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The Economic Fallout of the COVID-19 Pandemic on Hong Kong: For How Long?

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Abstract

Projections of the global economic impact of the COVID-19 pandemic are increasingly gloomy. While it is yet early days for the exact duration and severity of the impact to be made evident by official data, country-specific studies and early assessments provide useful guidance for policy purposes. In this exercise we use a novel methodology for such an assessment within the framework of structural vector autoregressions and intervention analysis. The exercise combines estimates from pre-crisis data with calibrated estimates for the intervention effect. The methodology can generate direct and indirect impacts on sectoral growth from the intervention variable, COVID-19.

Under the scenario that COVID-19 effect withers away after three quarters a V-shape or U-shape recovery within about nine quarters is likely for all the major sectors of Hong Kong except for ownership of premises sector. It is notable that finance & insurance and ownership of premises which are two of the five largest sectors of the economy can be expected to have a slower U-shape recovery. Furthermore, no sector is spared because of the indirect growth impact. The direct impact is more dominant on accommodation & food services and public administration, social & personal services. Sectoral growth rates indicate a 4.7% contraction of Hong Kong GDP in 2020. In the less likely scenario where the COVID-19 effect lingers on more than one year the country will be dragged to an L-shape continued contraction.

1. Introduction

The COVID-19 pandemic has paralyzed economies globally with economic costs that continue to mount. Projections on global GDP by international agencies uniformly point towards a devastating global economic downturn. The IMF in April 2020 projects a 3% contraction in world GDP for 2020 with advanced economies taking the brunt of the damage with a 6.1% contraction, making it potentially the worst economic downturn since the Great Depression (IMF, 2020). The ADB in May 2020 estimates a 6.4% to 9.7% contraction in world GDP depending on the duration of containment. The contraction for Southeast Asia is projected in the range of 4.6% to 7.2%. Similarly, advanced economies are projected to be the worst hit with contractions in the range of 7.3% to 11% for G3 economies and China in the range of 7.5% to 11.2% (ADB, 2020). The World Bank, in a number of COVID-19 related studies draws attention to the possibility of a massive increase in poverty levels globally (WB, 2020). The International Labour Organization, in a study released on April 7, 2020 projects devastating losses of working hours and employment globally and calls for swift policy actions and open trade regimes (ILO, 2020).

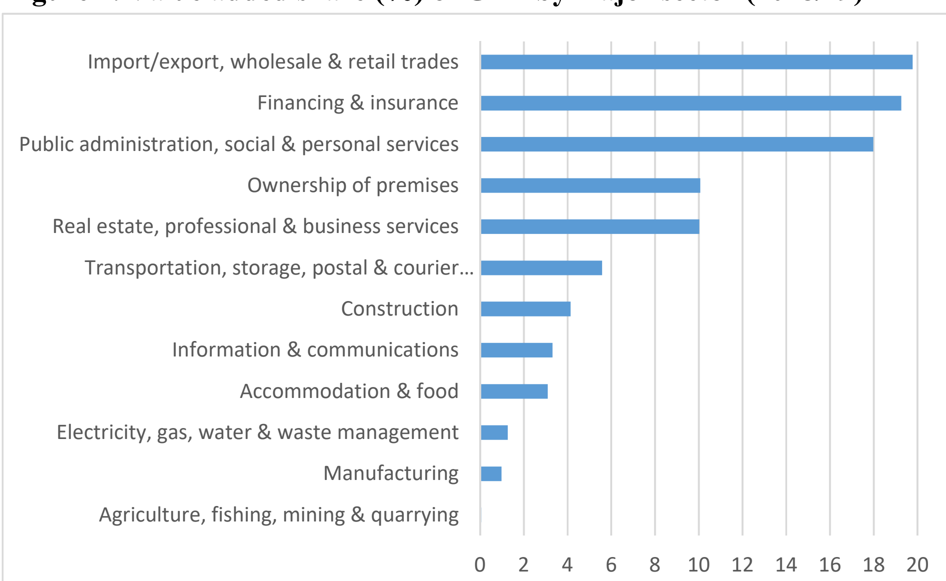
In the context of Hong Kong, official government forecast is a contraction of 4% to 7% (Government of the Hong Kong SAR, 2020a). While a downturn from the COVID-19 pandemic is inevitable, official studies do not yet give indication of the duration and potential sector specific impacts (Government of the Hong Kong SAR, 2020b). The objective of this paper is thus to provide an assessment of the duration of the economic downturn under different scenarios for different sectors of the Hong Kong economy as it was done in an early study focused on Singapore (Abeysinghe and Tan 2020).

