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# INPUT-OUTPUT ANALYSIS OF COVID-19: METHODOLOGY FOR ASSESSING THE IMPACTS OF LOCKDOWN MEASURES

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**TD Nereus 01-2020**
São Paulo
2020

# Input-Output Analysis of COVID-19: Methodology for Assessing the Impacts of Lockdown Measures[1]

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## 1. Introduction

This technical note describes in details the methodology developed for assessing the daily economic costs of control strategies for mitigating the effects of COVID-19. It is based on the partial hypothetical extraction approach to input-output systems.[2] This methodology is being currently applied to inform regional and national governments in Brazil and Colombia on the potential regional and sectoral economic costs of different strategies of lockdown measures. Simulated scenarios based on different durations and intensities of the control measures are also being used to help designing sectoral and territorial-based policies to ease lockdown against the coronavirus outbreak after reaching a downward trend in the growth rate of new infections.

Preparations to implement and further to roll back the lockdowns include setting up expert committees to examine initial control measures and to define gradual relaxing of social restrictions. Nonetheless, up against enormous uncertainties, combining epidemiological and socioeconomic simulation-based scenarios to examine *ex-ante* potential impacts may be fundamental for informing officials before committing to a strategy.

In what follows, we describe the proposed methodological approach. Average daily economic impacts may be integrated with potential scenarios for the progression of the COVID-19 epidemic based on the impact on the healthcare system.

[1] We thank Carlos Roberto Azzoni, Edson Paulo Domingues and Alexandre Alves Porsse for their participation in the brainstorming session from which some of the ideas contained in this note emerged.

[2] For a complete taxonomy of the extraction method, see Miller, R.E., Lahr, M.L., (2001).

## 2. Methodology

We consider an input-output flow-table for an $n$-sector economy (Figure 1).[3] We separate workers into $q$ different age groups, and identify payments by producers to wage earners to each of those groups.

**Figure 1. Input-Output Flows**

| | | *Processing sectors* 1 | ... | *n* | *Final demand* | | | | *Total output* |
|---|---|---|---|---|---|---|---|---|---|
| *Processing sectors* | 1 | $z_{11}$ | $\cdots$ | $z_{1n}$ | $c_1$ | $i_1$ | $g_1$ | $e_1$ | $x_1$ |
| | ... | $\cdots$ | $\cdots$ | $\cdots$ | $\cdots$ | $\cdots$ | $\cdots$ | $\cdots$ | $\cdots$ |
| | $n$ | $z_{n1}$ | $\cdots$ | $z_{nn}$ | $c_n$ | $i_n$ | $g_n$ | $e_n$ | $x_n$ |
| *Imports* | | $t_1$ | $\cdots$ | $t_n$ | $t_c$ | $t_i$ | $t_g$ | $t_e$ | $t$ |
| *Indirect taxes* | | $m_1$ | $\cdots$ | $m_n$ | $m_c$ | $m_i$ | $m_g$ | $m_e$ | $m$ |
| *Labor payments* | 1 | $l_{11}$ | $\cdots$ | $l_{1n}$ | | | | | $l_1$ |
| | ... | $\cdots$ | $\cdots$ | $\cdots$ | | | | | $\cdots$ |
| | $q$ | $l_{q1}$ | $\cdots$ | $l_{qn}$ | | | | | $l_q$ |
| *Other payments* | | $n_1$ | $\cdots$ | $n_n$ | | | | | $n$ |
| *Outlays* | | $x_1$ | $\cdots$ | $x_n$ | $c$ | $i$ | $g$ | $e$ | |
| *Employment* | 1 | $L_{11}$ | $\cdots$ | $L_{1n}$ | | | | | $L_1$ |
| | ... | $\cdots$ | $\cdots$ | $\cdots$ | | | | | $\cdots$ |
| | $q$ | $L_{q1}$ | $\cdots$ | $L_{qn}$ | | | | | $L_q$ |

$z_{ij}$, with $i, j = 1, \ldots, n$ represents interindustry sales of sector *i* to all sectors *j*

