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A novel approach for measurement and decomposition of the economywide costs of shutting down tourism and related service sectors against COVID-19

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Abstract

The trade-off between desirable public health outcomes and undesirable economic outcomes of anti-pandemic measures forces policy makers everywhere to seek the right combination of measures to balance the public health concerns against employment and income considerations. This article describes a novel input–output approach to assessing economywide costs of shutting down tourism and related sectors to curb the spread of COVID-19. Our framework allows for a decomposition of the total effects of shutdowns into sectoral output losses resulting from (i) suspension of the delivery of inputs to other sectors, (ii) termination of the demand for inputs produced by these sectors, and (iii) the interruption of payments to the owners of factors of production employed in the sectors ordered to shut down. We illustrate the use of this methodological framework to measure and decompose the effects of recent shutdown orders issued in Turkey, a country of major tourism activity.

Keywords

COVID-19, sectoral shutdowns, tourism, supply-driven input–output model, Turkey

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Introduction

Governments all over the world are taking unprecedented measures to prevent deaths and to keep national health systems from getting overwhelmed by the inflow of COVID-19 patients. Most of these measures aim to curb the spread of coronavirus (SARS-CoV-2) by limiting human mobility and contacts among residents within and across communities, cities, or countries.

While non-pharmaceutical measures like quarantines, curfews, lockdowns, shutdowns, and other restrictions of similar nature serve to that purpose, they also restrict (i) consumers' ability and/or willingness to purchase and consume and (ii) producers' ability to produce and sell various commodities and services. The resulting drop in the final demand together with the simultaneous contraction of supply have already created severe economic costs, including huge output and employment losses in various sectors.

In light of the trade-off between desirable public health outcomes and undesirable economic and social outcomes of anti-pandemic measures, the biggest challenge before policy makers everywhere is to pick the right combination of measures to balance the public health concerns against employment and income considerations. While a complete shutdown of all productive activity not essential for human survival may stop the spread of the virus and minimize detrimental health effects, it will lead to massive unemployment and huge income losses, threatening the survival of not only businesses but also people whose livelihood is put at risk. At the other end of the spectrum, avoiding to impose any restrictions on economic activity could minimize immediate output and job losses but will eventually generate disastrous health effects—and second round supply effects. Most governments in the world have so far targeted economic and health outcomes that are strictly between these two extremes. While distance of the measures actually taken to either end of the spectrum varies across countries, almost all governments have taken legally enforceable steps to largely or completely restrict supply-side activity in a number of sectors due to health risks.

Tourism industry itself and the sectors supplying related services rank high among the most affected. The pandemic has indeed dealt a particularly severe blow to domestic and international tourism everywhere. According to the World Tourism Organization (UNWTO, 2021a), the world witnessed an unprecedented 74 percent contraction in international tourism in 2020, as international arrivals dropped from nearly 1.5 billion to 381 million due to shutdowns, lockdowns, and other restrictions on travel, as well as low traveler confidence. Total worldwide loss in tourism receipts in 2020 is estimated to have reached 1.3 trillion US dollars (UNWTO, 2021b), a huge loss that is almost equal to the pre-pandemic GDP of Spain, the 14th largest economy in the world. By the UNWTO (2021b) estimates, the pandemic also put 100 to 120 million direct tourism jobs at risk.

More than a year later, the pandemic keeps people all over the world grounded,[1] thereby continuing to add to the huge losses of tourism and travel industries in 2020. Tourism demand has remained low globally due to both health risks and economic uncertainties which trigger "precautionary saving reactions" from the consumers (Balli et al., 2018). The return to pre-COVID-19 levels in international tourism spending is estimated to take several years, after creating a total loss ranging from three to eight trillion US dollars globally (Binggeli et al., 2020; OECD, 2020a; UNWTO, 2021b), implying a cumulative loss expected to exceed the pre-pandemic GDP of India, the fifth largest economy of the world.

