Special Feature A

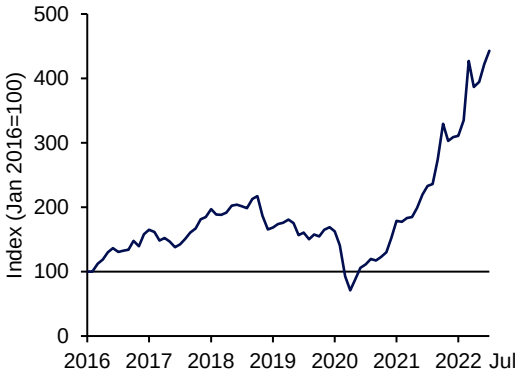
Effects of Higher Global Input Costs on Prices in Singapore

This Special Feature examines how recent surges in global energy and agricultural product costs impacted inflation across countries and sectors, eventually transmitting to domestic prices in Singapore. The analysis involved calibrating a tractable supply chain model using global industry input-output data. The findings indicate recent spikes in energy and agriculture prices explain over two-thirds of core inflation pressures in Singapore over June 2021 – June 2022. The study also reveals considerable heterogeneity in the cost impact on inflation across sectors and countries. In Singapore, most of the international price effects on the domestic sectors are transmitted via intermediary sectors located abroad. In contrast, the contributions of global energy and agriculture costs to inflation in the US and the EU occur through their respective domestic supply chains.

1 Introduction

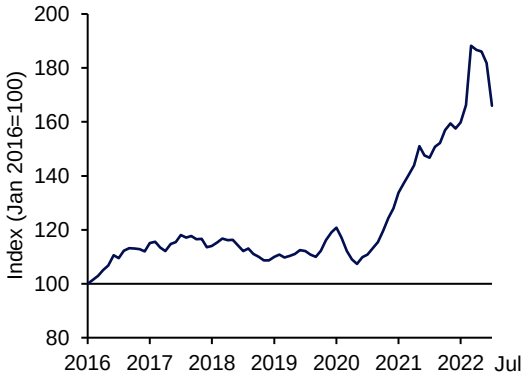
Energy and food commodity prices have risen substantially across the world. Compared to last June, the International Monetary Fund's (IMF) fuel price index rose by 92% in June this year **(Chart 1)**. Similarly, data from the UN Food and Agriculture Organization (UNFAO) indicates global prices of food commodities grew by 23% during the same period **(Chart 2)**.

Chart 1 Global Energy Price Index



Source: IMF Price Index

Chart 2 Global Food Price Index



Source: UN FAO Price Index

Several factors explain this surge in energy and food prices. Economies around the world started recovering from COVID-19 during 2021, leading to a rebound in oil and food consumption. However, during the same period, OPEC+ kept oil supply below pre-COVID

levels, depleting oil inventories and raising oil prices.[1] Meanwhile, higher freight prices, costlier inputs and trade restrictions during the pandemic caused food prices to increase.[2] Finally, the ongoing Russia-Ukraine conflict has further disrupted energy and food supply chains.[3]

Energy and food derived products account for a significant weight (10.7%) in Singapore's CPI basket.[4] Hence, higher energy and food commodity prices explain part of recent price inflation in Singapore, via their direct effect on energy and food-related components of the CPI. Specifically, on a y-o-y basis, these items contributed to one quarter of both MAS Core inflation (4.4%) and CPI-All Items inflation (6.7%) in June.[5]

However, higher energy and food commodity prices could have elevated costs for a broader range of industries too, via domestic and global supply chains. For example, by making electricity more expensive in Singapore, higher energy prices likely raised food & beverage (F&B) operators' costs, inducing them to increase prices for consumers.[6] Given the importance of energy as well as agricultural products as inputs into many industries, their higher international costs likely contributed—through supply chain linkages—to higher prices across many Singapore sectors.

In this vein, this Special Feature seeks to quantify the effects of costlier energy and agricultural products more fully on inflation across sectors in Singapore. This is done in two ways. First, global input-output (I-O) data is used to analyse how supply chains feature in cost and price inflation determination across sectors and countries. Second, the routes through which shocks to energy and agriculture markets affect other industries are traced through their domestic and global I-O linkages. These two aspects allow measurement of general equilibrium effects of the aforementioned cost shocks on sectors unrelated to energy or food. The same features also permit comparison over how much domestic and foreign supply chains affect inflation.

The results indicate that from this broader perspective, recent shocks to global energy and agriculture costs could effectively explain just over two-thirds of y-o-y core inflation in June 2022 for Singapore. Besides pushing up consumer prices, these shocks also buttressed costs for exporting sectors, and possibly raised export prices. Notably, there is considerable heterogeneity in the cost impact across industries. Singapore's manufacturing and transport services sectors are heavily affected by energy cost shocks. In contrast, costlier agricultural products mainly affect food-related sectors (i.e., F&B manufacturing and F&B services).