$t_i$ and $m_i$with $i = 1, \ldots, n, c, i, g, e$ represent, respectively, indirect taxes payments, and imports

$l_{ij}$ and $L_{ij}$ with $i = 1, \ldots, q$ and $j = 1, \ldots, n$ represent, respectively, payments by sectors for labor services, and total number of workers

$n_j$, with $j = 1, \ldots, n$ represents payments by sectors for all other value-added items

$c_i$, $i_i$, $g_i$,and $e_i$with $i = 1, \ldots, n$ represent the components of final demand, $f_i$, respectively, household purchases, investment purchases, government purchases, and exports

$x_i$, with $i = 1, \ldots, n$ is the total sectoral output

[3] For presentation purposes, we focus on a national economy model. In the aforementioned applications for Brazil and Colombia, we rely on interregional input-output systems.

We assume that a given lockdown strategy may initially restrict part of the labor force to perform their tasks. In the context of the COVID-19 pandemics, lockdown strategies are usually both age and sector-specific.[4] Thus, we define $q$x$n$ factors, $F_{q,n}$, $0 < F_{q,n} < 1$, defining the share of non-restricted workers in each group in each sector. Therefore, for instance, if you do not want to restrict activities by workers from the health sector, we set the factor to unity; for activities that would face stronger restrictions, such as those in the entertainment sector, we set the factor closer to zero.

We then apply each factor $F_{q,n}$ to its corresponding element in both the employment matrix and the labor payments matrix. In the former case, we are able to define the number of workers facing lockdown; in the latter case, we can calculate the contribution of those workers to total labor income in each sector. Once we know the aggregate income associated with restricted (and non-restricted) workers, we use its share in total labor payments by sector together with the sectorial labor payment coefficients, $\sum_i^q l_{ij}/x_j$. Based on the properties of the Leontief production function, we can then define a new set of sector-specific penalty factors, $F_n$, $0 < F_n < 1$, identifying the share of output in each sector associated with non-restricted workers.

This approach also allows performing different scenarios based on targets for compliance to the measures. Suppose we want to examine a scenario that is both consistent with the set of pre-defined factors, $F_{q,n}$, and a desirable level of compliance, α. We can then find an adjustment factor or weight, ω to be applied across all $F_{q,n}$ so that

$$\omega F_{q,n} => \sum_i^q \sum_j^n L_{ij}^{restricted} / \sum_i^q \sum_j^n L_{ij} = \alpha \qquad (1)$$

Once we have computed the factors, $F_n$, the next step is to use this set of information to partially extract some of the sectorial flows in the input-output table, considering both demand and supply reductions.

Interindustry demand:

[4] In our multiregional modeling framework, control measures can also be region-specific.

$\forall\ z_{ij}, i, j = 1, \dots, n$ we compute a corresponding restricted flow, $\overline{z_{ij}}$, such that

$$\overline{z_{ij}} = \begin{cases} F_i z_{ij}, \text{if } F_i < F_j \\ F_j z_{ij}, \text{if } F_i > F_j \end{cases} \tag{2}$$

Final demand:

In addition to supply-side restrictions, associated with the factor $F_i$, additional demand-side constraints can be added to complete the decision rule.

For each final demand user, a demand-side factor, $F_u$, $u = c, i, g, e$, can be specified. We define each $F_u$ as follows:

$F_c$ is calculated based on changes in foregone earnings by workers affected by the control strategies for mitigating the effects of COVID-19. While informal workers affected by the lockdown face a full loss of income, those in the formal sector may face only a partial loss, according to a parameter $\delta$, $0 < \delta < 1$. We then assume labor income changes are fully translated into household demand changes. Other possible income-related changes, such as government transfers to specific groups of workers as a measure to attenuate the effects of the crisis, would also affect $F_c$ after properly mapped into household purchases.

$F_i$ and $F_g$ are set to unity. The implicit assumption is that investments decisions that are taking place are not affected in the very short-run, while government expenditures are kept unchanged, from the demand perspective, so that we can use government reactions for simulating policy scenarios and providing alternative values for $F_g$.

