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The Case of Singapore during COVID-19**

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Projecting GDP from Input-Output Linkages: The Case of Singapore during COVID-19*

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Abstract

We demonstrate that projecting GDP growth via input-output linkages is a viable solution in the absence of sufficient time series data. Using Singapore’s COVID-19 experience as a case study, we simulate the changes in sectoral outputs in response to shocks to final demands. Our results show that the travel, hotel, and transport is the hardest hit sector, while the manufacturing sector is less susceptible to the COVID-19 outbreak. Taking into account the sequential re-opening of the economy, we estimate that the cost of the pandemic, due to demand-side factors, is 5.1% of GDP. This projection is consistent with the official estimate reported by the Ministry of Trade and Industry.

1 Introduction

The coronavirus disease 2019 (COVID-19) has caused a prolonged recession globally since the beginning of 2020. As commented by Kristalina Georgieva, the Managing Director of the International Monetary Fund, “one hundred and seventy countries would be smaller in the end of the year.”

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Among different economic sectors, location-dependent services sectors appear to have been hit the hardest. These sectors include airlines, tourist attractions, hotels, restaurants and retail outlets. Some industries are able to work out alternative plans to minimise the losses. For example, restaurants and retail outlets may choose to conduct businesses through online platforms. Other industries, such as airlines and tourist attractions, have no choices but to bear the entire costs of COVID-19. Nevertheless, projecting the impact of COVID-19 remains a challenging task, due to the lack of prior experience and data.

In this technical note, we demonstrate that, in the absence of time series data, GDP growth can be projected from the input-output linkages of an economy. Such a projection builds on the fact that industries are dependent on each other in their production processes. In other words, the output of one economic sector may be used as an input by another. Conversely, changes the demand of final goods in one sector leads to changes in the output of another sector. Such associations between sectors are also known as the input-output linkages.

This technical note aims to assess the economic impact of COVID-19 through the input-output linkages in Singapore. The impacts of COVID-19 are results of both demand and supply side factors. In the case of Singapore, the demand side factors play the more prominent role, as Singapore is a highly open economy. Kuan (2017) studies the impact of changes in final demand on the outputs and value added of the manufacturing and services sectors in Singapore, using the inverse Leontief matrix derived from Singapore's input-output table. For the case of COVID-19, Abeysinghe and Tan (2020) examine the network effect among sectors of Singapore. On the supply side, the "circuit breaker" implemented in April and June has interrupted businesses in the non-essential sectors. Recent studies on the supply-side factors include Baqae and Farhi (2020) and Baqae et al. (2020), among others. These studies rely on detailed assumptions on the preferences of consumers and workers.

This technical note focuses on the impact of demand-side factors. We simulate the outcome of decreased private consumption and services exports using IO Tables. We make assumptions

regarding the economic recession as a result of both the COVID-19 and the “circuit breaker”, as well as sequential re-opening of the economic sectors. Our results show that the cost of the pandemic to the Singapore economy is 5.7% of GDP.

The remainder of this article is organised as follows. Section 2 introduces the methodology for our analysis. Section 3 describes the results. Section 4 concludes.

2 Data and Empirical Methodology

This study examines the effect of decreased final demand on industrial outputs in a Leontief Model. The main data source is the IO tables published by the Department of Statistics Singapore. The IO tables represent the production network in terms of its inter-industry linkages, where a sector’s output is dependent on the inputs flowing from other sectors. Similarly, any given sector’s output also flows into the other sectors as an input for production.

The industries from the IO Table are matched and aggregated according to the consumption trends data, with the following broad industries

- Travel, Hotels, Transport (T)
- Food and Beverages establishments (F)
- Retail (R)
- Other services (S)
- Manufacturing (M)
- All other industries (O)

With the above categories, the input-output table of Singapore is transformed into a 6×6 industry

by industry table. In our model, the total output of our economy can be represented as such.