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1 According to the Energy Information Administration (2021b), during 2021, inventories for crude oil and other liquids declined, while OPEC+ restraining oil production meant oil prices were elevated.

2 See Deloitte Insights (2022) for more details.

3 According to the Energy Information Administration (2021c), Russia was the world's third largest producer of petroleum and other liquids, and the second largest supplier of dry natural gas in 2020. Russia and Ukraine also supply a signficant amount of agricultural products. Data from The Observatory of Economic Complexity indicates both countries together account for 25% of global exports of wheat and barley, and 14% of corn in 2020.

4 Here, food and energy derived products refer to fuels & lubricants, electricity & gas, and non-cooked food. Note core CPI excludes fuels & lubricants.

5 These items contributed 43% and 70% to headline inflation in the US and EU over the same period, respectively, This partly reflects the items' larger weights in the US CPI (17.5%) and EU harmonised index of consumer prices (15.9%) baskets.

6 According to *The Business Times* (2022), food court operator Koufu saw its electricity bill surge by 80%. The operator passed on 30% of this hike in cost to its stall tenants through additional miscellaneous charges since 1 March 2022.

Finally, in line with Singapore's heavy reliance on imported inputs for economic activity, linkages through both domestic and foreign supply chain intermediaries are responsible for transmitting recent cost-push inflation in Singapore. In contrast, inflation in the US and the EU appear driven primarily by domestic supply chain effects.

2 Brief Description of Methods and Data

The empirical strategy is adapted from Valadkhani & Mitchell's (2002) study of how oil prices affect Australia's economy. The primary dataset is the latest I-O table (for the year 2018) from the Organisation for Economic Co-operation and Development (OECD).[7] This table contains intermediate input flows between 204 sectors located across 12 regions, denominated in 2018 US$.[8] The same table also yields value-added and net taxes paid by each sector.[9]

It is assumed that producing a dollar's worth of a good in each sector requires inputs in fixed proportions from the remaining sectors. So for $i = 1, \dots, 204$, assembling a unit of sector i's output requires a_{1i} units of sector 1's output, …, and a_{204i} units of sector 204's output, where $a_{1i}, \dots, a_{204i}$ are fixed parameters. Crucially, the fixed parameters implies there is zero elasticity of substitution between different sectors' inputs. This restriction is tenable due to how broadly the sectors are defined in the data. For example, while steel and aluminium are imperfect substitutes in the production of many goods, output from 'US manufacturing' and 'Australian agriculture' are unlikely to be equally substitutable.

The model implies

$$\boldsymbol{p} = \boldsymbol{A}'\boldsymbol{p} + \boldsymbol{va} + \boldsymbol{tax}.$$

Here, $\boldsymbol{A}$ is the matrix of input-output coefficients a_{ij}, $\boldsymbol{va}$ is a vector of value added per output across sectors, and $\boldsymbol{tax}$ consists of net tax revenues per output across sectors. As alluded to above, $\boldsymbol{A}$, $\boldsymbol{va}$, and $\boldsymbol{tax}$ are considered exogenous determinants of prices $\boldsymbol{p}$. Hence, this study calibrates $\boldsymbol{A}$, $\boldsymbol{va}$, and $\boldsymbol{tax}$ with OECD data.

This Special Feature aims to shed light on how shocks to energy costs affect other sectors worldwide. One of the sectors (energy mining, quarrying & manufacturing) in each sampled region corresponds to energy production. Hence, the empirical strategy designates prices for energy sectors across each region as exogenous. The variables are thus partitioned to obtain:

$$\begin{bmatrix}\boldsymbol{p}_e \\ \boldsymbol{p}_n\end{bmatrix} = \begin{bmatrix}\boldsymbol{A}_{ee}{}' & \boldsymbol{A}_{ne}{}' \\ \boldsymbol{A}_{en}{}' & \boldsymbol{A}_{nn}{}'\end{bmatrix}\begin{bmatrix}\boldsymbol{p}_e \\ \boldsymbol{p}_n\end{bmatrix} + \begin{bmatrix}\boldsymbol{va}_e \\ \boldsymbol{va}_n\end{bmatrix} + \begin{bmatrix}\boldsymbol{tax}_e \\ \boldsymbol{tax}_n\end{bmatrix}.$$

Prices for the remaining region-sector pairs $\boldsymbol{p}_n$ respond to a shock in exogenous energy prices $\boldsymbol{p}_e$ as follows:

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7 OECD releases several I-O tables every four to five years. The 2018 I-O table was released in 2021.