2. Methodology

The econometric methodology of the exercise is exactly the same as that of Abeysinghe and Tan (2020). To reduce the hassle to the reader it is copied in Appendix. In essence, the methodology involves intervention analysis cast within a structural vector autoregression (SVAR) framework. The intervention variable is a binary dummy variable to represent the Covid-19 impact over 2020 Q1, Q2, and Q3. The methodology combines estimates from pre-crisis data with calibrated parameter estimates for the intervention variable. The calibration is done by first forecasting value added growth for the first three quarters of 2020 using the full VAR model and assumed future values on the two exogenous variables in the model, export-weighted GDP growth of Hong Kong's trading partners (61 of them including the rest of the world, FORGDP) and the growth rate of visitor arrivals to Hong Kong (VISITOR) and then running separate regressions to estimate the intervention parameters (see Appendix). At the estimation stage, dummy variables were also used to account for data outliers caused by events like the SARS outbreak, the Global Financial Crisis and the various major periods of social unrest including the Occupy Central, Umbrella, Mong Kok and 2019 student protests. Quarterly data over the period 2000-2019 are used in the estimation of the pre-crisis parameter values. One important feature of the methodology is that it can generate not only the direct growth impact of Covid-19, but also indirect effects propagated by other sectors.

GDP by economic activity in Hong Kong comprises 12 sectors plus ‘taxes on products’ and statistical discrepancies. ‘Taxes on products’ is ignored in this study as it is not classified as an economic activity. Figure 1 presents the 12 major sectors of Hong Kong ranked by the sector value added share in GDP. Hong Kong’s manufacturing sector has shrunk to the bottom, just above agriculture, as a result of industrial hollowing out over the years.

Figure 1. Value added share (%) of GDP by major sector (2018/19)



Source: Authors’ calculations based on data from Census and Statistics Department, Hong Kong SAR

3. Results

The basic regression estimates for each sector value-added growth rate are given in Table 1. It is worth highlighting some observations from the table. First, sectoral interdependence is clear from the coefficients of y* (weighted sum of value-added growth of the remaining sectors). The results are not this clear-cut if we used a regression like (7, in Appendix) to estimate interdependence.

Second, Utilities, Construction, and Information and communications sectors have their own dynamics; apart from their own lags, the other variables in the model do not show a statistically significant link with other sectors. Ownership of premises demonstrates a unique case, on top of not having any statistically significant link to other sectors, it does not have any significant link to its own lags. This sector is fundamentally different from other economic sectors as it captures the *assumed* leasing service provided by residential owners to occupants.

Third, as expected, performance of many sectors is strongly linked to FORGDP with the highly globalised sectors of Import/export, wholesale and retail trades, Accommodation and food services and Financing and insurance showing the strongest links.

Fourth, interestingly visitor arrivals correlate with only three of the sectors, Accommodation and food services, Transportation, storage, postal and courier services, Information & communications. The most directly affected sector by the drop in visitor arrivals are Accommodation & food services. Given that the visitor arrivals include labour from Mainland China, the limited significance may suggest that the impact of migrant labour on the Hong Kong economy is limited.

Table 1. Regression estimates for sector value added growth

	Agri	Manuf	Utilities	Cons	W&R sale	Accom & food	Trans	Info-com	Fin & Ins	Real estate	Public services	Own premises
Constant	-0.760	**-1.879**	**2.107**	0.827	**-1.493**	**-3.372**	**-0.946**	**0.616**	-1.068	.237	**0.433**	0.079
y(-1)	-0.174	0.053	**-0.373**	**-0.328**	-0.019	**0.097**	-0.150	**0.196**	0.080	**0.271**	0.116	0.212
y(-2)	0.112	-0.001	-0.087	-0.024	0.042	**0.256**	-0.013	-0.077	-0.051	-0.163	0.089	0.166
y*	-0.197	0.363	0.228	-0.011	**0.387**	**0.776**	**0.547**	0.117	0.339	**0.466**	**0.171**	0.003
y*(-1)	0.071	0.120	0.002	0.022	**0.348**	0.042	**0.375**	0.147	-0.391	-0.168	**-0.098**	-0.006
y*(-2)	**0.452**	**0.383**	-0.216	0.034	0.034	-0.230	0.050	0.269	**0.744**	-0.006	-0.027	0.032
FORGDP	0.237	0.733	0.106	0.006	**2.479**	**1.869**	**0.785**		**1.817**	0.031		0.101
VISITOR	0.009					**0.282**	**0.071**	**0.024**			0.201	0.002
SARS			0.535	0.552	0.973	**-6.983**	**-3.490**	**3.532**	**3.148**			
Occupy Central					**-2.702**							
Umbrella			-0.984									

Note: Highlighted are the estimates that are statistically significant at the standard levels. Empty cells indicate a dropped variable because of a negative estimate. y refers to the growth rate of the relevant sector, y* is the weighted sum of growth rates of other sectors, FORGDP is export-share weighted growth rate of Singapore's trading partners, VISITOR is growth rate of visitor arrivals to Singapore. Sample period 2000Q1-2019Q4.

