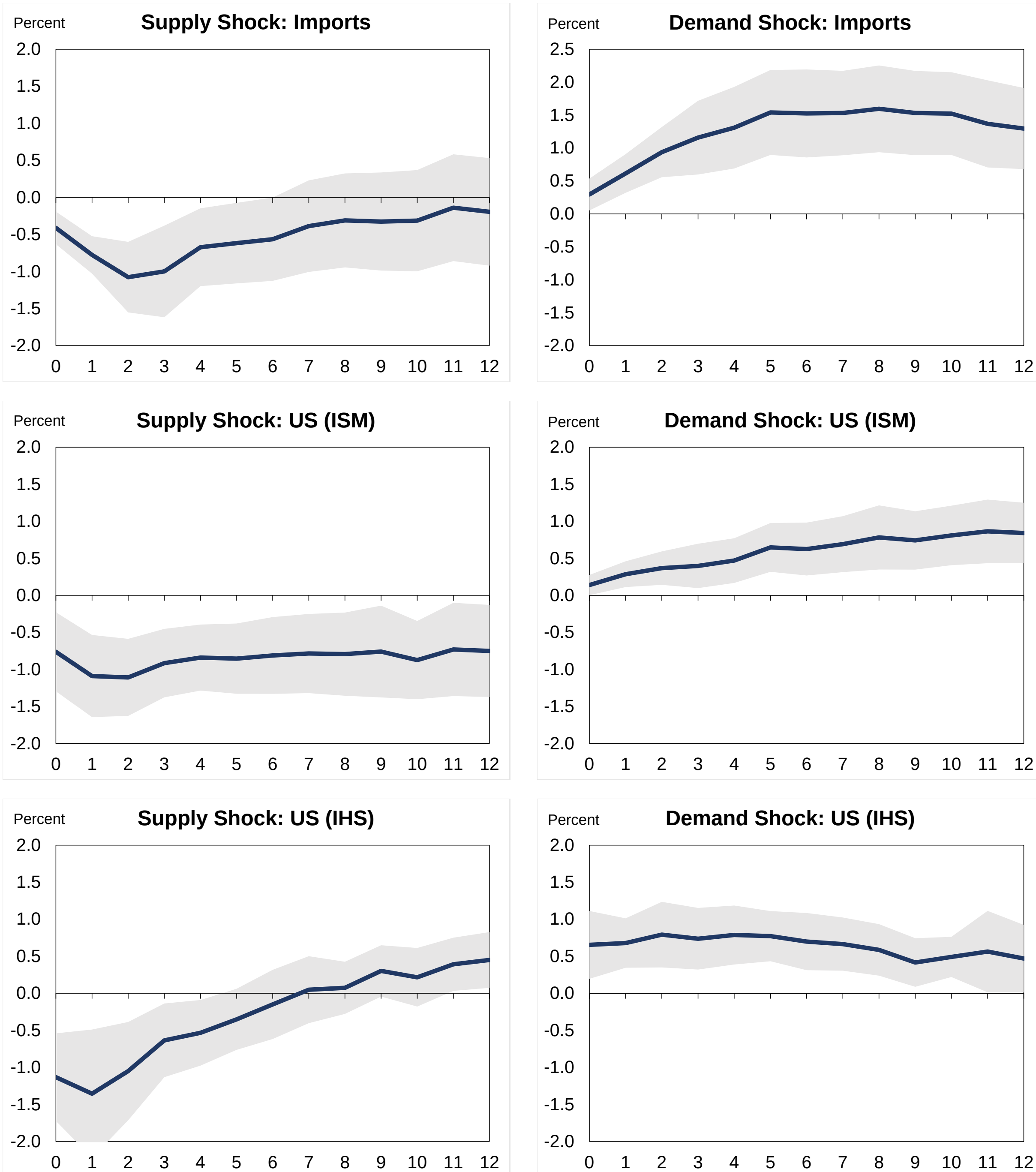


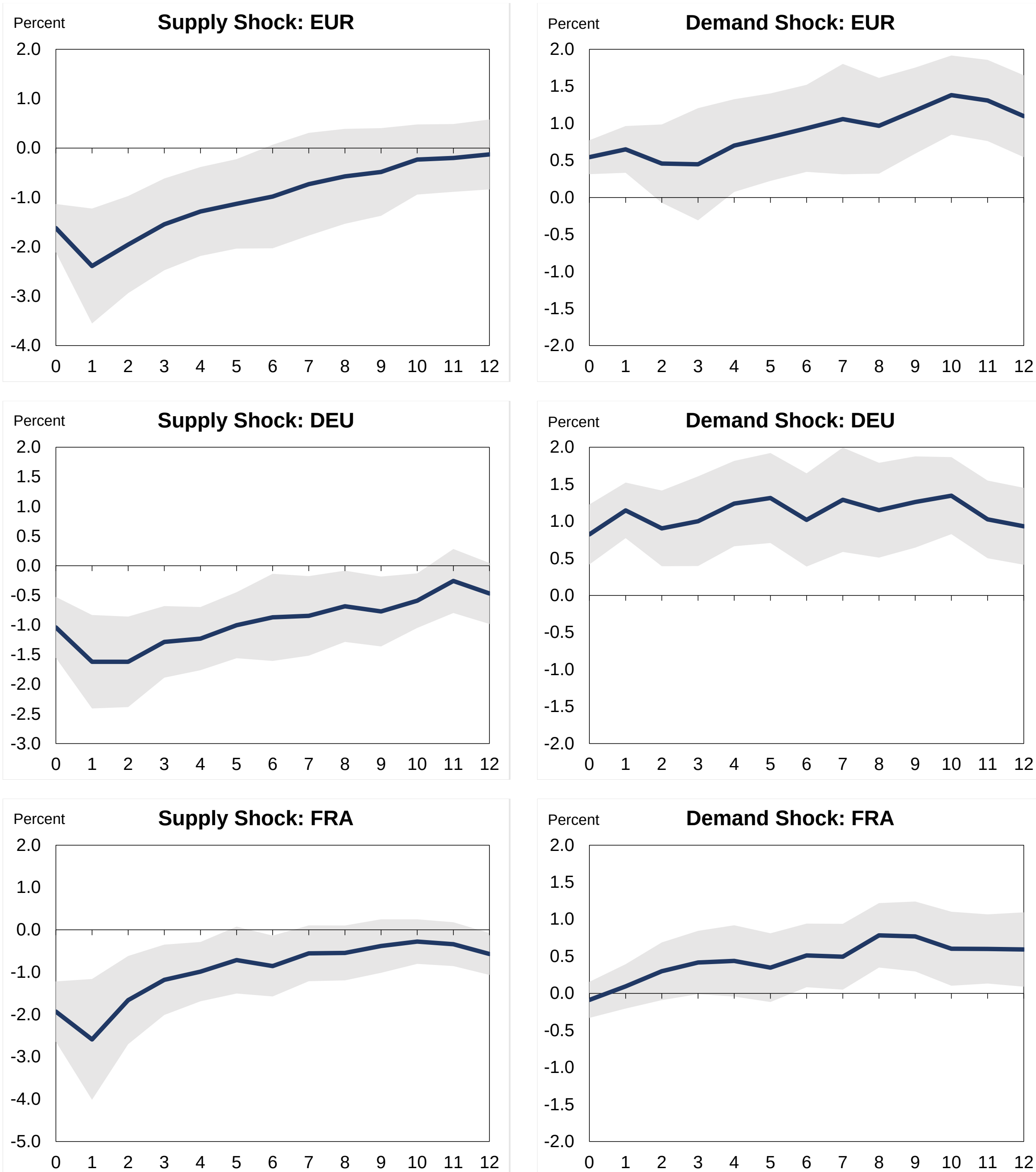


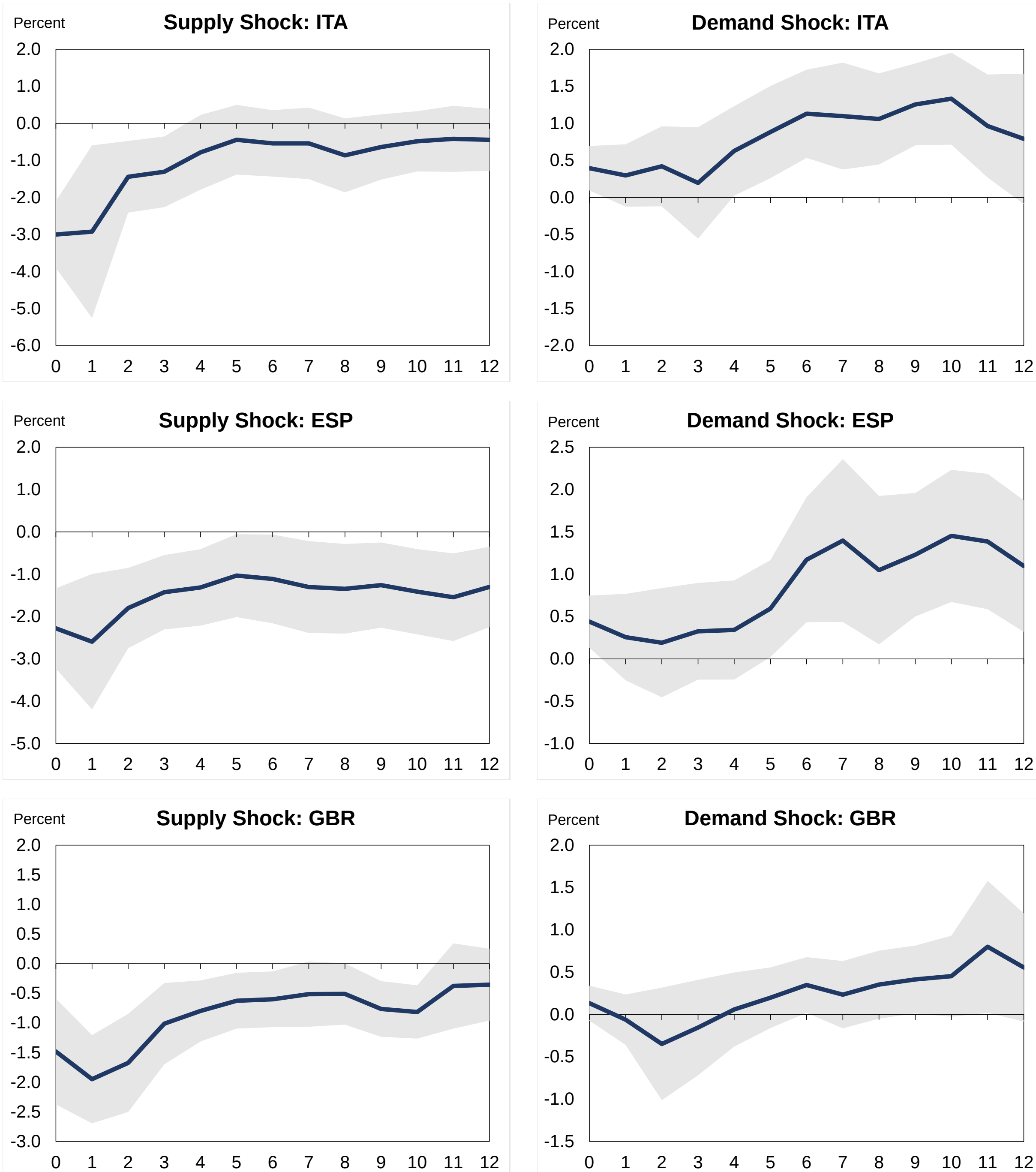


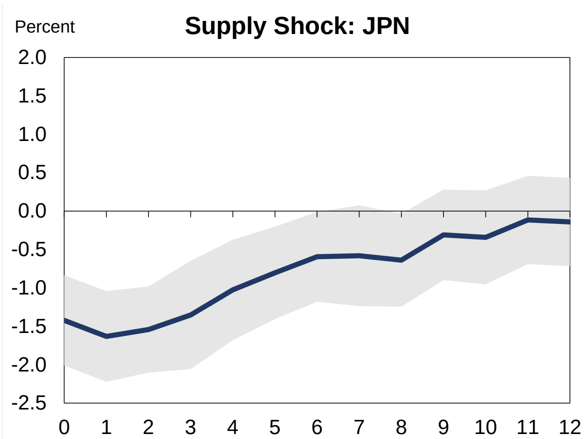


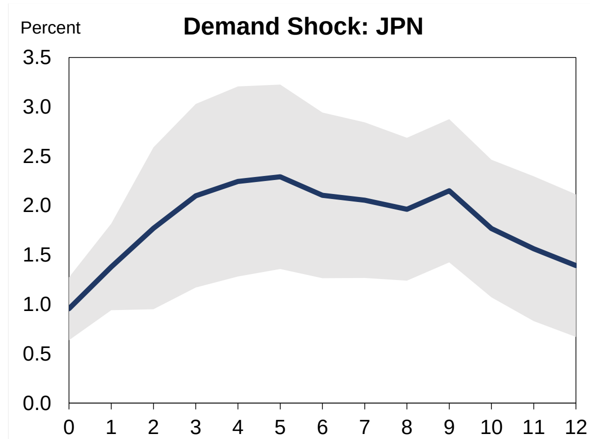


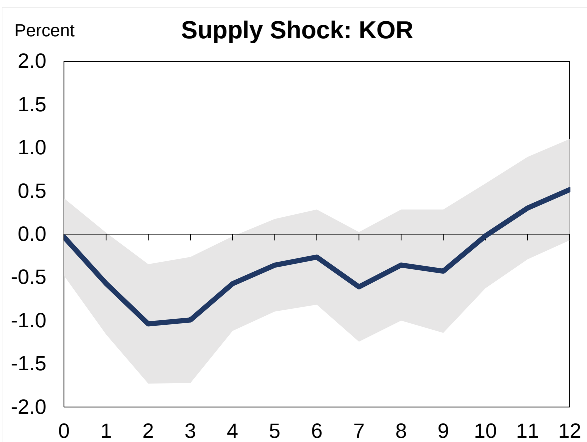

Percent
Supply Shock: Imports
Percent
Demand Shock: Imports
Percent
Supply Shock: US (ISM)
Percent
Demand Shock: US (ISM)