8 The regions are Singapore, the US, the EU, the Hong Kong Special Autonomous Region, China, Malaysia, Australia, Chinese Taipei, Mexico, Brazil, Russia and the Rest of the World. Chart 3's horizontal axis enumerates each region's sectors.

9 The original table yields trade flows between 67x45 country-industry pairs. The countries and industries were aggregated into 12 regions and 17 broad sectors respectively. See https:/www.oecd.org/sti/ind/input-outputtables.htm for a deeper description of the data.

$$\boldsymbol{infl}_n = 100\% \times (\boldsymbol{I} - \boldsymbol{A}'_{nn})^{-1}\boldsymbol{A}'_{en}(\boldsymbol{p}_e^{new} - \boldsymbol{p}_e^{old}). \quad (1)$$

Here $\boldsymbol{infl}_n$ consists of inflation rates for non-energy sectors, in response to energy prices increasing by $\boldsymbol{p}_e^{new} - \boldsymbol{p}_e^{old}$. To examine how prices for the remaining sectors change in response to the recent rise in energy prices, $\boldsymbol{p}_e^{new} - \boldsymbol{p}_e^{old}$ is set at 92%, the increment in the IMF's fuel price index over June 2021 – June 2022.[10]

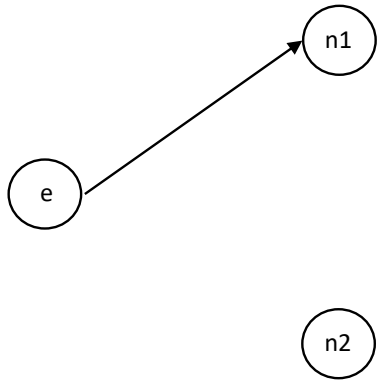
This Special Feature also examines the impact of higher agriculture prices on non-agriculture sectors. To do so, this study replicates the same sequence of steps that was used to analyse energy cost shocks. Notably, agriculture prices were perturbed upwards by 23%, the y-o-y increment in food commodity prices in June 2022.[11] Inflation rates across the remaining endogenous sectors for each region were then computed using an analogous equation to (1).

Finally, whether inflation stemming from energy and agriculture cost shocks transmits through direct I-O linkages between exogenous and endogenous sectors, or indirectly via intermediary industries, is also of interest. This is examined by decomposing the effects of each shock on inflation into two components:

$$\boldsymbol{infl}_n = 100\% \times \Big[\underbrace{\boldsymbol{A}'_{en}(\boldsymbol{p}_e^{new} - \boldsymbol{p}_e^{old})}_{\leftarrow \text{ direct effect } \rightarrow} + \underbrace{\left(\boldsymbol{A}'_{nn} + \boldsymbol{A}'^{2}_{nn} + \boldsymbol{A}'^{3}_{nn} + \cdots\right)\boldsymbol{A}'_{en}(\boldsymbol{p}_e^{new} - \boldsymbol{p}_e^{old})}_{\leftarrow \text{ indirect effect } \rightarrow} \Big]. \quad (2)$$

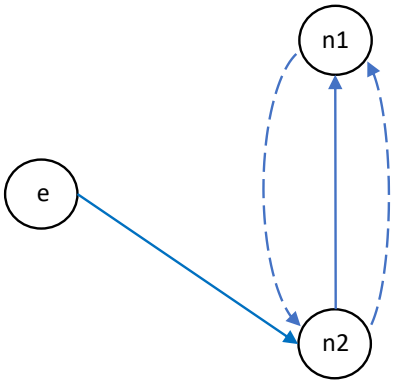
The first component in (2) reflects inflationary effects transmitted through direct links between exogenous and endogenous sectors in the I-O table. These direct effects occur because inputs flow directly from exogenous to endogenous sectors **(Chart 3)**. For example, American energy producers can supply fuel to Singaporean shipping firms, linking the US energy and Singapore transport services sectors.

Chart 3 Example of Direct Effects in 3 Sector Economy



Note: In this diagram, Sector e supplies inputs to Sector n1.

Chart 4 Example of Indirect Effects in 3 Sector Economy



Note: In this diagram, sectors e and n2 and n1 supply inputs to sectors n2, n1 and n2 respectively.

10 Alternatively, one can think of the energy shock as perturbing the value-added per output for the energy sectors, so that energy prices rise by 92% in equilibrium.