The main focus of the study is the impulse response analysis or assessing the time profile of the growth effect of the COVID-19 outbreak. For this we consider two scenarios: (i) COVID-19 effect withers away after three quarters, (ii) COVID-19 effect persists longer. The former is what is likely to happen with effective global policy actions including successful management of the Corona spread and the latter is what is likely to happen in the absence of effective policy interventions.

Figure 2 presents the impulse responses (growth effects) pertaining to the first scenario and Table 2 shows the results under the second scenario by letting the COVID-19 effect persists over two years. The base numbers generated are in percent; percentage point responses to a one percentage point growth shock. These base numbers can be multiplied by a suitable number to magnify the effect. Comparing with the forecast numbers we generated from model (10) we find that multiplying the base numbers by 10 provides some indication of the severity of the growth effect (see also point 4 below). Therefore, the results in Table 2 are after multiplying the base numbers by 10. Furthermore, the direct effect shows how a sector is affected directly by the COVID-19 shock and the indirect effect shows how a sector is affected through the other sectors.[1]

Some key findings from the impulse response analysis are the following.

[1] This type of direct and indirect impact is not possible with a single equation regression.

1. Under the scenario where the COVID-19 effect withers away after three quarters, there is likely to be a V-shape or U-shape recovery within one to two years for all the sectors. The most concerning result is that the major sectors of Financing & insurance and Ownership of premises both demonstrate U-shaped recoveries.

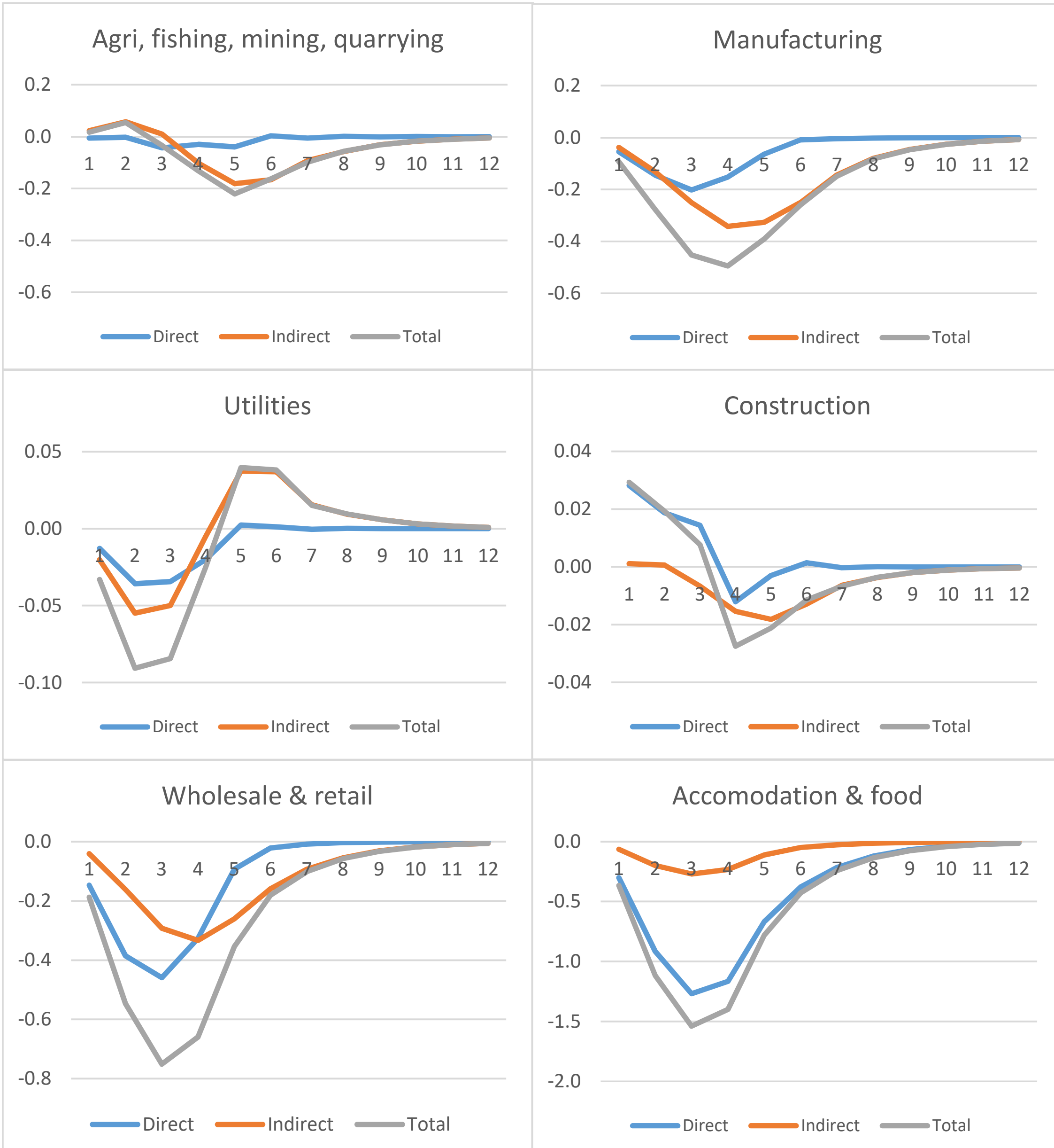
2. The severity of the downturn depends on how Hong Kong's trading partners are going to be affected by the COVID-19 outbreak. COVID-19 involves a double whammy, FORGDP and VISITOR. Although our assumptions on VISITOR are reasonable, how FORGDP is going to behave is a wild guess.