$$X = \begin{bmatrix} T \\ F \\ R \\ S \\ M \\ O \end{bmatrix} = \begin{bmatrix} a_{tt} & a_{tf} & a_{tr} & a_{ts} & a_{tm} & a_{to} \\ a_{ft} & a_{ff} & a_{fr} & a_{fs} & a_{fm} & a_{fo} \\ a_{rt} & a_{rf} & a_{rr} & a_{rs} & a_{rm} & a_{ro} \\ a_{st} & a_{sf} & a_{sr} & a_{ss} & a_{sm} & a_{so} \\ a_{mt} & a_{mf} & a_{mr} & a_{ms} & a_{mm} & a_{mo} \\ a_{ot} & a_{of} & a_{or} & a_{os} & a_{om} & a_{oo} \end{bmatrix} \begin{bmatrix} T \\ F \\ R \\ S \\ M \\ O \end{bmatrix} + \begin{bmatrix} f_t \\ f_f \\ f_r \\ f_s \\ f_m \\ f_o \end{bmatrix} = AX + F$$

where X is the vector of sectoral output, A is the matrix of intermediate consumption of the various industries and F is the exogenous final demand of the industry in our model. Each element in A represents the input-output relationship between the two sectors. As an example, a_{tf} represents the economic flow from the Transport industry (output) into the Food and Beverages industry (input).

Rearranging the equation yields

$$X = (I - A)^{-1}F \quad (1)$$

where $(I - A)^{-1}$ is the Leontief Inverse Matrix, also known as the Total Requirement Coefficient Matrix. The j^{th} column sum of the Total Requirement Coefficient Matrix represents the output multiplier of industry j . This is the total output that is generated by all industries in the economy resulting from the particular level of industry j 's production to meet the final demand.

The Total Requirement Coefficients Matrix can then be used to derive other useful IO matrices such as the Industrial Output by Final Demand, which will be used in this note. The Industrial Output by Final Demand shows how much each industry produced, both directly and indirectly, to meet the given level of final demand. The tables above are used to estimate the levels of production and inputs required to meet the level of final demand posted during COVID-19.

Finally, a linkage table can also be calculated from the Total Requirement Coefficients Matrix.

There are two types of linkages, forward and backward. Industry j 's forward linkage is supply oriented, and indicates how much other industries are reliant on industry j 's output in the intermediate consumption matrix. The backward linkage is demand oriented, and it indicates how much industry j is reliant on the other industries for inputs. Linkages are normalised to a value of 1, and a value greater than one indicates an above average linkage to the other industries. Similarly, a value lesser than one indicates a below average linkage to the industries. A R^2 value can also be derived for the linkage values. A high R^2 indicates that a shock the industry experiences will affect other industries unevenly, while a low R^2 value indicates changes in the industry affects other industries evenly.

Different scenarios of the impact on final demand due to COVID-19 were simulated. The various scenarios were derived from advanced release of government data, which showed the impact of COVID-19 on private consumption and export during Q1 of 2020.

Our simulations are carried out by introducing shocks to the final demand matrix F in Equation 1. The impact on the output can subsequently be obtained from the matrix X , demonstrating some 'multiplier effects' in the economy resulting from the demand shock. The changes in final demand are obtained from Asia Competitiveness Institute's internal quarterly estimates, which combine data from public and private sectors. The quarterly estimates are then aggregated to obtain the annual-level changes, measured as differences from the steady state of the 2016 economy presented by the 2016 IO Table. As expected, the negative demand shock was highest for the travel, hotels, and transport category. Leveraging on these numbers, we introduce negative shocks to the private consumption and exports categories in the final demand, as summarised in Table 1. We assume two scenarios for the economic recession in which the economic sectors regain their final demands, to about 5%-10% below the original steady state values, in 2020Q3 and 2020Q4 respectively. The latter is labelled as an "extended recession".

Table 1: Estimated Decline in Sectoral Final Demand, 2020Q1

Estimated Decline in Final Demand	
Travel, Hotels, Transport	-37%
Food and Beverages	-10%
Retail	-4%
Other Services	-1%
Manufacturing	0%
All others	0%

3 Results

3.1 Sectoral Impacts of COVID-19

3.1.1 Travel, Hotel and Transport

Analysing the individual transport industries that make up the transport sector, we obtain the input-output flows of the transport sector, depicted as a Sankey diagram in Figure 1. The matrix is represented as a flow from the industries on the left into the industries on the right. The width of the bars are proportionate to the dollar amount of flows between industries.

The impact of COVID-19 on the various transport industries are listed in Table 2.

Examining the linkages of the three transport industry in Table 3, land transport has both linkages value greater than 1, while water and air transport has both linkages value less than 1.