Percent
Supply Shock: US (IHS)
Percent
Demand Shock: US (IHS)
0 1 2 3 4 5 6 7 8 9 10 11 12

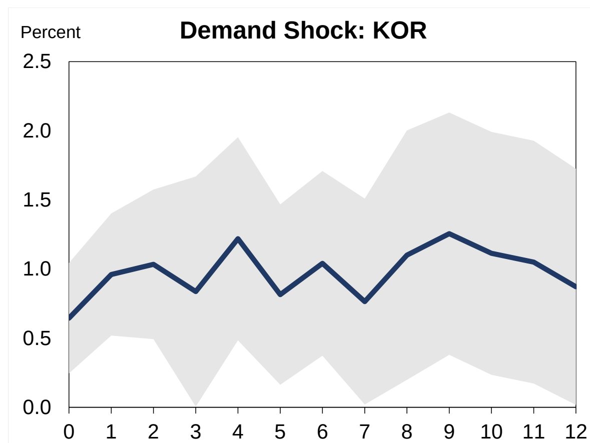

Percent
Supply Shock: EUR
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Demand Shock: EUR
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Supply Shock: DEU
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Demand Shock: DEU
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Supply Shock: FRA
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Demand Shock: FRA
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
0 1 2 3 4 5 6 7 8 9 10 11 12

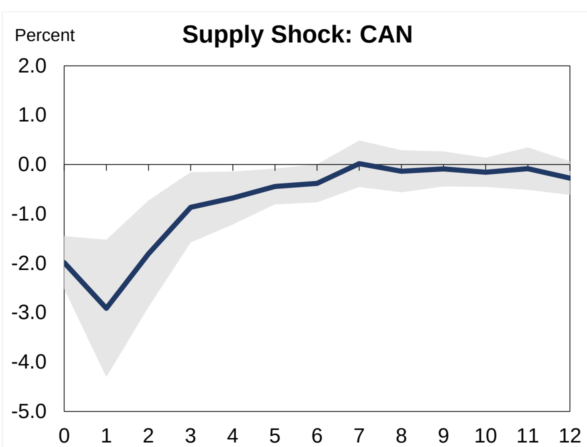

Percent
Supply Shock: ITA
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Demand Shock: ITA
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Supply Shock: ESP
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Demand Shock: ESP
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Supply Shock: GBR
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Demand Shock: GBR
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
0 1 2 3 4 5 6 7 8 9 10 11 12