3. For the 5 sectors of Agriculture, fishing, mining and quarrying, Manufacturing, Utilities, Information & communications and Real estate, professional and business services the indirect effect generated by the other sectors is stronger than the direct effect throughout the 12 quarters. For Accommodation & food services and Public administration, social and personal services it is the direct impact of COVID-19 that dominates. Accommodation & food services bears the brunt of the drop in visitor arrivals while Public administration, social and personal services largely require in-person interaction which will see a large persistent drop in demand.

4. Construction, Import/export, wholesale and retail trades, Transportation, storage, postal and courier services, Financing & insurance and Ownership of premises are 5 sectors where the direct impact of COVID-19 dominate in the nearer term of 2 to 3 quarters and in the subsequent periods are largely impacted by indirect impacts. With the exception of Construction, these are all services sectors that are largely business to business.

5. Under the less likely scenario where the COVID-19 effect persists at a constant level then negative growth also persists and settles to constant values. Table 2 shows the impact after one year and two years. These numbers indicate that GDP contraction in 2020 is about 4.7%. In contrast, as a result of the Global Financial Crisis, GDP contracted on an annualized basis by 7.1% in 2009Q1. If the COVID-19 effect persists for another year total GDP contraction by 2021 would be about 5.4%. Such a long persistence is speculative and depends on how unsuccessful the countries are going to be in controlling the COVID-19 spread and on disruptions it creates.

Figure 2. Growth effect if COVID-19 outbreak withers away after three quarters (Baseline impulse responses over 12 quarters)