Table 2: Breakdown of Transport Industries Decline

	Recovery in Q3	Extended Recession
Land Transport	-28.4%	-47.5%
Water Transport	-34.5%	-56.9%
Air Transport	-34.1%	-56.3%

Air and water transport both have forward linkages value of <1 , it is not dependent on the intermediate consumption of other industries. Other industries do not purchase from air and water transport during the recession, causing output to fall heavily. The two industries are not protected

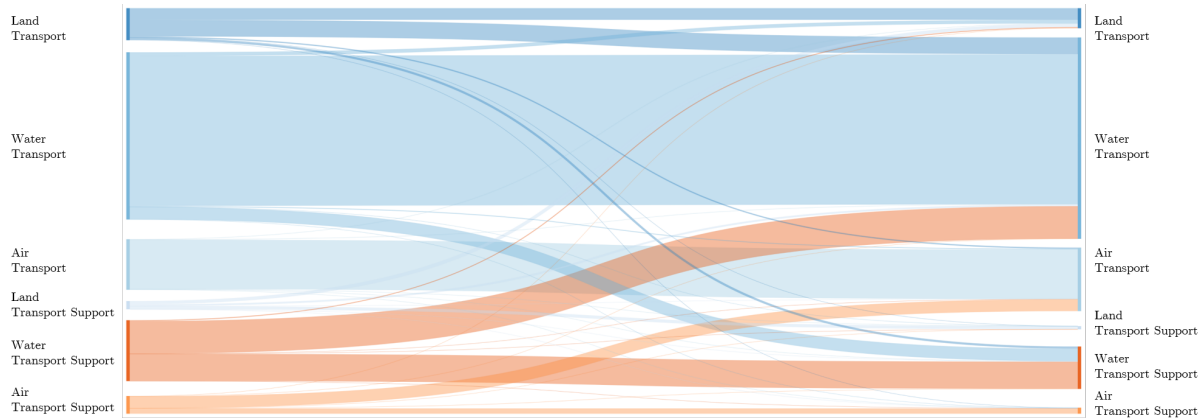


Figure 1: Input-Output Flows of Transport Sector

Table 3: Linkages of Transport Industries

	Forward Linkage	R^2	Backward Linkage	R^2
Land Transport	1.06	2.17	1.03	2.35
Water Transport	0.87	2.89	0.90	2.78
Air Transport	0.91	2.84	0.95	2.71

by the production network.

Instead, it is heavily reliant the external final demand for production. As COVID-19 heavily impacts private consumption & exports particularly heavily, air and water transport will consequently be affected.

Amongst the transport industries, water transport is the most reliant on imports for inputs. It also relies on exports very heavily (70.5% of outputs by water transport are due to the final demand, while 29.5% of outputs are from intermediate consumption of the economy). The heavy reliance on imports & exports of water transport causes it to be the most severely impacted transport sector.

Both water and air transport are very reliant on imports as inputs to production (Table 4). with a large fall in imports, the production water and air transport will be heavily impacted. The linkage values of water transport is lower than the linkage values of air transport. Water transport is more reliant on final demand than the intermediate consumption of the economy. With a heavy decrease in final demand, water transport will drop the most at -56.9%.

Table 4: Largest Source of Input, per \$1,000 of Output

	Land Transport	Water Transport	Air Transport
Manufacturing	45.32	65.65	57.51
Other services	227.50	58.96	72.99
Imports	42.80	607.12	393.70

Land transport, with its high linkage values & R^2 values, (e.g. land logistics to move goods) is an integral part of the economy, and its breakdown might lead to disruptions in their supply chain and other industries' productivity. Land transport has a forward linkage >1 . Although land transport is dependent on other sectors for their purchases downstream, manufacturing and other services, which makes up most of the demand for land transport, are not hard hit by COVID-19. Thus land transport will not be impacted as badly as the other two transport sectors. With a backward linkage value of >1 , land transport is dependent on the production of other industries, specifically \$227.50 from 'other services' for every \$1000 of output. Its decline will be cushioned because the industries land transport depends on, such as manufacturing are still producing normally.

As tour agencies and accommodations are very reliant on private consumption and exports to drive output, the fall in final demand due to COVID-19 will lead to large impacts on these industries.