This is not the first time tourism industry experiences a disease-induced crisis, but the current one has been "one of the most damaging" as Assaf and Scuderi (2020) note. In some countries where tourism has a significant share in GDP, the COVID-induced contraction in demand alone had the potential to trigger a recession (Mariolis et al., 2020). OECD (2020b) suggests that domestic tourism is the main chance for driving recovery in its members where it accounts for around 75 percent of the total tourism economy (OECD, 2020c). Barkas et al., (2020) also argue that countries where domestic tourism's share in total tourism income is high are likely to see faster recovery (see also Arbulu et al., 2021). Yet, government-ordered shutdowns in many countries prevent domestic tourism from emerging as an alternative channel for speedy recovery. As a matter of fact, sector businesses in many countries often fail to get a share even from the already reduced demand for travel due to legally enforced shutdowns which, in many countries, have been relaxed at times but only to be reintroduced after a while, as incidence rates go up.

Such shutdowns create severe output and employment losses not only in the sectors directly receiving the shutdown orders but also in sectors that sell/purchase inputs to/from sectors that have been shut down. Further reductions in output and employment experienced by these sectors add to total costs of COVID containment measures. These costs vary across countries depending upon relative shares of the covered sectors in GDP, employment, and foreign exchange receipts, as well as their connectedness to the rest of the economy but are expected to be quite heavy for most countries. Given that mass immunization is not expected to be completed before late 2022 or early 2023 in many developing countries and before 2024 in poorer countries (EIU, 2021), the governments around the world will continue to have to weigh public health benefits of shutdowns against their economic costs in their policy making processes in the years ahead.[2]

In this article, we first propose a novel methodology to measure and decompose the economywide costs of sectoral shutdowns introduced to control the spread of COVID-19 (and other epidemics), in terms of the resulting losses in sectoral outputs and the contraction of GDP by using a supply-driven input–output model inspired by previous work by Sayan and Demir (1998). Our methodology allows for a relatively quick but systematic calculation of potential economic costs of the shutdowns of any number of sectors in any country (or region) for which the (relevant) input–output table is available. Such a systematic method of measuring output (and hence, job) losses to result from sectoral shutdowns is imperative for informed decision making and is much needed by policy makers who are forced to meet the challenge of striking a balance between public health and economic costs of the pandemic.

We then illustrate how the methodological framework we develop could be used to measure and decompose the costs of anti-pandemic measures by considering the case of Turkey, a country where tourism and related services, including airlines and other modes of passenger transportation, dining, sports, and entertainment services sectors were subjected to complete and partial shutdowns at different lengths of time since the beginning of the pandemic.[3] For this purpose, we carry out four simulation experiments by feeding the most recent input–output data into a *supply-side* input–output model of the Turkish economy. The experiment results allow not only for a measurement of the total cost of sectoral shutdowns, but also for a decomposition of total effects. Our findings point to sizable spillover effects and output losses.

The following section presents an overview of the relevant literature. The next section describes the methodological framework, and is followed by a section illustrating the use of the proposed technique based on input–output data for Turkey. The final section concludes the article and discusses possible extensions for research.

Literature review

Consistently with the size of the blow that tourism and related sectors around the world has received from the COVID-19 outbreak, a vast literature studying the pandemic's economic effects on tourism has emerged rapidly. Numerous articles in this literature looked into effects of the disease on tourism ecosystems in individual countries (see, for example, Gil-Alana and Poza, 2020; Jaipuria et al., 2021; Payne et al., 2021), groups of countries (see, for example, Beh and Lin, 2021) or the world as a whole (Skare et al., 2021; Yang et al., 2021), by concentrating on various aspects of the COVID-induced effects.

A number of articles have focused on evaluation of policy responses of governments to the pandemic and their implications for tourism (see Collins-Kreiner and Ram, 2020; Grech et al., 2020 for reviews) including studies on post-COVID stimulus packages provided by governments to help out national tourism industries (Khalid et al., 2021). Particularly relevant to the purposes of the present study are articles on economywide effects of government-issued shutdown orders and similar travel restrictions on tourism and related sectors' activities. Some of the articles address this issue by relying on econometric techniques and without distinguishing any other sectors than tourism itself (see, for example, Yu et al., 2021). These studies do not consider sectoral breakdown of economic activity and ignore (input–output and other) linkages between the tourism ecosystem at large and the rest of the sectors in the economy. They therefore tend to underestimate the economywide damage resulting from the supply restrictions imposed on tourism and related sectors to control spread of the disease.