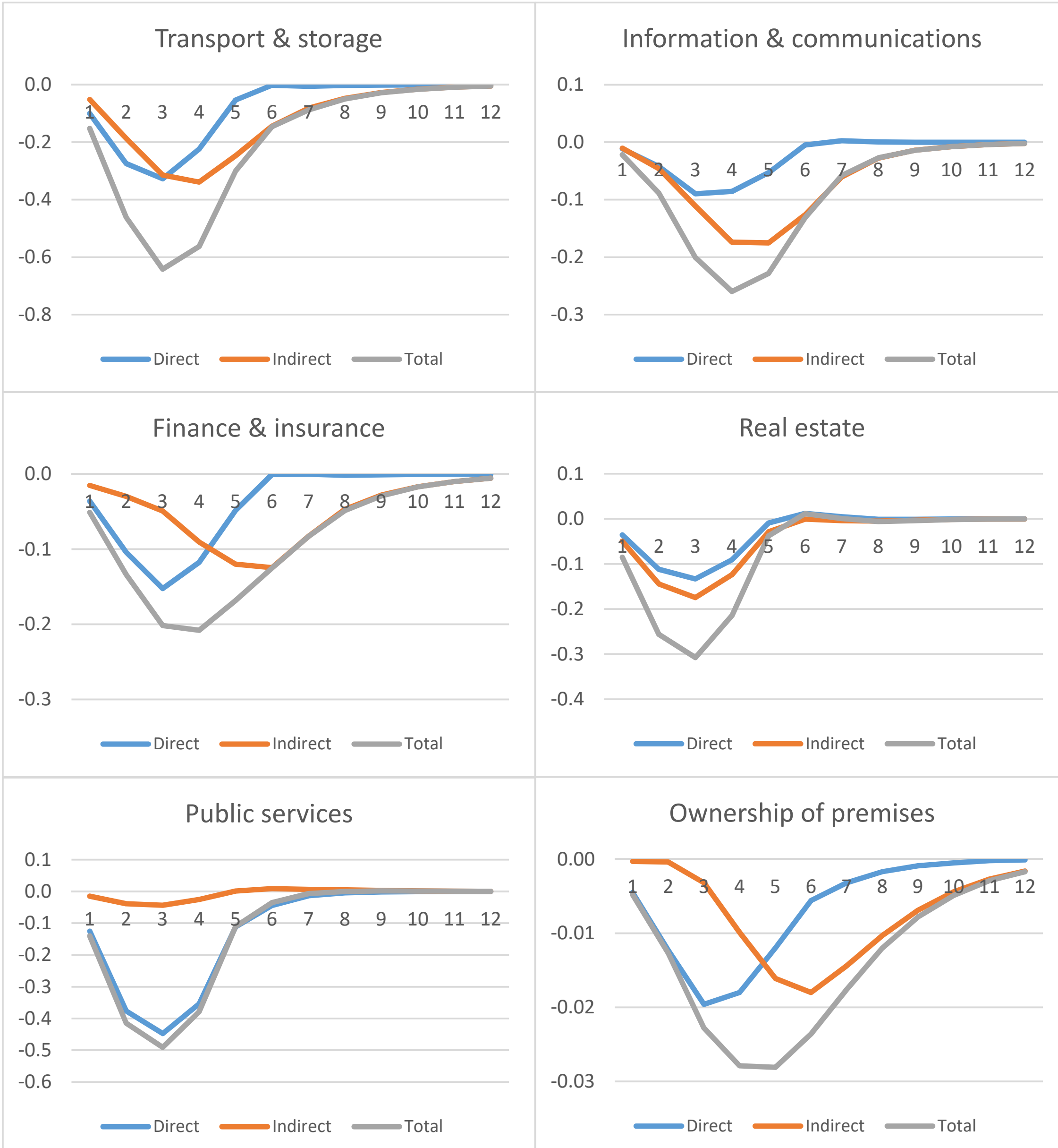

Transport & storage
0.0
-0.2
-0.4
-0.6
-0.8
1 2 3 4 5 6 7 8 9 10 11 12
Direct
Indirect
Total
Information & communications
0.1
0.0
-0.1
-0.2
-0.3
1 2 3 4 5 6 7 8 9 10 11 12
Direct
Indirect
Total
Finance & insurance
0.0
-0.1
-0.2
-0.3
1 2 3 4 5 6 7 8 9 10 11 12
Direct
Indirect
Total
Real estate
0.1
0.0
-0.1
-0.2
-0.3
-0.4
1 2 3 4 5 6 7 8 9 10 11 12
Direct
Indirect
Total
Public services
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
1 2 3 4 5 6 7 8 9 10 11 12
Direct
Indirect
Total
Ownership of premises
0.00
-0.01
-0.02
-0.03
1 2 3 4 5 6 7 8 9 10 11 12
Direct
Indirect
Total

Table 2. Persisitent growth impact of COVID-19 (% change)

	After	Direct	Indirect	Total
Agriculture, fishing, mining and quarrying	One year	-0.361	-0.798	-1.159
	Two years	-0.416	-1.821	-2.237
Manufacturing	One year	-2.071	-3.807	-5.878
	Two years	-2.12	-5.391	-7.511
Utilities	One year	-0.329	-0.254	-0.583
	Two years	-0.333	-0.083	-0.416
Construction	One year	0.161	-0.143	0.018
	Two years	0.158	-0.213	-0.055
Import/export, wholesale and retail trades	One year	-4.733	-3.742	-8.475
	Two years	-4.819	-4.769	-9.588
Accommodation & Food Services	One year	-14.695	-2.974	-17.669
	Two years	-17.054	-3.263	-20.317
Transportation, storage, postal and courier services	One year	-3.24	-3.908	-7.148
	Two years	-3.3	-4.812	-8.112
Information & Communications	One year	-0.972	-1.844	-2.816
	Two years	-0.949	-2.491	-3.44
Finance & Insurance	One year	-1.536	-1.055	-2.591
	Two years	-1.54	-1.967	-3.507
Real estate, professional and business services	One year	-1.264	-1.732	-2.996
	Two years	-1.22	-1.779	-2.999
Public administration, social and personal services	One year	-4.787	-0.398	-5.185
	Two years	-4.925	-0.321	-5.246
Ownership of premises	One year	-0.225	-0.102	-0.327
	Two years	-0.26	-0.268	-0.528

Note: Baseline numbers are multiplied by 10 for a better reflection of the severity of the downturn.