11 Data taken from the UN FAO food price index.

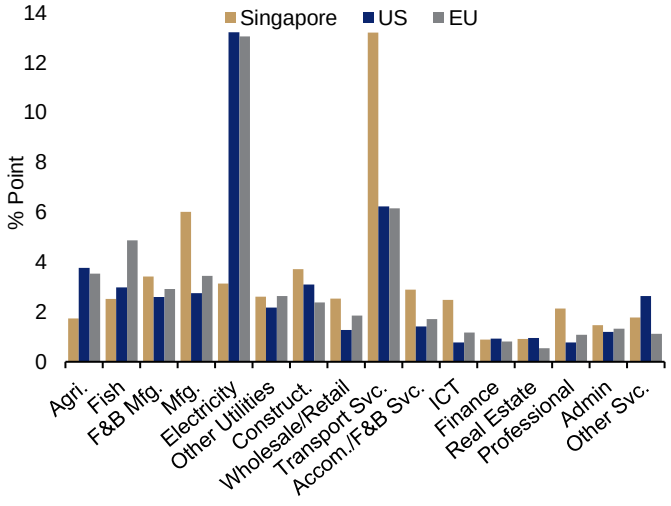
The second component in (2), referred to as the 'indirect effect' henceforth, reflects 2nd, 3rd and additional round effects, due to all extended transaction chains between exogenous and endogenous sectors. These chains are created by intermediary sectors adjoining exogenous and endogenous sectors (Chart 4, blue arrows). For example, US energy producers can supply Chinese shipbuilders that in turn, deliver inputs to Singaporean ship operators. Thus, China's manufacturing sector transacts with both the US energy and Singapore transport services sectors.

It should be noted that the indirect chains can also cycle across a sector multiple times, before reaching its destination sector (**Chart 4**, bold and dashed arrows combined). Returning to the same example, domestic shipping companies may supply some level of services to China's manufacturing sector, allowing the latter to provide more inputs to Singapore shipping firms. Such circular feedback effects mean US energy inputs to China's manufacturing sector could have an amplified effect on Singapore's transport services sector.

3 Findings

Chart 5 displays the predicted price inflation across sectors in Singapore, the US and the EU, in response to a 92% increase in global energy prices. In Singapore, this effect is most salient in the manufacturing and transport services sectors. These sectors' prices rise by 6.0% and 13.2% respectively. In the US and the EU, prices also increase substantially in these sectors. However, price inflation overseas is more notable in the electricity industry (which encompasses air-conditioning, gas and steam in the OECD data). For this sector, prices pick up by approximately 13% in the US and the EU.

Chart 5 Price Change in Singapore, the US and the EU due to Costlier Energy



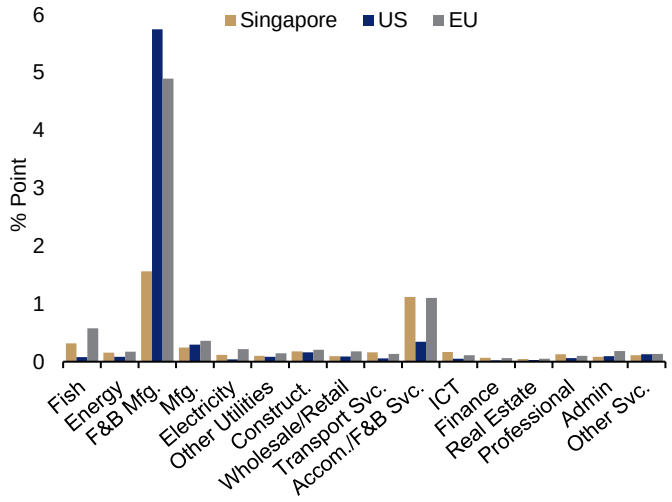
Source: OECD and EPG, MAS estimates

The inflation rates in **Chart 5** may appear surprisingly small, vis-à-vis the 92% increase in energy prices. However, this reflects that energy comprises a minor portion of total costs for many industries. For example, the average Singapore sector allocates 2% of its intermediate inputs expenditure on energy.[12]

Also, with the exception of agriculture, fisheries and electricity, price increases in Singapore sectors exceed or approximately equal their US or EU counterparts. As a later subsection will clarify, supply chains supporting Singapore's sectors are largely located in foreign countries. This increases the exposure of Singapore's sectors to global economic cost shocks.

Chart 6 summarises sectoral inflation as agriculture prices worldwide rise by 23%. Unsurprisingly, the price impact is largest in food-related sectors (F&B manufacturing and accommodation & food services). However, the impact on F&B manufacturing is smaller in Singapore than in the US and the EU. Specifically, prices increase by 1.6% locally, compared to 4.9–5.7% overseas.