A notable exception to studies investigating the economywide effects of travel restrictions without overlooking intersectoral linkages is Liu (2020). The author uses multipliers calculated from 2016 input–output tables for Canada and investigates the effects of travel restrictions on the Canadian economy under different scenarios about the length of restrictions and assumed recovery paths. Similarly, Taymaz (2020) used a demand-side input–output model to estimate the economywide effects of shutdowns and supply restrictions imposed by the Turkish government on economic activity in a number of service sectors ranging from "Accommodation and food services" to "Transportation." Like Liu (2020), Taymaz (2020) considered supply restrictions as shocks leading to (forced) contractions in demand. Taymaz (2020), however, estimated sectoral output losses resulting from these restrictions directly from the solution of the demand-side input–output model rather than input–output multipliers. Another notable, input–output model-based article studying the economywide cost of the effects that the pandemic inflicted upon tourism is Mariolis et al. (2020), where the authors feed input–output data for the Greek economy into a multisectoral model allowing for joint production activities and heterogenous labor to estimate multiplier effects of the COVID-19–induced contraction of tourism on gross domestic product (GDP), total employment, and trade balance in Greece. Mariolis et al. (2020) also rely on input–output multipliers.

Finally, Van Heerden and Roos (2021) use a 40-sector Computable General Equilibrium (CGE) model of the South African economy to simulate the effects of industry-level capacity constraints imposed by the lockdown regulations in that country. Their CGE model does not only take into account input–output transactions between sectors but also allows for endogenous adjustment of relative prices. Upon solving the model under their lockdown scenario, Van Heerden and Roos (2021) find, not surprisingly, that the tourism industry will take by far the hardest hit, experiencing an output decline amounting to 21 percent below its baseline (i.e., no lockdown) value.[4]

Besides tourism economics studies, broader economics literature also includes many contributions aiming to trace the effects of shutdowns and similar measures spreading over to the rest of the economy through supply chain linkages and production networks. Barrot et al. (2020) use a standard model of production networks to analyze sectoral effects of the COVID-induced social distancing rules and measures in France. Barthélémy et al. (2020) study the role of global supply chains in spreading the impact of the pandemic by building a model of world production and trade, using the OECD Inter-Country Input–Output (ICIO) database. Navaretti et al. (2020) propose an approach to identify production activities whose total or partial shutdown (and then reopening) would have the greatest impact on the Italian economy in terms of GDP, output, and employment, using input–output tables and network centrality measures in production chains. Similarly, Giammetti et al. (2020) study the impact of COVID-19 lockdown on the Italian value chains by employing complex networks analysis and (demand-side) input–output techniques. Like the present article, Giammetti et al. (2020) aim "to contribute to the strand of this fast-growing literature that studies the output losses generated by governments' restrictions on economic activity."

The present article also links up with the recently emerged literature on the effects of COVID-19 shock on the Turkish economy. This literature has grown very rapidly, but relatively few studies used multisectoral models. Other than the study by Taymaz (2020) described above, contributions that were particularly relevant came from Cakmakli et al. (2020) and Deger (2020). Like Taymaz (2020), Deger (2020) used a demand-driven input–output model of the Turkish economy to investigate spillover effects of COVID-triggered drops in demand for the outputs of selected service sectors as revealed by data on credit card purchases.

Methodology

Overview

Methodologically, our analysis builds upon the innovative approach proposed by Sayan and Demir (1998) to measure interdependence between a group of sectors and the rest of the economy using demand- and supply-driven input–output models. The supply-side version of this methodology is the one that is particularly useful for measuring and decomposing the sectoral and economywide effects of shutdowns that many countries imposed on tourism and related services sectors as part of their fight against the spread of COVID-19.

