Corona Squeeze of the Sri Lankan Economy: A Sectoral Outlook

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Abstract

Given the stark choice between saving lives with no certainty vs saving livelihood with some certainty, Sri Lanka, like some other countries, opted for the former and acted early. Would this wreak havoc in the Sri Lankan economy? Using a forward-looking econometric methodology that combines estimates from pre-crisis data with calibrated estimates for the Covid-19 impact, this exercise tries to shed some light on what to expect by fifteen major sectors of the Sri Lankan economy. This is not a forecasting exercise. Instead, the methodology that accounts for sectoral interdependence generates not only the direct growth impact on a sector from the 'Covid-19 sentence', but it also generates the indirect growth impact propagated by other sectors. It is these indirect effects that prolong the downturn in many sectors. One sector cannot recover fully in isolation.

Under the optimistic scenario, if Covid-19 pandemic withers away and normalcy returns before the end of the year, a V-shape or U-shape recovery is likely for all the sectors. Some sectors, however, may take more than two year to fully recover. This is too much of a drag and calls for effective policy interventions to expedite the recovery process. Under the less likely pessimistic scenario where Covid-19 outbreaks linger on, the economy would go into an L-shape drag. The growth numbers by sector indicate that GDP in 2020 alone may contract by about 4.3%. The very objective of these warning lights is not to realize the bad outcome.

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1. Introduction

It was a choice between saving lives vs saving livelihood under enormous uncertainties. Some countries tried to do both initially and failed. Some countries including Sri Lanka opted to save lives first. Many countries including Sri Lanka, for no other choice, were forced to adopt somewhat blindfolded measures to control the spread of the corona virus disease (Covid-19) though at a heavy cost to their economies and the global economy in general. International institutions like the World Bank (2020), International Monetary Fund (2020), and International Labour Organization (2020) have already provided warnings on the economic fallout of the pandemic. Opinion pieces also abound. It suffices to say that the social and economic despair caused by the pandemic at the global scale is likely to be unprecedented.

In the optimistic scenario the pandemic may wither away completely, before the end of the year, like the SARS episode did in 2003. In the pessimistic scenario the pandemic may linger on for a long time with waves of varying amplitudes and duration. The severity and duration of the economic downturn that Sri Lanka has faced will be known much later only when the official statistics are out. Nevertheless, it is worth assessing what to expect. The objective of this exercise is to provide a quantitative assessment of the growth impact on fifteen major sectors of the Sri Lankan economy under these two scenarios. Such prior analyses and early warnings are of immense value to policy makers in steering the economy away from potential danger zones. At the outset it should be emphasized, however, that prior indicators should not be assessed against the actual outcomes because the very objective of early warnings is not to realize the bad outcome.

2. Methodology

This type of analysis requires forward-looking methodologies instead of those that rely only on past data. For the ease of reading, mathematical details of the methodology, developed within the framework of intervention analysis, are given in Appendix. In less-technical terms, the key aspects of the methodology are the following.

1. The econometric model consists of 15 regression equations, one for each sector. The sectors are all interdependent. The intervention variable is the Covid-19 shock, represented by a binary dummy variable.
2. The sectoral growth interdependence among the 15 sectors is estimated from pre-crisis data. The parameter estimates for the intervention variable are calibrated.

3. In addition to the Covid-19 intervention variable, the model uses two other exogenous variables, export-share weighted GDP of Sri Lanka's trading partners (FORGDP, for foreign GDP) and visitor arrivals (VISITOR). These two variables are used in estimating the parameters from pre-crisis data and for obtaining sectoral forecasts for calibrating the intervention parameters.
4. The calibration is done by first forecasting each sector value-added growth for the first three quarters of 2020 and then estimating the parameters of the Covid-19 dummy for 2020 Q1 Q2 and Q3 by running another regression for each sector.
5. After obtaining all the parameter estimates (285 in total), the growth effects of the Covid-19 shock are estimated by deriving what are known as impulse responses. These growth effects indicate what to expect from 2020Q1 onwards over 16 quarters or four years.