Chart 6 Price Change in Singapore, the US and the EU due to Costlier Agricultural Products



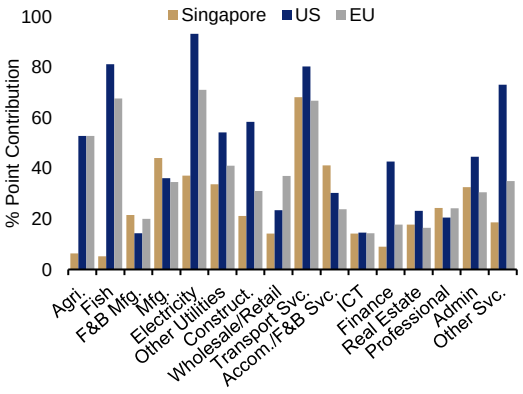
Source: OECD and EPG, MAS estimates

Chart 7 plots the proportion of inflationary effects directly driven by higher global energy costs, with the remainder accounted for by indirect supply chain effects. Across most sectors, direct links between energy and other sectors transmit a significant portion of price pressures in the US and the EU. In comparison, the bulk of energy driven inflation in the Singapore economy appears driven by indirect links.

The same is true for agriculture cost-push inflation in the sector most affected by the agriculture shock. **Chart 8** shows that the indirect contribution of agricultural price increments to inflation in Singapore's F&B manufacturing sector is more than twice of its US or EU counterparts.

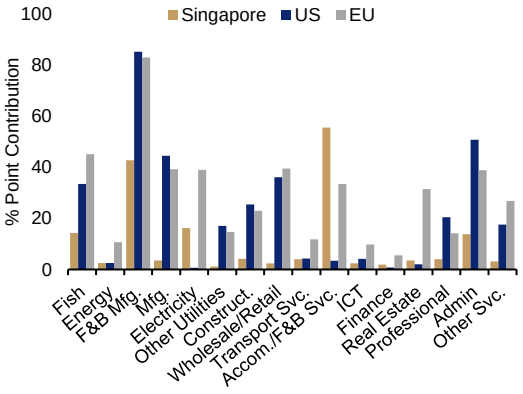
12 On average, energy comprises 5.2% and 3.1% of US and EU intermediate input costs, respectively.

Chart 7 Direct Contribution of Energy to Inflation in Singapore, the US and the EU



Source: OECD and EPG, MAS estimates

Chart 8 Direct Contribution of Agriculture to Inflation in Singapore, the US and the EU



Source: OECD and EPG, MAS estimates

The larger contribution of indirect channels to price inflation in Singapore reflects the economy's greater integration into global value chains. The following subsection examines the indirect effects of energy and agriculture costs on inflation in more detail.

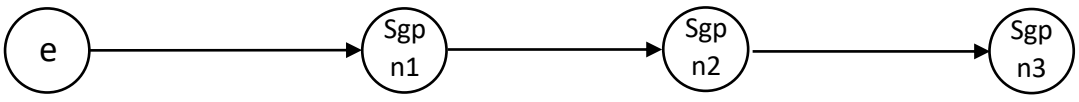
Indirect Effects on Inflation: Domestic versus Foreign Industries

The indirect effects on prices decomposes into three components, reflecting the geography of transaction chains connecting exogenous to endogenous sectors. Specifically, price inflation across sectors in Singapore can be written as:

$$\boldsymbol{IndirInfl}_{sgp} = \boldsymbol{DomesticIndirInfl}_{sgp} + \boldsymbol{ForeignIndirInfl}_{sgp} + \boldsymbol{MixIndirInfl}_{sgp}.$$

The first term on the right-hand side captures price changes arising from energy or agriculture cost shocks affecting Singapore sectors indirectly through I-O linkages between domestic sectors. **Chart 10** illustrates an example of how such 'domestic indirect effects' arise.

Chart 10 Domestic Indirect Transmission Channel

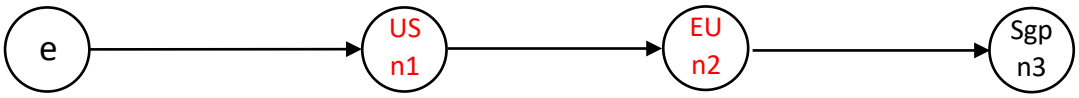


Note: In this diagram, sectors e, n1 and n2 supply inputs to sectors n1, n2 and n3 respectively. Sectors n1, n2 and n3 are located in Singapore.

In this example, energy is an input into Sector n1, which delivers inputs for use by Sector n2. In turn, Sector n3 depends on inputs from Sector n2. Critically, all intermediary sectors are Singapore-based, making the transaction chain between e and n3 an entirely 'domestic' one.

The second term, labelled 'foreign indirect inflation', captures price increases arising from transmission channels involving only foreign sectors as intermediaries. **Chart 11** illustrates such a transmission chain.