Our methodology has its roots in the original work of Wassily Leontief and its extension by Ambica Ghosh. Just to remind the reader, Leontief (1936) wrote down fundamental material balance equations of what later became known as the *demand-side* input–output model in matrix notation as follows

$$\dot{A}x + f = \boldsymbol{x} \tag{1}$$

where $\dot{A} = [x_{ij}/x_j]$ is an $n \times n$ matrix of the ratios of input purchases of sector j from each sector i (x_{ij}) to the value of this sector's output (x_j) for $i, j \in \{1, 2,..., n\}$, whereas $\boldsymbol{x}$ and $\boldsymbol{f}$ are respective $n \times 1$ vectors of the values of sectoral outputs and final demands. If x_{ij}/x_j ratios are stable (enough) over time, their values in a given base year (a_{ij}) can be taken as technological parameters characterizing a production function that (linearly) maps intermediate inputs delivered by sector $i \in \{1, 2,..., n\}$ to the sectoral output of sector j. If the matrix in (1) is replaced with $\boldsymbol{A} = [a_{ij}]$ and sectoral final demands are also considered exogenous, (1) becomes a simple (all linear) general equilibrium model of n-simultaneous equations in n-unknowns (i.e., sectoral outputs, x_j). Letting $\mathbf{I}$ represent the $n \times n$ identity matrix, (1) can be solved through

$$\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{f} = \boldsymbol{Lf} \tag{2a}$$

provided that the determinant of $(\boldsymbol{I} - \boldsymbol{A})^{-1}$ or the so-called Leontief inverse, $\boldsymbol{L}$, is different than 0. Since (2a) implies that

$$\Delta\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\Delta\boldsymbol{f} = \boldsymbol{L}\Delta\boldsymbol{f} \tag{2b}$$

one can quantitatively assess the effects on sectoral outputs of changes in $\boldsymbol{f}$ resulting from shocks such as COVID-19 by letting $\Delta\boldsymbol{f}_c \neq 0$ for final demands of affected sectors c (accordingly with the contractionary or expansionary nature of final demand shocks). This is in fact the route recently taken by Deger (2020) and Taymaz (2020) who investigated the output effects of contractions in final demand due to COVID-19.

Two decades after Leontief, Ghosh (1958) suggested a supply-side variant of Leontief's input–output model, which could be solved using the same base year data as the demand-side model above. Ghosh noted that corresponding to (1) on the demand-side was the following identity on the supply-side

$$\boldsymbol{x}' = \boldsymbol{x}'\dot{\boldsymbol{B}} + \boldsymbol{v}' \tag{3}$$

Here $'$ is the transpose operator, $\boldsymbol{v}'$ is the $1 \times n$ vector of exogenously given value-added (payments to primary factors of production) and $\dot{\boldsymbol{B}} = [x_{ij}/x_i]$ is an nxn matrix of the ratios of input purchases of sector j from sector i (x_{ij}) to the value of sector i's output (x_i) for $i, j \in \{1, 2, ..., n\}$. Ghosh (1958) turned this (accounting) identity into an economywide equilibrium model by substituting base year values of the entries in $\dot{\boldsymbol{B}}$, which he treated as technological coefficients, b_{ij}. Given a matrix $\boldsymbol{B} = [b_{ij}]$ and the values of sectoral value-added payments calculated from base year data, the vector that provides a solution to the set of unknown sectoral outputs can be found through

$$\boldsymbol{x}' = \boldsymbol{v}'(\boldsymbol{I} - \boldsymbol{B})^{-1} = \boldsymbol{v}'\boldsymbol{G} \tag{3a}$$

if the determinant of $(\boldsymbol{I} - \boldsymbol{B})^{-1}$, or the so-called Ghosh inverse, $\boldsymbol{G}$, is different from 0. The solution to the supply-side model in (3a) will be the same as the solution (2a) obtained from the demand-side for the base year (Bon and Bing, 1993). Obviously, however, changes in sectoral outputs projected by the demand-side model in response to a change in $\boldsymbol{f}$ would not be the same as changes resulting from the supply-side model in response to a change in $\boldsymbol{v}$. The latter can be found from

$$\Delta\boldsymbol{x}' = \Delta\boldsymbol{v}'(\boldsymbol{I} - \boldsymbol{B})^{-1} = \Delta\boldsymbol{v}'\boldsymbol{G} \tag{3b}$$