3. Data

Quarterly value-added data (at constant prices) over the period 2010Q1-2019Q4 by major sector and sub-sector are provided online in the Department of Census and Statistics website.[1] Figure 1 shows the 15 major sectors ranked by the average GDP share during 2018-19. Manufacturing sector is the largest with a GDP share of 15.6% and information & communications sector is the smallest, with a GDP share of 0.7%. In contrast, manufacturing is the smallest sector in Hong Kong that resulted over the years because of industrial hollowing out. Singapore, however, tries to sustain the prominence of the manufacturing sector.

Information & communications sector in Sri Lanka is relatively very small; this sector in Hong Kong accounts for 3.3% of GDP and in Singapore 4.1%. The utilities sector that includes electricity, gas and water supply and waste management is typically a small sector in terms of value added because these services are essential and not run on a commercial basis. In Sri Lanka, the accommodation and food services sector that includes hotels and restaurants is also small with a GDP share of 1.6% whereas in Hong Kong this sector's contribution to GDP is 3.1% and in Singapore 2.1%. This reflects the smallness of Sri Lanka's tourism sector.

[1] All the data series are seasonally adjusted. Seasonal adjustment had to be done carefully because of some data anomalies.

Figure 1. GDP share (%) of value added of the 15 major sectors during 2018-19

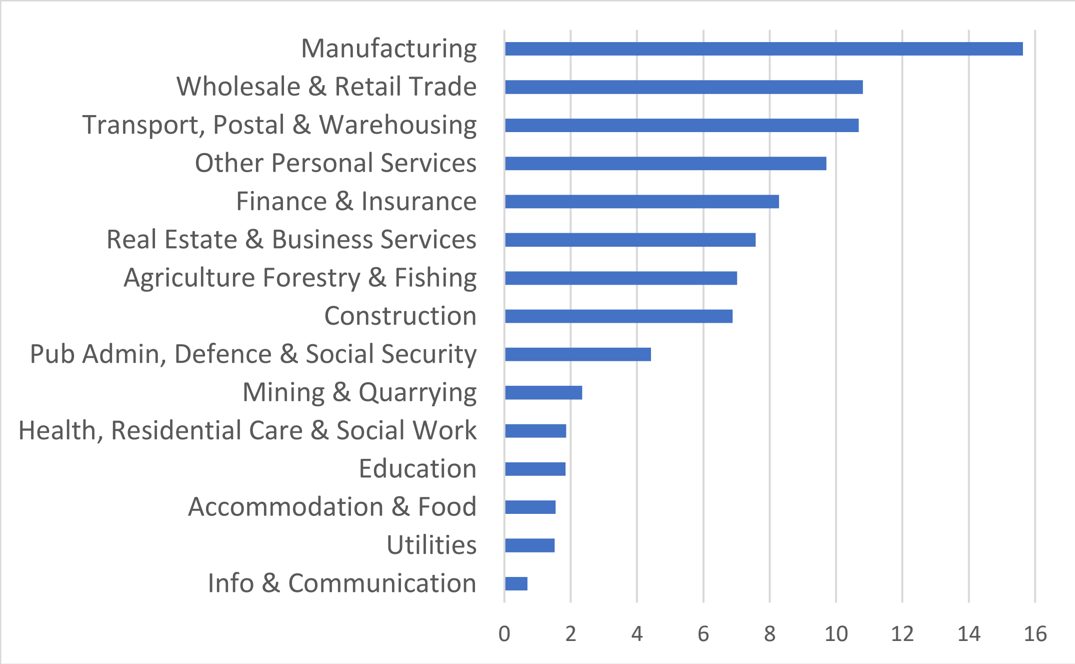
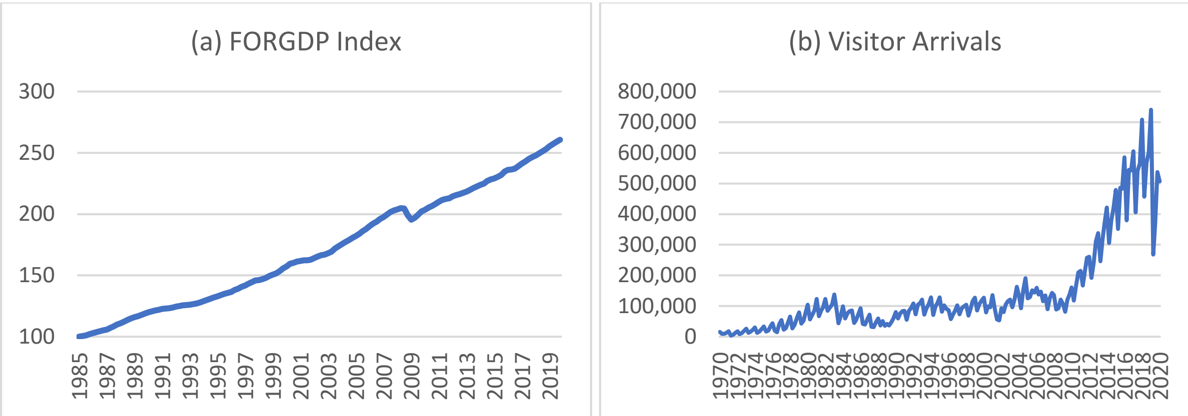