Chart 11 Foreign Indirect Transmission Channel

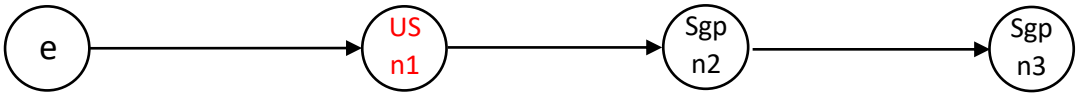


Note: In this diagram, the flow of inputs is identical to the previous chart. But sectors n1 and n2 are located in the US and the EU respectively (as highlighted in red), while n3 is located in Singapore.

Here, sectors n1 and n2 are based in the US and the EU respectively. Because both sectors are foreign to Singapore, the transaction chain linking energy to Sector n3 is entirely foreign.

The final term captures price inflation transmitted through both domestic and foreign sectors as intermediaries **(Chart 12)**. Price changes propagated via such transmission channels are classified as contributing to 'mixed indirect inflation'.

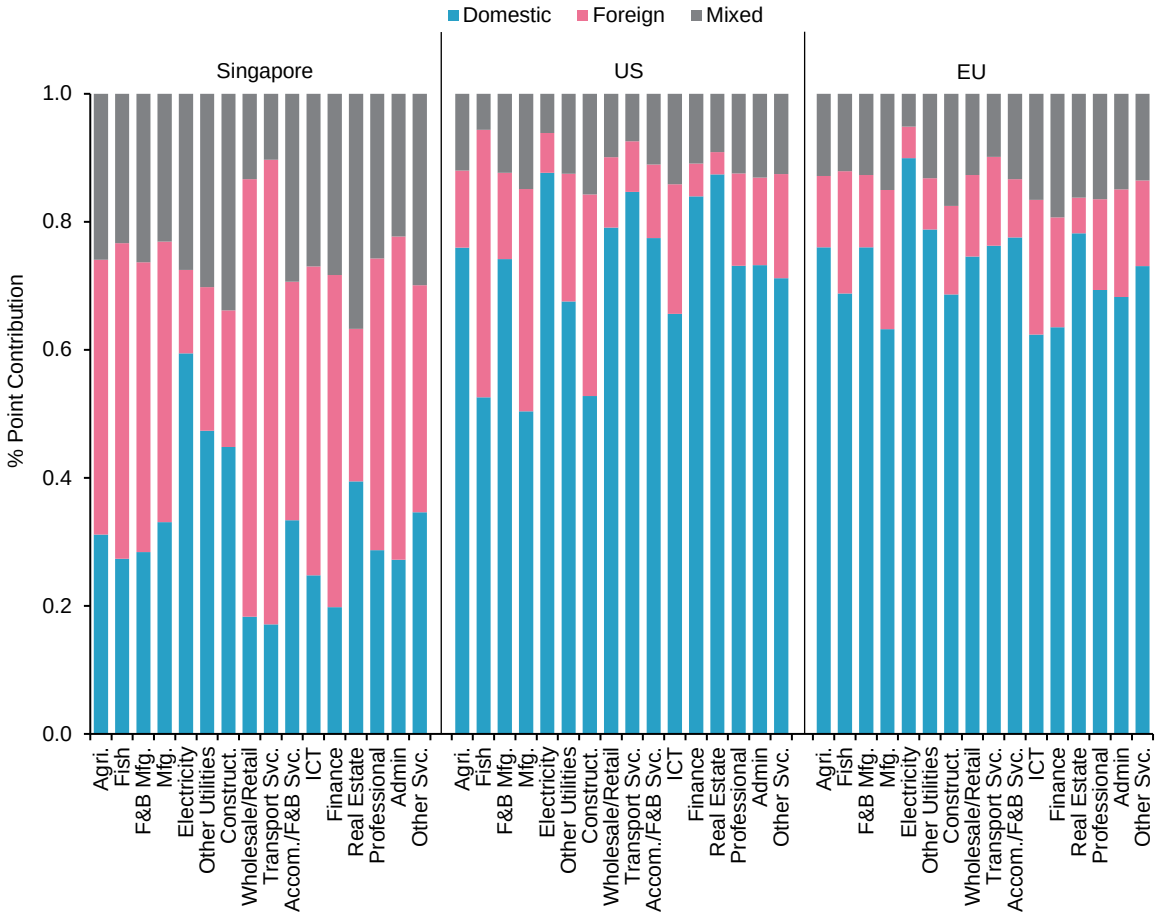
Chart 12 Mixed Indirect Transmission Channel



Note: In this diagram, the flow of inputs is identical to the previous chart. But Sector n1 is located in the US, while sectors n2 and n3 are based in Singapore.

Chart 13 decomposes the indirect effects of energy costs on Singapore prices into the three terms: domestic, foreign and mixed. For comparison, the chart also breaks down indirect inflation into the same components, but for the US and the EU.