Equation (3b) can be used to quantitatively assess the effects on sectoral outputs of sudden exogenous changes in payments to primary factors of production (i.e., in sectoral magnitudes of value-added) in different sectors due to shocks such as coronavirus-triggered shutdowns of businesses in tourism and related sectors by letting the relevant elements of $\Delta\boldsymbol{v}$' corresponding to the affected sectors be different from 0—accordingly with the contractionary or expansionary nature of value-added shocks.

In an input–output model, an exogenously induced change in the output of a particular sector, whether induced by a change in final demand for that product or in the availability of primary factors of production needed to produce it, has two kinds of effects on other sectors in the economy (Miller and Blair, 2009). First, an increase in sector j's output will raise demand (from sector j as a purchaser) for inputs produced by other sectors. Second, a rise in the output of sector j also implies that a higher supply (from sector j as a seller) of product j is available for delivery as inputs to other sectors that use it in their production.

Various multipliers have been defined to assess a sector's capacity to create positive or negative spillover effects on activity levels in other sectors (Miller and Blair, 2009). There is, in fact, a vast branch of input–output and network literatures ranking the sectors in different countries, based on strengths of their so-called backward and forward linkages as measured by different indicators. Knowing which individual sectors have the largest capacity to generate activity in the rest of the economy is obviously important for policy makers due to a significant number of economic and social policy implications. At least as useful to know for policy making purposes is the degree of economic connectedness of a *group* or *cluster* of sectors together. Carter (1965) proposed a methodology allowing for an evaluation of the significance of such a cluster, using the demand-side model. Sayan and Demir (1998) not only extended Carter's demand-side methodology[5] but also proposed a complementary methodology to measure the degree of interdependence between a cluster of sectors, that they called a bloc, with the rest, using the supply-side model as well. The bloc interdependence methodology proposed by Sayan and Demir (1998) is extremely useful to investigate the effects of shutdowns induced by COVID-19 (or other epidemics/pandemics). It allows for not just a quick measurement of the sum total of effects resulting from shutdowns (in tourism and elsewhere) but also for a decomposition of effects as described in the next section.

Bloc interdependence in the IO framework

Sayan and Demir (1998) describe the need for analyzing bloc interdependence by noting that exogenous shocks (such as COVID-19 epidemic) or policy changes (such as shutdowns) often affect or target not just an individual sector but an entire group/cluster or bloc of sectors simultaneously. For such cases, a measure of bloc interdependence *on the supply-side* could be obtained by partitioning the Ghosh inverse, or the $\boldsymbol{G}$ matrix, into submatrices and counterfactually setting the b_{ij} coefficients capturing the linkages among sectors in *different* blocs equal to zero. A comparison of the actual (i.e., observed) values of sectoral outputs to those resulting from the counterfactual assumption of a lack of input–output transactions across different blocs would show the strength of bloc interdependence (Sayan and Demir, 1998). The same approach could be adopted to measure the effects of COVID-induced shutdowns which essentially suspend all productive activity and input–output transactions between a bloc of sectors and the rest.

To facilitate a better understanding of the measurement process, let $\boldsymbol{B} = [b_{ij}]$ be the $n \times n$ matrix of supply-side input–output coefficients as defined before. If k sectors ($k < n$) in the economy are marked to be shut down during the COVID-19 outbreak, these k sectors could be treated as a cluster or a bloc. Then, there will be another bloc made up of the remaining $(n - k)$ sectors. Clustering all n sectors in $\boldsymbol{B}$ into two blocs called S (made up of sectors that are shut down) and O (containing other sectors) allows for a partitioning of $\boldsymbol{B}$ matrix into four submatrices as follows

$$\boldsymbol{B} = \begin{bmatrix} B_{SS}^{kxk} & \vdots & B_{SO}^{kx(n-k)} \\ \cdots\ \cdots\ \cdots & \vdots & \cdots\cdots\cdots\cdots \\ B_{OS}^{(n-k)xk} & \vdots & B_{OO}^{(n-k)x(n-k)} \end{bmatrix} \tag{4a}$$