From the input-output table, travel agencies directly relies on \$ 14.90, \$ 9.40 \$ 62.70 of output from land, water, air transport respectively as inputs to produce \$ 1000. It is especially reliant on air transport. With a decrease in air transport outputs due to COVID-19, the production of travel agencies will be affected by it, even before factoring in the impacts due to decreased final demand.

3.1.2 Food & Beverages Establishments

The Industrial Output by Final Demand of Food & beverages establishments are presented in Figure 2. Private consumption and exports make up 96% of the final demand required of the F&B industry. During COVID-19, when household consumptions and exports fall drastically, the output of F&B will fall by a large extent as well — by about 21% if the economy recovers quickly, to about 42%

in an extended recession.

In terms of intermediate consumption, 28.4% of the output of Food & Beverages' output for intermediate consumption goes to 'Travel Hotel & Transport', while 34.9% goes to 'Other services'. As these two sectors are reliant on 'Food & Beverages' for inputs, a drop in Food & Beverages' output will adversely impact these two sectors more than the other sectors.

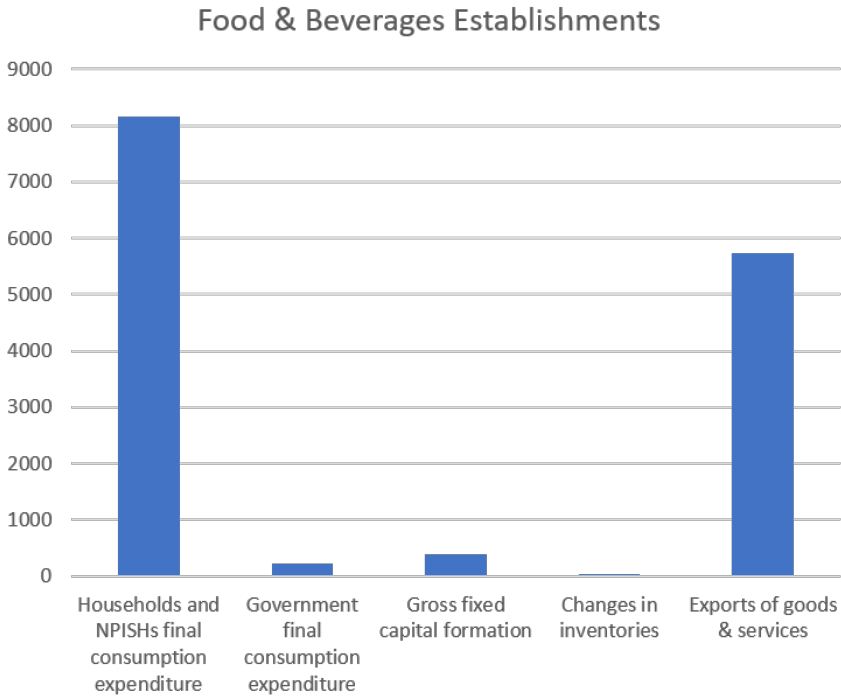


Figure 2: Industrial Output by Final Demand of F&B Establishments

3.1.3 Retail Sector

Table 5: Decline in Retail & Wholesale Trade Industry

	Q3	Q4
Wholesale Trade	-7.75%	-15.9%
Retail Trade	-8.27%	-17.0%
Overall Change	-8%	-16%

Table 6: Linkages of Retail Sector

	Forward Linkage	R^2	Backward Linkage	R^2
Wholesale Trade	0.84	2.47	0.89	2.14
Retail Trade	0.79	2.60	1.08	1.83

The retail sector is made up of two main industries, Wholesale Trade and Retail Trade. Wholesale trade is a relatively independent industry, with both forward and backward linkage <1 . It will be less severely affected by shocks and fluctuations in other industries. Retail trade, however, is dependent on upstream industries' production for supply, with a backward linkage of >1 . Thus, when production of other industries decrease due to the COVID-19 shock, its output will decrease significantly as well, and it is more badly affected than wholesale trade.

However, on the whole, both industries are more dependent on final demand than intermediate consumption of other industries. In addition to the harsh fall in final demand due to COVID-19, the network effect that might dampen the shocks are weaker, leading to a decline in the industry.