4. Conclusion

The key objective of the exercise is to provide an early assessment of the impact of COVID-19 on different sectors of the Hong Kong economy using a forward-looking methodology presented in Abeysinghe and Tan (2020).

The study is carried out through the application of a novel structural vector autoregression framework together with intervention analysis. Key to the analysis is the impulse response analysis that enables the assessment of the severity and duration of economic downturns under different scenarios. The model can be used for simulations of various scenarios based on different assumptions on the future behavior of the exogenous variables.

As for the results, the presence of U-shaped recovery patterns in the two major sectors of Finance & insurance and Ownership of premises requires special attention. Given that that the U-shaped patterns in both sectors appear to be attributable to the indirect impacts of other sectors in the economy, policy intervention directly targeting these sectors may well have limited application.

At this juncture, it is worthwhile to note several areas of improvement with regards to this study. First, with regards to the methodology as already indicated in Abeysinghe and Tan (2020), the computation of the weight matrix to obtain the weighted sum of growth rates of the remaining sectors of the economy needs further attention. A fixed weight method was used in the study but smoothly changing weights are likely to produce better estimates. Such a weight matrix can be developed from input-output tables that are available at different time points though this may be constrained by data availability. Some experimentation is required to assess the operationaity of this method.

Second, the applicability of Foreign GDP and Visitor Arrivals as the only control variables seem too limited. While they are largely apropriate for the major sectors of the Hong Kong economy and in the wider Singapore economy, it has been observed that these two control variables have no significant impact on the majority of the economic sectors in Hong Kong. Further experimentation with other control variables may improve results but will necessitate the added complication of forecasting additional variables.

Third, the analysis of Hong Kong situation is more complicated than the Singapore case because of mass protests that have been ongoing since 2019. As the current political situtation evolves even with the apparent containment of COVID-19 the potential remains for an extended downturn.

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Appendix

General Methodology

The standard workhorse for this type of setting is the vector autoregression (VAR) framework.[2] As is well known, however, the standard VAR models become unwieldy when the number of variables to be modelled increases. This problem is addressed in various ways in structural VAR models. We adapt the methodology in Abeysinghe (2001), Abeysinghe and Forbes (2005) and Yifan and Abeysinghe (2020). In this section we present the general methodology that can be applied in similar settings. The empirical methodology we adopt is described in the next section.

Let y_{it} be the growth rate (%) of value added (Y_{it}) of sector *i*. We can estimate the following equation for each sector separately using pre-crisis data.

$$y_{it} = \phi_{0i} + \sum_{j=1}^{p} \phi_{ji} y_{it-j} + \sum_{j=0}^{p} \beta_{ji} y^{*}_{it-j} + \lambda' Z_t + \varepsilon_{it} \qquad (1)$$

where $y^{*}_{it} = \sum_{j=1}^{n-1} w_{ijt} y_{jt}$, $j \neq i$ is the weighted sum of the growth rate of the remaining sectors. The weights can be worked out in different ways as discussed in the next section. *Z* are other relevant exogenous (control) variables for the sector. The equation can be estimated by OLS, but there is an endogeneity problem because of contemporaneous y^{*}_{it} on the RHS of (1). This is unlikely to be a serious problem as observed in Abeysinghe and Forbes (2005) where they have tried both OLS and 2SLS.