Figure 2 plots the two exogenous variables in the model, (a) FORGDP index and (b) Visitor arrivals. FORGDP is derived from export-share weighted GDP growth rate of Sri Lanka's trading partners (61 economies including the rest of the world). The sharp drop of the variable in 2009 is a result of the Global Financial Crisis.

For the sake of information, quarterly visitor arrivals are plotted since 1970. Visitor arrivals are highly seasonal with peaks occurring in December and January. What is important to notice is that during the LTTE war period (1983-2009) tourism hovered below 200,000 per quarter and picked up noticeably only after the war ended in 2009. The impact of the Easter bombing on April 21, 2019 is also clearly visible in the graph.

We need to forecast these two variables for the first three quarters of 2020 in order to calibrate the Covid-19 related parameters of the model. Although we can set forecast values for VISITOR growth with some certainty, generating forecasts of FORGDP growth is anybody's guess. 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 growth in every quarter of 2020. Nevertheless, based on preliminary information coming from other countries we set FORGDP to -1% growth in Q1. For the next two quarters we set -3% growth. These are obviously too conservative numbers.[2] Visitor data for 2020Q1 are available and shows 18.1% drop over the previous quarter. For 2020 Q2 and Q3 it is safe to assume zero visitor arrivals because of travel restrictions and fear of travel.

Figure 2. (a) GDP of Sri Lanka's trading partners (FORGDP) and (b) Visitor arrivals (Quarterly)



4. Results

4.1 Regression estimates

Regression estimates based on data over 2010Q1-2019Q4 are shown in Table 1. Estimates highlighted in black are statistically significant at the standard levels. The short sample period may be the reason for insignificance of some other estimates. The key observations from the estimates are the following.

1. Most noteworthy are the estimates for y* (weighted sum of growth rates of the sectors excluding the sector in column heading, See Appendix). They are all positive and the sum of the coefficients of y*, y*(-1), y*(-2) is also positive. This indicates that sectoral interdependence is strong and reinforcing. Mining & quarrying and construction show the strongest dependence on other sectors.

[2] Experimenting with other numbers show that the basic conclusions remain unaffected except for inferences on the severity of the downturn.

2. Growth of Sri Lanka's trading partners (FORGDP) is highly conducive to the growth of the manufacturing sector. Although the construction sector coefficient is larger, it is not statistically significant. FORGDP is also important for a number of other sectors.
3. Interestingly growth of visitor arrivals (VISITOR) seems benefit many sectors. Visitor expenditure would have shown a much stronger effect. The sectors that do not pick up any direct effect from visitor arrivals are finance & insurance, public administration, and health. Nevertheless, there is an indirect effect as shown in Figure 3 later. As expected, the sector that is most affected by a drop in visitor arrivals is accommodation & food (hotels and restaurants) followed by transportation, and wholesale & retail trade.
4. Most of the autoregessive coefficients (those of y(-1) and y(-2) are negative. This is because quarterly growth rates tend to fluctuate a lot compared to annual growth rates.