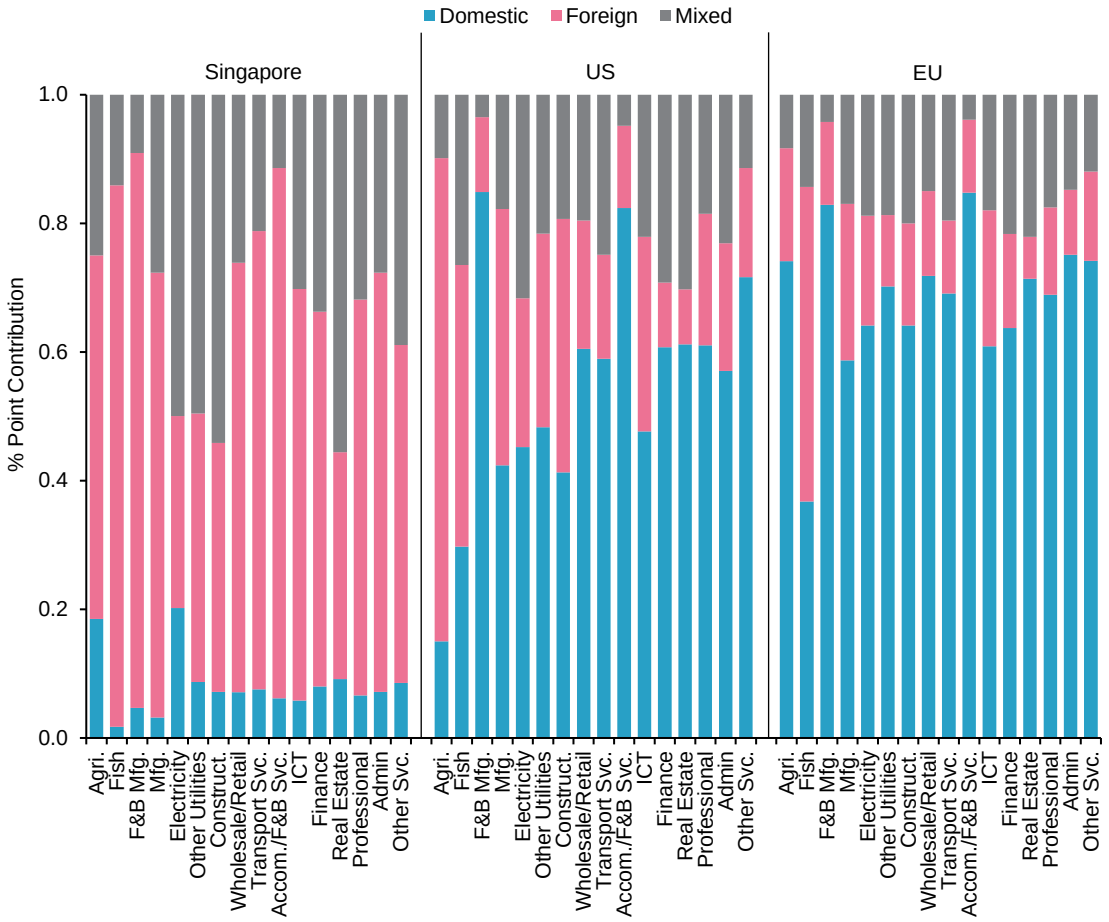
Chart 13 Decomposition of Indirect Effects of Energy on Inflation into Domestic, Foreign and Mixed Transmission Channels



Source: OECD and EPG, MAS estimates

In Singapore, a significant portion of indirect price effects arising from the energy shock is transmitted through foreign and mixed channels (**Chart 13**, LHS, pink and grey bars). The exceptions to this lie in the electricity and utilities sectors, which are highly upstream in the production process. In contrast, indirect effects in the US and the EU occur predominantly through domestic transaction chains delivering energy-derived value to US and European industries (**Chart 13**, RHS, blue bars).

Chart 14 Decomposition of Indirect Effects of Agriculture on Inflation into Domestic, Foreign and Mixed Transmission Channels



Source: OECD and EPG, MAS estimates

Chart 14 performs the same break down of indirect effects on Singapore, US and EU sectors, but only for the agriculture cost shock. As expected, the indirect effect of agriculture prices on inflation in Singapore is transmitted primarily through foreign supply chains. This holds even for food-related sectors (F&B manufacturing and accommodation & food services). In contrast, much of indirect inflation in the US and the EU occur through domestic I-O linkages.