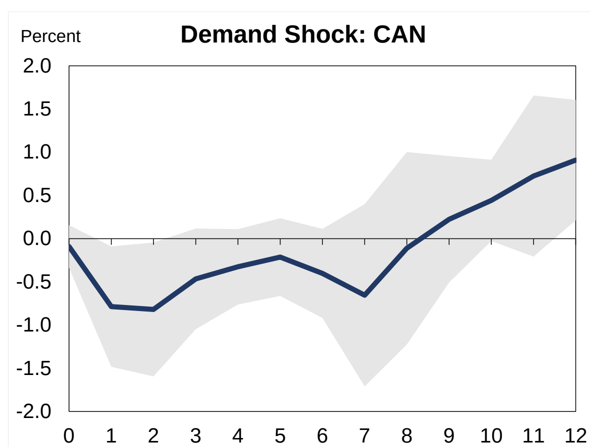

Percent
Supply Shock: JPN
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
0 1 2 3 4 5 6 7 8 9 10 11 12

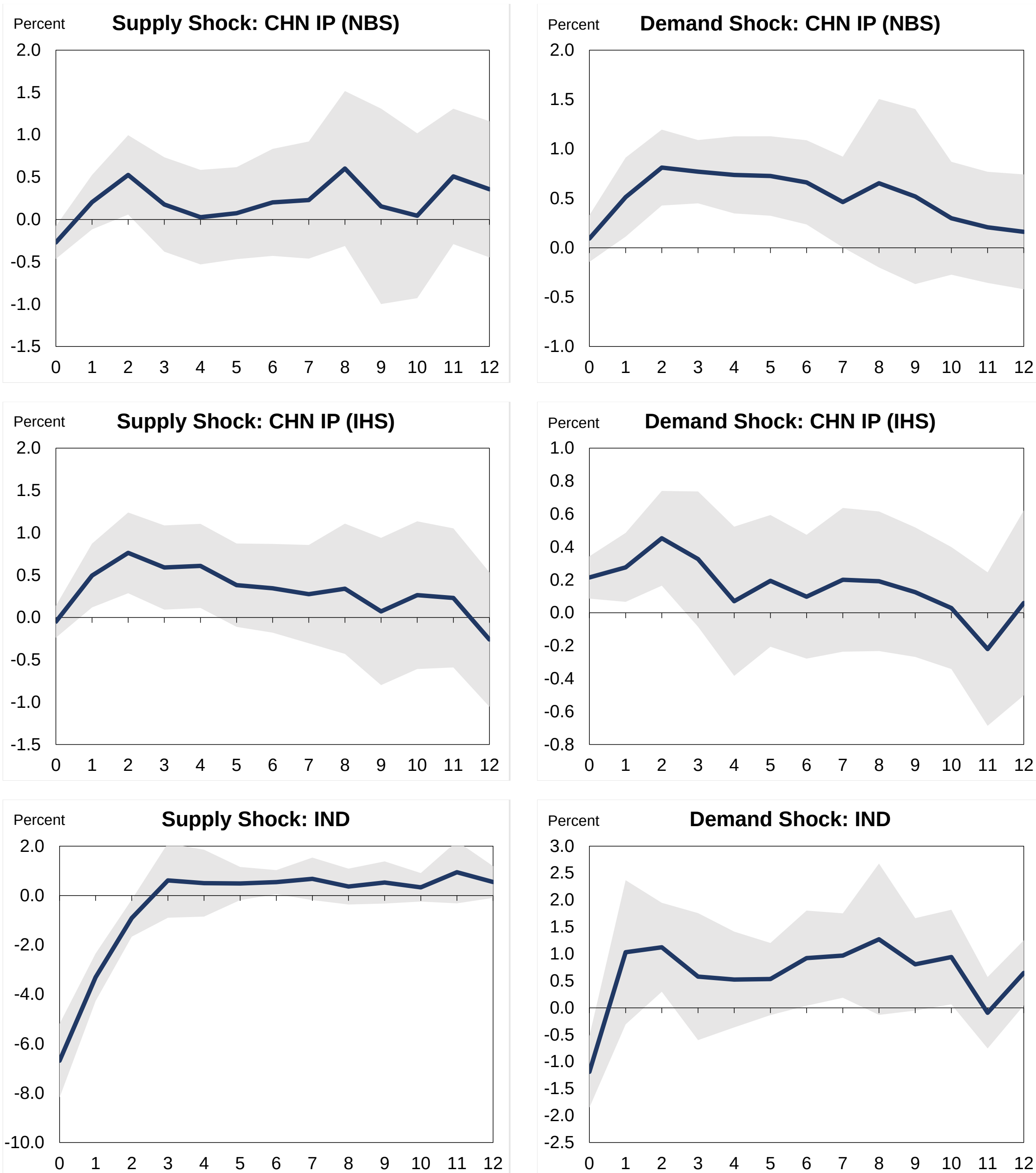

Percent
Demand Shock: JPN
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12