Table 1. Regression estimates for sector value added growth

	Agri	Mining	Manf	Util	Cons	WRtrd	Trans	Accom	Info	FinIns	BizS	Admn	Health	Edu	Other
y(-1)	**-0.38**	**-0.57**	**-0.54**	**-0.43**	**-0.42**	**-0.47**	**-0.32**	0.09	-0.13	-0.19	**-0.24**	0.03	0.13	-0.19	-0.11
y(-2)	0.03	-0.12	**-0.39**	-0.09	-0.26	**-0.31**	-0.14	0.06	-0.03	-0.11	0.09	0.17	0.05	-0.11	0.03
y*	0.67	**2.51**	0.43	**0.53**	**2.76**	0.35	0.15	**1.00**	0.62	**0.43**	**0.64**	**0.36**	0.60	0.27	**0.48**
y*(-1)	-0.23	**1.62**	0.30	-0.03	0.56	0.40	0.00	0.27	0.56	0.33	**0.49**	0.00	-0.60	0.01	0.13
y*(-2)	-0.21	-0.24	-0.08	0.02	1.57	0.36	0.38	0.50	-0.18	0.07	-0.36	0.08	0.23	0.41	0.27
FORGDP	-	0.22	**6.46**	0.79	8.48	1.46	-	2.23	1.35	-	0.30	-	-	-	1.23
VISITOR	0.05	0.07	0.01	0.06	0.14	**0.07**	**0.12**	**0.16**	0.00	-	0.05	-	0.08	-	0.04
Constnt	0.46	-2.12	-3.54	**1.43**	**-4.97**	-0.62	0.66	-3.54	1.55	**2.10**	0.11	-0.02	0.17	0.51	-0.79

Note: Full column headings are in Figure 1. y refers to the growth rate of the relevant sector in the column heading, y(-1) and y(-2) are the lags, y* is the weighted sum of growth rates of other sectors with two lags, FORGDP is export-share weighted growth rate of Sri Lanka's trading partners, VISITOR is growth rate of visitor arrivals to Sri Lanka. Some regressions included outlier dummies. Black highlighted are the estimates that are statistically significant at the standard levels. Empty cells indicate a dropped variable because of a negative estimate. Red numbers relate to FORGDP(-1) and VISITOR(-1). Estimation period 2010Q1-2019Q4.