In sum, a significant portion of Singapore's inflation occurs through global value chains propagating energy and agriculture cost shocks to domestic sectors. In contrast, transmission channels for US and EU sectoral inflation mainly reside within America and Europe, respectively.[13]

[13] These differences likely reflect Singapore's openness to international trade. From OECD data, Singapore firms spend approximately twice as much on domestically produced inputs than on imported ones. The ratios for the US and the EU are 15 and 10 respectively.

Consumer Price Inflation

Finally, the overall impact of energy and agriculture costs on Singapore's CPI can also be estimated. This is done by linking sectors in Singapore's economy to their respective components of the CPI basket, and multiplying the sectors' price effects with their linked components' CPI weights before summing. **Table 1** summarises the estimated impact.

Table 1 Singapore Core CPI Inflation (%) due to Costlier Energy and Agriculture

Energy Shock	Agriculture Shock	Combined
2.60	0.56	3.16

Source: OECD, Department of Statistics, International Trade Centre and EPG, MAS estimates

From the table, core CPI rises by 2.6% points and 0.6% point due to the energy and agriculture shocks respectively. Together, both shocks raise core CPI by 3.2% points. This indicates external shocks contributed to over two-thirds of actual y-o-y core CPI inflation of 4.4% in June 2022.

4 Conclusion

In sum, higher energy and agriculture costs appear to explain a significant portion of recent inflationary pressures in Singapore. Much of the price increases is transmitted from global energy and agriculture markets to domestic sectors via intermediary sectors located in other countries. The effects of shocks to energy and agriculture product costs on price inflation vary across sectors and regions.

That supply-side factors explain much of current inflation woes is consistent with other studies on the same topic. In a Federal Reserve study, Shapiro (2022) finds supply-side factors explain half of elevated core US Personal Consumption Expenditure inflation. Likewise, Santacreu and LaBelle (2022) argue that supply chain disruptions affected 2021 US Producer Price Index inflation significantly.

This Special Feature's findings rest on two caveats. First, it is implicitly assumed that inputs across each country's sectors are non-substitutable. In reality, firms often switch to cheaper alternatives in response to higher input costs, after a prolonged period. From this perspective, the results may overestimate the impact of cost shocks to current inflation. Second, the empirical framework underlying the results does not incorporate inflation expectations. Higher inflation expectations arising from the ongoing global oil and food price shocks may lead households and businesses to demand higher wages and prices. From this viewpoint, the analysis underpredicts cost-push inflation.

References

Deloitte Insights (2022), "Sizzling Food Prices are Leading to Global Heartburn", May 31. (URL: https://www2.deloitte.com/xe/en/insights/economy/global-food-prices-inflation.html).

Energy Information Administration (2021a), "Today in Energy: Electricity Power Sector CO2 Emissions Drop as Generation Shifts from Coal to Natural Gas", June 9. (URL: https://www.eia.gov/todayinenergy/detail.php?id=48296).

Energy Information Administration (2021b), "Short-Term Energy Outlook", December 7. (URL: https://www.eia.gov/outlooks/steo/outlook.php#issues2021).

Energy Information Administration (2021c), "Country Level Executive Summary: Russia", December 13. (URL: https://www.eia.gov/todayinenergy/detail.php?id=48296).

Energy Tracker Asia (2022), "Is LNG the Gas of the Future", March 17. (URL: https://energytracker.asia/is-lng-the-fuel-of-the-future/).

Mitsui O.S.K. Lines (2022), "Current Status and Future Prospects of LNG Fuel for Ships", June 7. (URL: https://www.mol-service.com/blog/lng-as-ships-fuel).

Our World in Data (2022), "How Could the War in Ukraine Affect Global Food Supplies", March 24. (URL: https://ourworldindata.org/ukraine-russia-food).

Santacreu, A M, and Labelle, J (2022), "Global Supply Chain Disruptions and Inflation During the Pandemic", *Federal Reserve Bank of St. Louis Review*, Vol. 104(2), pp. 78–91.

Shapiro, A H (2022), "How Much do Supply and Demand Drive Inflation", *Federal Reserve Bank San Francisco Economic Letters*, Vol. 2022-15, pp. 288–314.

The Business Times (2022) "Koufu to Charge Stallholders at Least S$200 More in Monthly fees on Higher Electricity Costs", March 18. (URL: https://www.businesstimes.com.sg/consumer/koufu-to-charge-stallholders-at-least-s200-more-in-monthly-fees-on-higher-electricity-costs).

The National Academy of Sciences (2022), "What You Need to Know About Energy, Our Energy Sources: Natural Gas", August 25. (URL: http://needtoknow.nas.edu/energy/energy-sources/fossil-fuels/natural-gas/).

Valadkhani, A, and Mitchell, W F (2002), "Assessing the Impact of the Change in Petroleum Prices on Inflation in Australia", *Australian Economic Review*, Vol. 35(2), pp. 122–132.