After estimating all equations using pre-crisis data, each y^{*}_{it} can be opened up with estimated βs and weights. Ignoring *Z* variables and if *n*=3 and *p*=1 equation (1) for sector 1 can be expanded as:

$$y_{1t} = \phi_0 + \phi_{11} y_{1t-1} + \beta_{01}(w_{12t} y_{2t} + w_{13t} y_{3t}) + \beta_{11}(w_{12t-1} y_{2t-1} + w_{13t-1} y_{3t-1}) + \varepsilon_{it} \qquad (2)$$

In matrix notation the three equations can be written (without the constant term) as

[2] McKibbin and Fernando (2020) and Maliszewska, Matto and Mensbrugghe (2020) have used the CGE framework to assess the global growth impact of COVID-19 outbreak.

$$\begin{pmatrix} 1 & -\beta_{01} & -\beta_{01} \\ -\beta_{02} & 1 & -\beta_{02} \\ -\beta_{03} & -\beta_{03} & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & w_{12t} & w_{13t} \\ w_{21t} & 1 & w_{23t} \\ w_{31t} & w_{32t} & 1 \end{pmatrix} \begin{pmatrix} y_{1t} \\ y_{2t} \\ y_{3t} \end{pmatrix} =$$

$$\begin{pmatrix} \phi_{11} & \beta_{11} & \beta_{11} \\ \beta_{12} & \phi_{22} & \beta_{12} \\ \beta_{13} & \beta_{13} & \phi_{33} \end{pmatrix} \cdot \begin{pmatrix} 1 & w_{12t-1} & w_{13t-1} \\ w_{21t-1} & 1 & w_{23t-1} \\ w_{31t-1} & w_{32t-1} & 1 \end{pmatrix} \begin{pmatrix} y_{1t-1} \\ y_{2t-1} \\ y_{3t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{2t} \end{pmatrix} \qquad (3)$$

where the notation "$\cdot$" indicates the Hadamard product giving the element-wise product of two matrices.

We have to combine pre-crisis parameter estimates with calibrated parameter values for the COVID-19 effect. COVID-19 is represented by the intervention dummy variable *X*. The full SVAR model in matrix notation for the *n* sectors can be written as

$$(B_0 \cdot W_t) y_t = \phi_0 + (B_1 \cdot W_{t-1}) y_{t-1} + ... + (B_p \cdot W_{t-p}) y_{t-p} + \Gamma_0 X_t + \Gamma_1 X_{t-1} + ... + \Gamma_p X_{t-p} + \varepsilon_t \qquad (4)$$

Where B are restricted parameter matrices (estimated from pre-crisis data), Γ are diagonal calibrated parameter matrices, and W_t are smoothly changing weights.

Using the lag operator L and by fixing W_t at a desired time point, in shorthand notation $B^w(L) = (B_0 \cdot W) - (B_1 \cdot W)L - ... - (B_p \cdot W)L^p$ and $\Gamma(L) = \Gamma_0 + \Gamma_1 L + ... + \Gamma_p L^p$, (4) can be written as

$$B^w(L) y_t = \phi_0 + \Gamma(L) X_t + \varepsilon_t \qquad (5)$$

or $$y_t = \phi_0^* + B^w(L)^{-1} \Gamma(L) X_t + u_t . \qquad (6)$$

The required impulse responses or growth effects with respect to $X_t = 1$ are given by the matrices $R(L) = B^w(L)^{-1} \Gamma(L)$.

Note that the model parameters are estimated using changing W_t values and as a result the effective parameter matrices $(B \cdot W)$ are changing over time. The impulse responses are computed by fixing W_t at a desired time point. When *X* is a pulse dummy we generate the transitory effects, when it is a step dummy we generate long term effects. The impulse responses cab be generated for up to desired number of quarters and accumulate to assess how the COVID-19 impact is going to last under different scenarios.[3]

Empirical Methodology

As stated in Section 2, there are 12 major sectors in the Hong Kong economy. In addition, FORGDP, VISITOR, and outlier dummies are used in the estimation of pre-crisis parameters.

Step 1

We have to work out the weights in equation (1) and thereby the weight matrix in (4) to account for interdependence among the sectors. One possibility is to use input-output tables from various years. One major practical problem in this regard is the averaging of highly disaggregated input-output coefficients to obtain the above 12 sectors. Ideally the averages must be weighted averages. For example, to obtain the weight for the manufacturing sector, the electronics sub-sector should be assigned a bigger weight than the chemicals sub-sector. In the absence of required data simple averaging is the only option available. This may not be appropriate. For this reason, we adopt a different method to work out the weights directly from sector value-added data.

In the standard VAR framework, all the parameters are estimated from the observations of the n variables in the model. We can adopt a two-step procedure to obtain B and W in (4) separately from these estimates. This method, however, provides a fixed-weight matrix instead of a time-varying one.