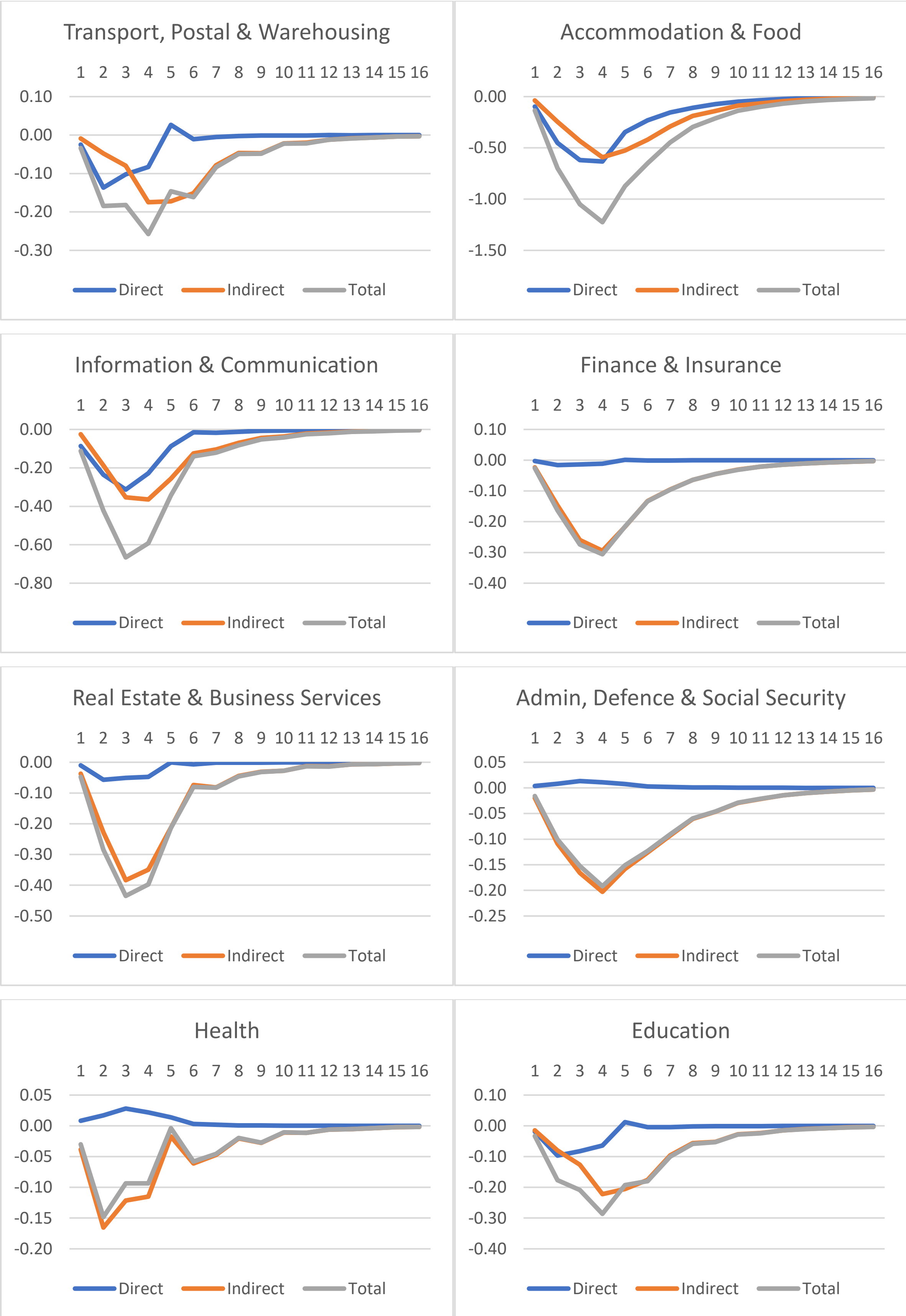
4.2 Covid-19 impact: Impulse response (growth effect) analysis

The key objective of this exercise to assess sectoral growth outlook under the two scenarios mentioned earlier, optimistic and pessimistic. Figure 3 presents the results under the optimistic scenario where we assume that the Covid-19 outbreak withers away by the end of the third quarter of 2020. The baseline numbers in Figure 3 are in percent; percentage point responses to one percentage point growth shock (Covid-19 shock). These numbers can be multiplied by a desired number to magnify the effect. Multiplying by 10 seems to produce numbers that are more in line with the growth forecasts that we generated to calibrate the parameters. These results are presented in Table 2 under the pessimistic scenario where the Covid-19 pandemic lingers on for a long time.

One important advantage of this analysis is that it can generate not only the direct growth impact of Covid-19 on a sector, but also the indirect impact coming through other sectors. In contrast, the numbers in Table 1 pick up only the direct impact. Results in Figure 3 and Table 2 lead to the following observations.