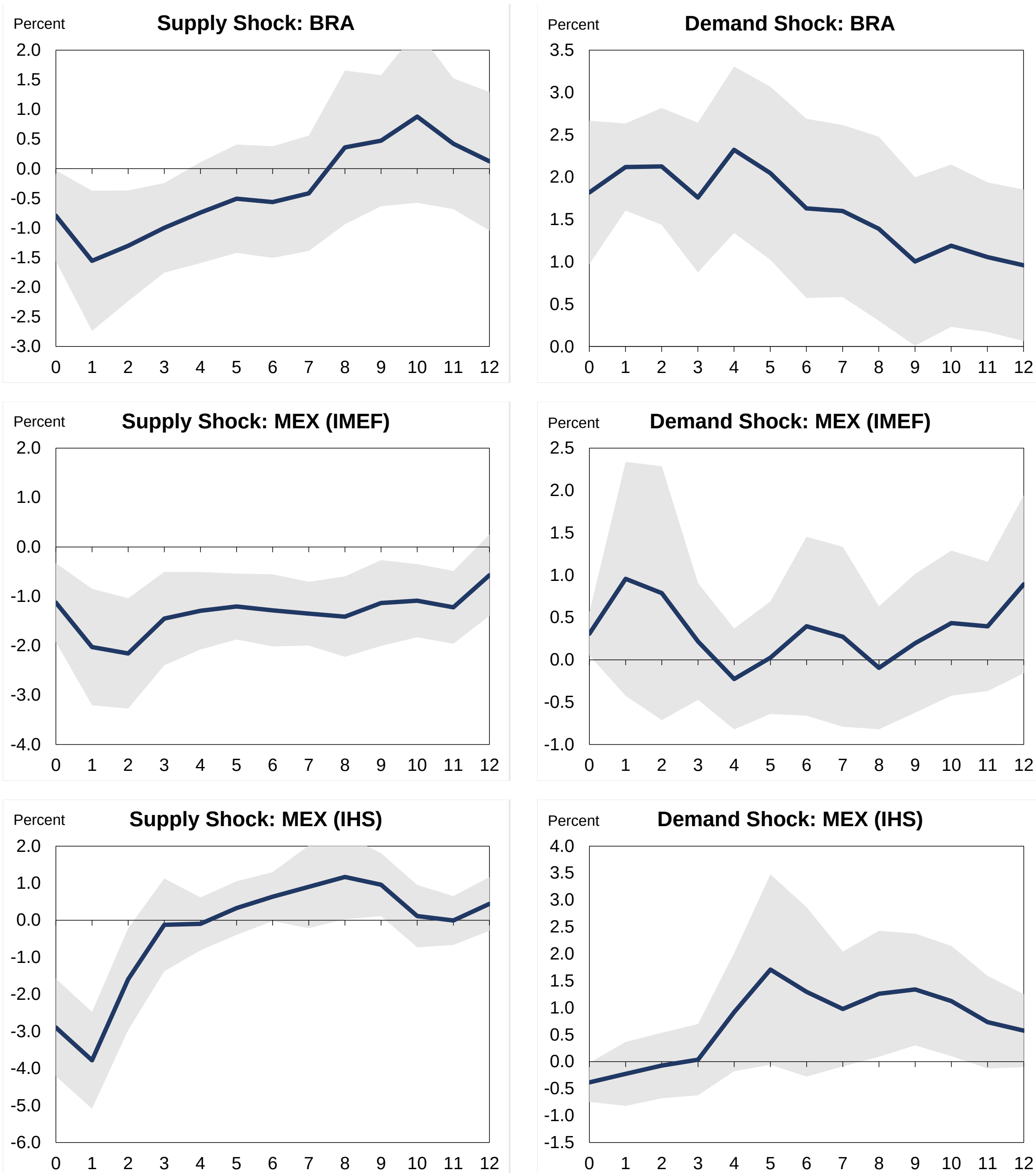

Percent
Supply Shock: KOR
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
0 1 2 3 4 5 6 7 8 9 10 11 12