$F_e$ is set to 0.75, based on the OECD projections for short-term declines in GDP for many major economies. Accordingly, in the median economy, output would decline by 25%.[5]

Thus, considering each component of final demand, $f_{iu}$, we apply the following rule:

[5] https://www.oecd.org/coronavirus/en/

$\forall\, f_{iu}, u = i, g, e$ we compute a corresponding restricted flow, $\overline{f_{\iota u}}$, such that

$$\overline{f_{\iota u}} = \begin{cases} F_i f_{iu}, \text{if } F_i < F_u \\ F_u f_{iu}, \text{if } F_i > F_u \end{cases} \tag{3}$$

In the case of household demand, we apply both the supply and the demand constraints, such that

$\forall\, f_{iu}, u = c$ we compute a corresponding restricted flow, $\overline{f_{\iota u}}$, such that

$$\overline{f_{\iota u}} = F_i F_u f_{iu} \tag{4}$$

Using the information from the original and the diminished sectoral flows, we have now two matrices of interindustry flows, $\mathbf{Z}$ and $\overline{\mathbf{Z}}$, and two vectors of final demand, $\mathbf{f}$ and $\overline{\mathbf{f}}$. For a given vector of sectoral output, $\mathbf{x}$, we can also derive two matrices of technical coefficients, $\mathbf{A}$ and $\overline{\mathbf{A}}$**.**

The extraction method, initially proposed by Dietzenbacher et al. (1993 [6], consists of the hypothetical extraction of a sector in the input-output matrix. The purpose is to quantify how much the total output of an economy with *n* sectors could change (or reduce) if a particular sector were removed from this economy. This technique allows analyzing the importance of a sector in an economic structure given its extraction and consequent reduction in the level of activity in the economy. It should be emphasized that the greater the level of interdependence of such a sector in relation to the others, the greater the impact, in a systemic way.

[6] There are broad aspects that are studied using the extraction method such as regional issues (Perobelli, et al. 2010); emissions (Ali, 2015; Zhang, et all, 2018; Zhao, Y, 2015, Zhao, Y, et all, 2013); sectoral analysis (Song, Y, et all, 2006; Temurshoev, 2010); and energy analysis (Guerra and Sancho, 2010).

We use a variant of the extraction method. Instead of hypothetically extracting completely a particular sector, we extract all sectors partially, according to the information combined in $\bar{\mathbf{Z}}$, and $\bar{\mathbf{f}}$.

In the complete model, with the original sectoral flows, the output of the economy is given by:

$$\mathbf{x} = \left(\mathbf{I} - \mathbf{A}\right)^{-1}\mathbf{f} \tag{5}$$

Using $\bar{\mathbf{A}}$ as the matrix associated with restricted intersectoral trade flows due to the lockdown, and $\bar{\mathbf{f}}$, the lockdown-related final demand, gross output in the economy would be given by:

$$\bar{\mathbf{x}} = \left(\mathbf{I} - \bar{\mathbf{A}}\right)^{-1}\bar{\mathbf{f}} \tag{6}$$

Therefore, after the partial extraction:

$$\mathbf{T} = \mathbf{i}'\mathbf{x} - \mathbf{i}'\bar{\mathbf{x}} \tag{7}$$

where **T** is the aggregate measure of annual loss in the economy – decrease in total output if the output associated with the lockdown measures "disappears". In other words, it is a measure of the relative importance of activities performed by workers affected by the lockdown, or the total linkages with which such activities are associated.

We can translate sectoral gross output outcomes in other variables' outcomes, as usual. We simply pre-multiply the vector of gross output, $\mathbf{x}$ or $\bar{\mathbf{x}}$, by a diagonal matrix, $\hat{\mathbf{v}}$, whose main diagonal contains the variable's coefficients, i.e. the ratios of the variable's values by sector divided the respective sectoral gross output.

Finally, assuming that production is a continuous on weekdays, daily foregone losses can be approached by dividing **T** (or $\hat{\mathbf{v}}\mathbf{T}$), by the number of weekdays in the benchmark year.

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