1. Under the optimistic scenario, if normalcy returns by the end of 2020 third quarter, a V-shape or U-shape recovery is likely for all the sectors. However, the duration varies from sector to sector. In the absence of effective policy interventions, full recovery even under the optimistic scenario may take more than two years. This is too much of a drag and calls for effective policy interventions to expedite the recovery process.
2. It is the indirect growth effect that drags many sectors into the prolonged downturn. For example, accommodation & food (hotels and restaurants) sector, as expected, is severely affected directly because of travel restrictions. But the indirect effect from other sectors propel a further drag as time go by. Similar situation seems to occur in manufacturing and transportation & storage sectors as well. Basically, one sector cannot recover fully in isolation.
3. Curiously, the indirect effect seems to be nearly the sole driver of the downturn in finance & insurance, public administration, defence & social security, and health sectors.
4. Numbers in Table 2 are quite suggestive on the growth impact in 2020 (column under 'one year'). A large contraction in the accommodation & food sector is easy to understand. Why the construction sector indicates a large contraction is difficult to explain. In general, construction sectors in many countries are subject their own dynamics and this type of model may not capture such dynamics well. The sectors that are least affected appear to be education, agriculture, forestry & fishing, utilities, and public administration, defence & social security. This is not a surprising result given the essential nature of these sectors.
5. GDP growth for 2020 indicated by the numbers in Table 2 is -4.3%. But this outcome can be changed with effective policy interventions.
6. Under the pessimistic scenario, which is less unlikely, the economy will go into an L-shape drag as shown by the numbers in Table 2 under columns 'two years' and 'four years'.

Figure 3. Optimistic scenario: V-shape or U-shape recovery if COVID-19 outbreak withers away after three quarters (Baseline growth effects (%) over 16 quarters)


Transport, Postal & Warehousing
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
0.10
0.00
-0.10
-0.20
-0.30
Direct Indirect Total
Accommodation & Food
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
0.00
-0.50
-1.00
-1.50
Direct Indirect Total
Information & Communication
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
0.00
-0.20
-0.40
-0.60
-0.80
Direct Indirect Total
Finance & Insurance
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
0.10
0.00
-0.10
-0.20
-0.30
-0.40
Direct Indirect Total
Real Estate & Business Services
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
0.00
-0.10
-0.20
-0.30
-0.40
-0.50
Direct Indirect Total
Admin, Defence & Social Security
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
Direct Indirect Total
Health
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
0.05
0.00
-0.05
-0.10
-0.15
-0.20
Direct Indirect Total
Education
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
0.10
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Direct Indirect Total

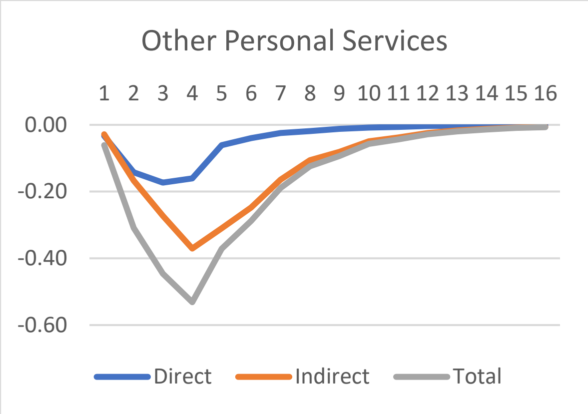

Table 2. Pessimistic Scenario: L-shape growth effect (%) if Covid-19 persists

Sectors ranked on One-Year effect	One Year	Two Years	Four Years
Construction	-16.0	-20.8	-22.2
Accommodation & Food	-13.6	-18.7	-20.1
Mining and Quarrying	-10.6	-13.9	-14.6
Information & communication	-7.0	-8.5	-8.8
Other Personal Services	-5.9	-8.0	-8.7
Real estate & Biz services	-4.4	-5.4	-5.6
Wholesale & Retail Trade	-4.0	-5.1	-5.5
Finance & Insurance	-3.3	-4.4	-4.7
Health, Residential Care & Social Work	-3.2	-4.3	-4.6
Manufacturing	-3.0	-3.7	-3.8
Transport, Postal & Warehousing	-2.9	-3.8	-4.1
Public admin, Defence & Social Security	-2.1	-3.1	-3.4
Agriculture, Forestry & Fishing	-2.0	-1.9	-1.9
Utilities	-1.7	-2.2	-2.3
Education	-1.2	-1.7	-1.9
GDP	**-4.3**	**-5.6**	**-6.0**

Note: Baseline numbers are multiplied by 10 for a better reflection of the severity of the downturn. Growth effect is the sum of both direct and indirects effects.