3.2 Aggregate Effect on Economy

Utilising ACI's internal estimates, we introduce negative shocks to the private consumption and exports categories in the final demand. The results are summarised in Table 7. As expected, the travel industry is the hardest hit, alongside the food & beverages and retail industries. Manufacturing is the least impacted, at a 1% drop. The overall change in GDP -7.3% for a recession with

recovery in Q3, and a -14.7% decrease for an extended recession. The input-output flows, Industrial Output by Final Demand & linkages should be analysed to achieve a clearer picture of the economy's structure, and the impact COVID-19 will have on it.

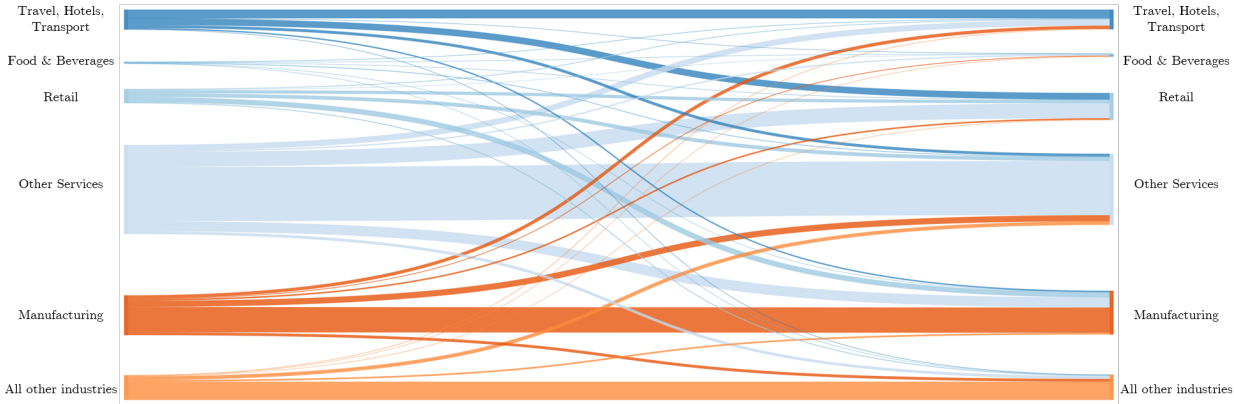


Figure 3: Industrial Input-Output Flows of the Whole Economy

From the 2016 IO Tables data, the input-output flows were obtained and represented in Figure 3. From Figure 3, strong linkages between ‘Retail’, ‘Travel, hotels & transport’ and ‘Food & beverages’, can be observed. Retail also has a strong dependence upon ‘Travel’ and ‘Other services’. A large flow from other services and manufacturing to the various industries can also be observed, demonstrating their importance in the production network.

The Industrial Output by Final Demand of the whole economy was obtained from the Total Requirements Coefficient matrix and represented in Figure 4.

From Figure 4, the ‘Travel, hotel & transport’ and ‘Retail’ industries are highly reliant on the exports for its total outputs at 85%. The Food & Beverages industry is very driven by private consumption at 57% and 39% on exports.

During the COVID-19 situation, because these 2 categories of final demand are the hardest hit, their output will be affected the most (Table 7. Industries that are highly reliant on these two categories of final demand will be heavily impacted due to the reduced private consumption and exports caused by COVID-19.

Looking at the linkages of the various economies, the ‘Travel, hotel, transport’ industries are

Table 7: Spillover effects based on 2016 Input-Output Table

Industry	Original output as percentage of GDP	% change of output percentage	
		Recovery in Q3	Extended recession
Travel, Hotel, Transport	24.7%	-33%	-54%
Food beverages	3.3%	-21%	-42%
Retail	38%	-8%	-16%
Other services	94.6%	-7%	-16%
Manufacturing	65.0%	-1%	-2%
All other industries	20.0%	-2%	-3%
Total Output	245%	-7.3%	-14.7%

Table 8: Linkages

	Forward Linkage	R^2	Backward Linkage	R^2
Travel, Hotel, Transport	0.988	1.855	0.959	1.837
Food and Beverages	0.914	1.695	1.013	1.430
Retail	0.818	2.009	0.923	1.673
Other Services	1.065	1.963	0.941	2.172
Manufacturing	0.914	2.083	0.902	2.020
Others	1.300	1.966	1.262	1.942