For illustration consider sector 1. The basic equation to estimate the weights is of the form:

$$y_{1t} = \phi_0 + \phi_1 y_{1t-1} + \phi_2 y_{1t-2} + \omega_2 y_{2t} + \omega_3 y_{3t} + \ldots + \omega_{10} y_{10t} + \lambda' Z_t + u_t \quad (7)$$

Where Z includes FORGDP, VISITOR and dummy variables to account for data outliers caused by events like SARS and global financial crisis. Some experimentation is needed with these variables in the effort to obtain positive estimates for ω coefficients. If all the ω estimates are positive, then adjust them to sum to unity. But some ω values may turn out to be negative; largely due to the collinearity problem. Since weights cannot be negative, add the largest negative ω in absolute terms to all the ω coefficients and adjust them to sum to unity. This linear transformation does not change the relative position of the coefficients and the

[3] Abeysinghe and Forbes (2005) discuss in detail the advantages of this type of SVAR model compared to the standard VAR framework.

correlation between the original and transformed vectors is one. The adjusted ω's are the weights.[4]

Step 2

After obtaining the weights, work out y_t^* in (1) and re-estimate the equation with two lags:

$$y_{1t} = \phi_0 + \phi_1 y_{1t-1} + \phi_2 y_{1t-2} + \beta_0 y_{1t}^* + \beta_1 y_{1t-1}^* + \beta_2 y_{1t-2}^* + \lambda' Z_t + u_t . \tag{8}$$

Residual autocorrelation tests indicate that two lags are sufficient. After estimating the equations for all the sectors B and W matrices for (4) can be compiled.

Step 3

The most difficult task in the exercise is calibrating the parameter values for the COVID-19 intervention dummy in (4) (Γ matrices). Since we set the lag length to two, we need these estimates to account for the first three quarters of 2020. With these in hand we have to generate forecasts for each sector in order to calibrate the parameter values. Two exogenous variables in the model are FORGDP and VISITOR. If these variables can be projected to the first three quarters of 2020, we can generate the forecasts for the sectors.

Although we can set forecast values for VISITOR with some certainty, generating forecasts of FORGDP is anybody's guess. Visitor data for 2020Q1 are available and shows a 57.4% drop over the previous quarter. For 2020Q2 it is very safe to assume zero visitor arrivals because of travel restrictions. As for the third quarter, even if the travel restrictions are lifted, it is very unlikely that tourism will pick up because of the fear-persistence. Therefore, even for 2020Q3 zero visitor arrivals is assumed.

FORGDP is a key determinant of Hong Kong's economic growth. Given the extreme uncertainties that prevail, it would be best to use a non-informative prior (as in the Bayesian analysis) and set a uniform contraction of FORGDP in every quarter of 2020. Nevertheless, based on the preliminary information we set FORGDP to zero growth in 2020Q1 and -2% for the next two quarters.[5]

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[4] In the Singapore context we tried constrained estimation of (7) with the restrictions $\omega_j \geq 0$ and $\sum \omega_j = 1$. Although there is some correspondence of the estimates under the two methods, constrained estimation tends to produce more zero weights.

[5] These are obviously conservative numbers. We tried a couple of alternative scenarios by setting FORGDP in every quarter of 2020 to -1% and -3%. But these affect the severity of the downturn and not the key findings of the exercise.

These two variables alone are not enough to generate forecast growth rates for the sectors. We also have to account for sectoral interdependence. Using the structure in (4) we can obtain the forecasting model from:

$$(B_0 \cdot W)y_t = \phi_0 + (B_1 \cdot W)y_{t-1} + (B_2 \cdot W)y_{t-2} + \Lambda^* FORGDP + \Delta^* VISITOR_t + \varepsilon_t \tag{9}$$

where Λ^* and Δ^* are diagonal matrices. Pre-multiplying (9) by $(B_0 \cdot W)^{-1}$ the forecasting model has the format:[6]

$$y_t = A_0 + A_1 y_{t-1} + A_2 y_{t-2} + \Lambda FORGDP + \Delta VISITOR_t + u_t \tag{10}$$

After forecasting sectoral growth rates for the first three quarters of 2020 and appending the data set with these values we run a regression for each sector growth rate in the form:

$$y_{1t} = \phi_0 + \phi_1 y_{1t-1} + ... + \phi_2 y_{1t-p} + \gamma_0 X_t + \gamma_1 X_{t-1} + \gamma_2 X_{t-2} + v_t \tag{11}$$

Where $X_t = 1$ for 2020Q1 and zero otherwise. The estimated γ values provide the calibrated parameter estimates for equation (4).

Step 4

After obtaining all the required numbers, use a dedicated software like SAS to generate the impulse responses as described in equation (6).

[6] One may question why not use the model for forecasting directly. It is, however, not that simple because we need additional models to forecast variables like FORGDP and VISITOR.