5. Concluding Remarks

The key findings from the Covid-19 growth impact analysis are summarized above in Section 4.2 and not repeated here. Instead, it is worth drawing attention to a couple other aspects. First, although a V-shape or U-shape recovery is likely for all the sectors, the question is the duration of the downturn. Expediting the recovery process requires policy interventions. Rich countries have already earmarked huge sums of money for stimulating their economies. In the case of

Sri Lanka, already faced with the problem of public debt sustainability, stimulating the economy through fiscal means or otherwise is a question open for discussion.[3]

Second, it is a common belief that the Corona pandemic is going to create major shifts in the global economic structure. The nature of structural shifts is uncertain at this stage. Therefore, such unknown shifts cannot be modelled easily. Nevertheless, the early warning lights through this type of analyses are helpful in designing corrective actions and even structural shifts.

Appendix

A.1. General Methodology

The standard workhorse for this type of setting is the vector autoregression (VAR) framework.[4] 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.

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

where $y^{*}_{it} = \sum_{j=1}^{n-1} w_{ijt} y_{jt}$, $\text{j} \neq i$ 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) and Yifan and Abeysinghe (2020) where they have tried both OLS and 2SLS.

[3] Commenting on this exercise both Harsha Aturupane and Indrajit Coomaraswamy raised this question.

[4] 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.

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

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

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

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

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

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 $B^w(L) = (B_0 \cdot W) - (B_1 \cdot W)L - \ldots - (B_p \cdot W)L^p$ and $\Gamma(L) = \Gamma_0 + \Gamma_1 L + \ldots + \Gamma_p L^p$, (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.[5]

A.2. Empirical Methodology

Apart from value added growth rate (%) of the 15 major sectors two additional variables are used in the model: FORGDP, export-share weighted GDP growth rate of Sri Lanka's trading partners (61 economies including the rest of the world) and VISITOR, growth rate of visitor arrivals to Sri Lanka. In addition, dummy variables to account for data outliers are also considered. Quarterly data that are available online over the period 2010Q1-2019Q4 are used in the estimation of the pre-crisis parameter values.

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. For various practical issues we did not follow this approach. Instead, we 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:

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

where Z includes FORGDP, VISITOR and dummy variables to account for data outliers. Some experimentation is needed with these variables in the effort to obtain positive estimates for ω

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

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

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. 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. Forecast assumptions we made on these two variables are explained in Section 3 and not repeated here.

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:

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

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).

References

Abeysinghe, T. (2001) "Estimation of direct and indirect impact of oil price on growth", *Economics Letters,* 73, 147-153.

Abeysinghe, T. and Forbes K. (2005) "Trade linkages and output-multipliers: A structural VAR approach with a focus on Asia", *Review of International Economics,* 2005, 356-375. (NBER Working Paper W8600, 2001).

International Labor Organization (April 2020), *COVID-19 causes devastating losses in working hours and employment*, (online).

International Monetary Fund (April 2020), *World Economic Outlook,* (online).

Maliszewska M, Matto A and Mensbrugghe D van der (April 2020), "The Potential Impact of COVID-19 on GDP and Trade: A Preliminary Assessment", Discussion Paper, World Bank Group, East Asia and the Pacific Region.

McKibbin, W J and Fernando, R (March 2020), "The Global Macroeconomic Impacts of COVID-19: Seven Scenarios", *CAMA Working Paper No. 19/2020*.

World Bank (April 2020), *Poverty and Distributional Impacts of COVID-19: Potential Channels of Impact and Mitigating Policies,* (online).

Yifan, S. and Abeysinghe, T. (2020) "International transmission mechanism and world business cycles", *Economic Inquiry* (forthcoming).