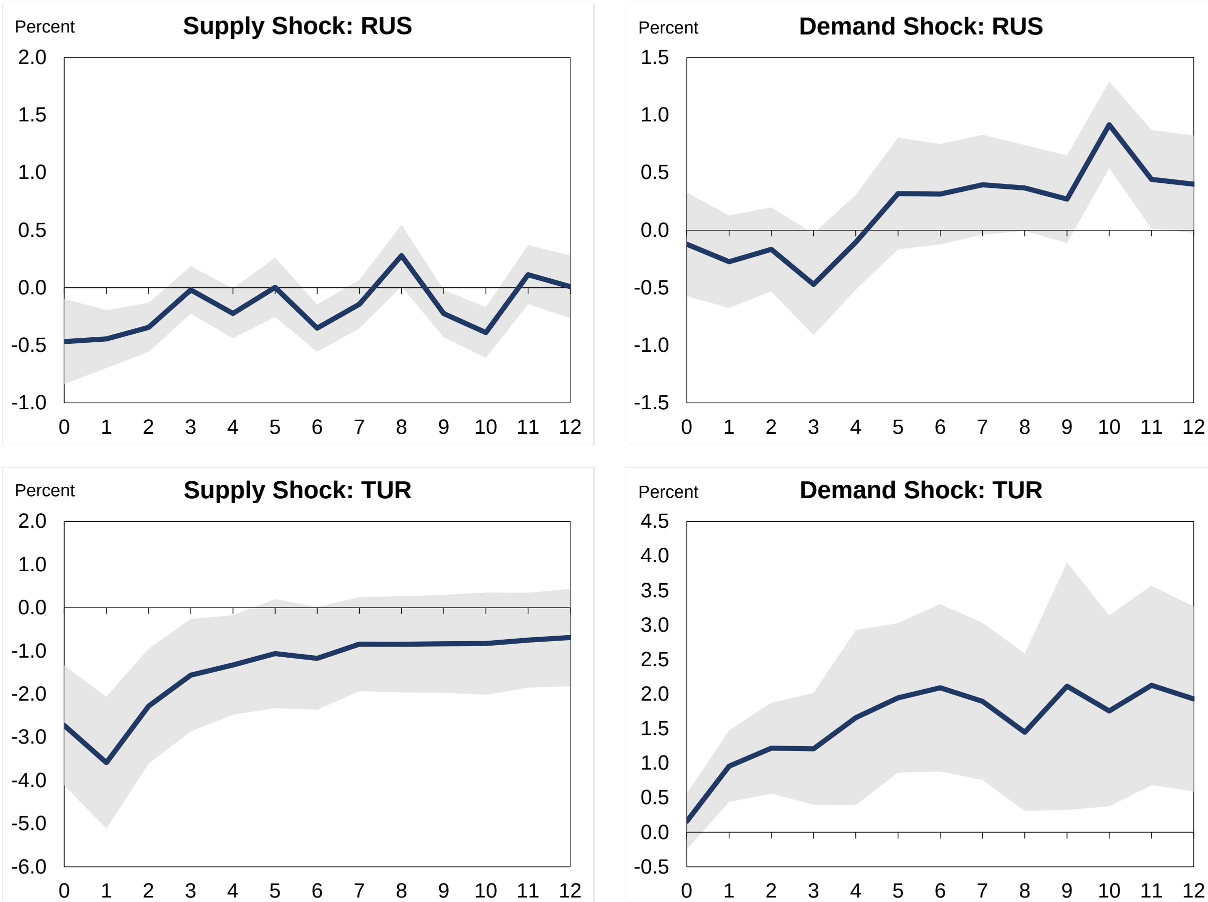

Percent
Demand Shock: KOR
2.5
2.0
1.5
1.0
0.5
0.0
0 1 2 3 4 5 6 7 8 9 10 11 12


Percent
Supply Shock: CAN
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
0 1 2 3 4 5 6 7 8 9 10 11 12


Percent
Demand Shock: CAN
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
0 1 2 3 4 5 6 7 8 9 10 11 12

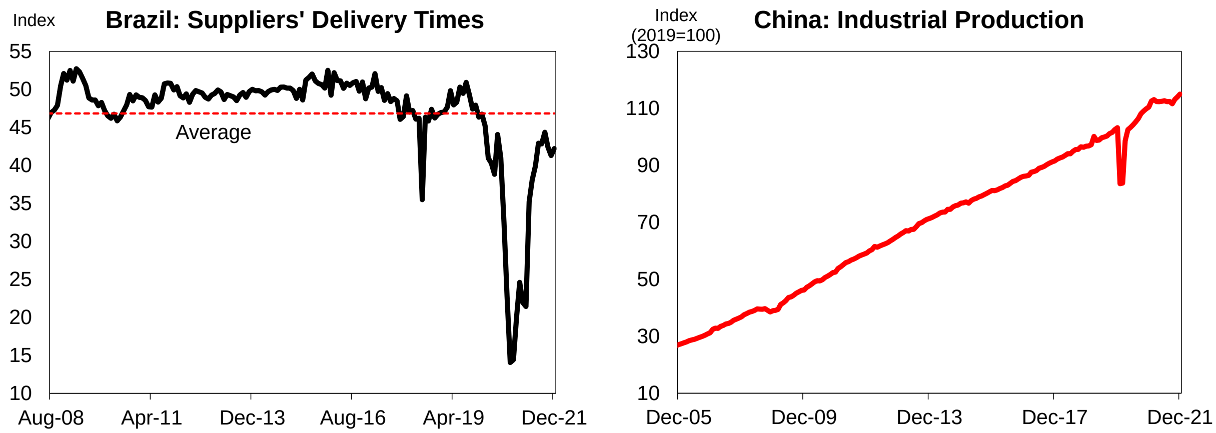

Percent
Supply Shock: CHN IP (NBS)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Demand Shock: CHN IP (NBS)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Supply Shock: CHN IP (IHS)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Demand Shock: CHN IP (IHS)
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Supply Shock: IND
2.0
0.0
-2.0
-4.0
-6.0
-8.0
-10.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Demand Shock: IND
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
0 1 2 3 4 5 6 7 8 9 10 11 12


Percent
Supply Shock: BRA
Percent
Demand Shock: BRA
Percent
Supply Shock: MEX (IMEF)
Percent
Demand Shock: MEX (IMEF)
Percent
Supply Shock: MEX (IHS)
Percent
Demand Shock: MEX (IHS)


Percent
Supply Shock: RUS
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Demand Shock: RUS
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Supply Shock: TUR
2.0
1.0
0.0
-1.0
-2.0
-3.0
-4.0
-5.0
-6.0
0 1 2 3 4 5 6 7 8 9 10 11 12
Percent
Demand Shock: TUR
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
0 1 2 3 4 5 6 7 8 9 10 11 12

Annex III. Additional Charts

Figure A1. Brazil Suppliers' Delivery Times and China Industrial Production



Sources: Haver Analytics, S&P Global , and authors' calculations.

PUBLICATIONS

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