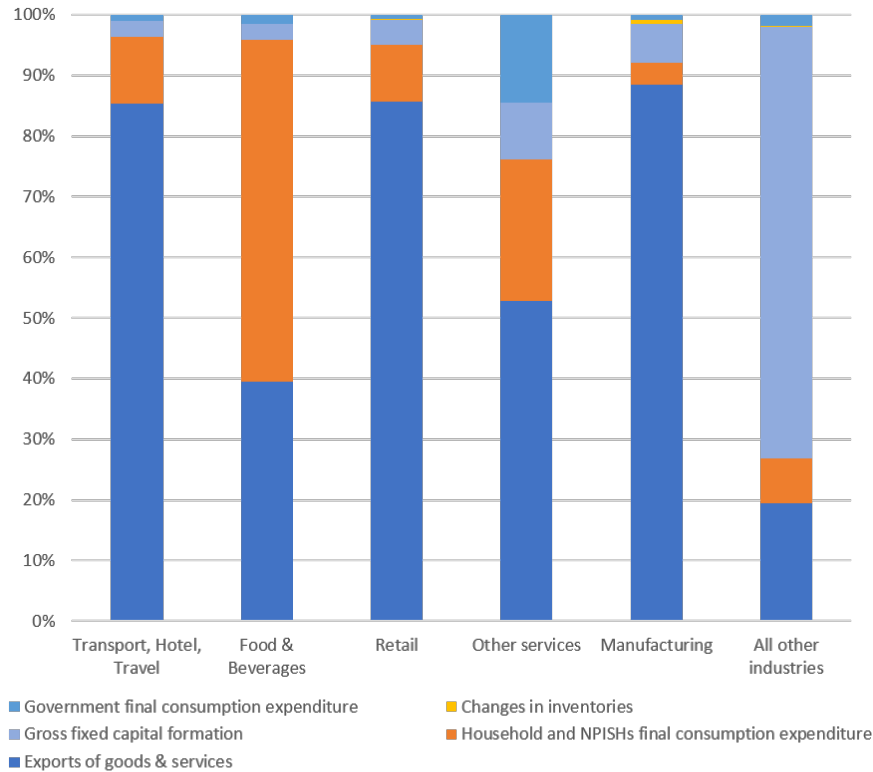


Figure 4: Industrial Output by Final Demand of Whole Economy

generally independent of other industries, with both linkages value <1 . The impact of economic shocks will not affect the rest of the economy too strongly. However, the higher R^2 values imply that the few industries that they are linked to, will be strongly impacted by any fall in demands from said industry, and the fall might in turn have second and third order impacts on the economy.

Retail has a low forward linkage value of 0.818 but high R^2 value of 2.009, the economic shrinkage of retail will unevenly impact the industries that are reliant on it for purchases such as manufacturing and other services, but will not impact travel, hotel & transport downstream.

As Singapore exits the 'circuit breaker' period gradually to minimize economic fallout from COVID-19. This study also simulates a scenario where Food & Beverages establishment re-opens, following the retail trade and other services. The final demand for sectors that re-open gradually

Table 9: Change in Industrial Output following re-opening of economy

	Percentage Change
Travel, Hotel, Transport	-32.5%
Food & Beverages	-13.1%
Retail	-5.1%
Other Services	-3.8%
Manufacturing	-1%
All other industries	-1%
Overall Change	-5.1%

increases in this model, to a conservative estimate of about 45% to 60% of its previous levels. As the travel and transport industry is very uncertain, travel, hotels and transport will be re-opened last, and recovery is uncertain. The results are summarised in Table 9.

Following the re-opening, the overall decrease in GDP is 5.1%. The other sectors perform better compared to a recession through three quarters, showing that a re-opened economy can potentially be resilient and recover from the recession faster.

4 Conclusion

This technical note aims to assess the impact of COVID-19 on the Singapore economy. In order to do so, we derive a version of input-output table with the most susceptible sectors. We calculate the resulting output and GDP from changes to final demand components. Our findings suggest that the cost of the pandemic is between 7.3% to 14.7% of GDP. With sequential re-opening of the sectors after the “circuit breaker” in 2020Q2, the cost of GDP is estimated to be 5.1% of GDP. While our estimate is consistent with the latest one from the Ministry of Trade and Industry, one should bear in mind that this technical note merely aims at demonstrating the possibility of projecting GDP changes from sectoral performance. The scope of data used in this technical note is limited. The supply-side factors are also omitted from the study. Hence, it is imperative that one interprets our

estimation alongside any latest official data.

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