where B_{SS} and B_{OO} respectively are the $k \times k$ and $(n - k) \times (n - k)$ submatrices containing the supply-side coefficients corresponding to input–output transactions among the sectors *within* each bloc, whereas B_{SO} and B_{OS} are rectangular submatrices showing the supply-side coefficients corresponding to input–output transactions across blocs (i.e., between sectors from different blocs). In other words, $B_{SS} = [{}^{SS}b_{ij}]\ \forall\ i, j \in \{1, 2,..., k\}$ and $B_{OO} = [{}^{OO}b_{ij}]\ \forall\ i, j \in \{k + 1, k + 2,..., n\}$ are diagonal submatrices capturing the within-bloc linkages among sectors marked to be and not to be shut down, respectively. Of the two off-diagonal submatrices, $B_{SO} = [{}^{SO}b_{ij}]\ \forall\ i \in \{1, 2,..., k\}$ and $\forall\ j \in \{k + 1, k + 2,..., n\}$ contains input–output coefficients depicting deliveries of inputs from the sectors within bloc S to the remaining sectors (i.e., those in bloc O), while the elements of $B_{OS} = [{}^{OS}b_{ij}]\ \forall\ i \in \{k + 1, k + 2,..., n\}$ and $\forall\ j \in \{1, 2,..., k\}$ are coefficients representing purchases of inputs by the sectors within bloc S from those in bloc O.

By the same token, $(\boldsymbol{I} - \boldsymbol{B})$ can be written as

$$(\boldsymbol{I}-\boldsymbol{B}) = \left[\begin{array}{ccc} S_{SS}^{kxk} & \vdots & S_{SO}^{kx(n-k)} \\ \cdots\cdots\cdots & \vdots & \cdots\cdots\cdots\cdots \\ S_{OS}^{(n-k)xk} & \vdots & S_{OO}^{(n-k)x(n-k)} \end{array}\right] \tag{4b}$$

where S_{SS}, S_{SO}, S_{OS} and S_{OO} are submatrices obtained by subtracting the elements of corresponding submatrices in (4a) from the matching elements of the nxn identity matrix. Thus, $(\boldsymbol{I}-\boldsymbol{B})$ in (4b) has $(1-b_{ij})$ terms as the diagonal elements of diagonal submatrices S_{SS} and S_{OO}, and $-b_{ij}$'s elsewhere. Given (4b), it can be shown that the Ghosh inverse, **G**, would be equivalent to the following partitioned matrix (Sayan and Demir, 1998)

$$\boldsymbol{G} \equiv (\boldsymbol{I}-\boldsymbol{B})^{-1} = \left[\begin{array}{ccc} \left(S_{SS} - S_{SO}\, S_{OO}^{-1} S_{OS}\right)^{-1} & \vdots & -S_{SS}^{-1} S_{SO} \underline{S} \\ \cdots\cdots\cdots & \vdots & \cdots\cdots\cdots\cdots \\ -\underline{S} S_{OS} S_{SS}^{-1} & \vdots & \underline{S} \end{array}\right]. \tag{4c}$$

where $\underline{S} = (S_{OO} - S_{OS}\, S_{SS}{}^{-1}\, S_{SO})^{-1}$.

Suspension of production activity in certain sectors during a coronavirus-induced shutdown would obviously disrupt intersectoral input–output flows in the economy. A shutdown, in fact, creates two types of effects on these flows. First, the shutdown would interrupt deliveries of inputs from sectors that have been shut down *to* others. Second, sectors covered by the shutdown (bloc S) would no longer need to purchase inputs *from* other sectors (bloc O). Our methodology allows for a calculation of these effects separately.

The first type of effects can be captured first by counterfactually setting all elements of S_{SO} equal to 0.[6] This will yield the following modified version of the Ghosh inverse, $\boldsymbol{G}|_{SO=0}$

$$\boldsymbol{G}|_{SO=0} = \left[\begin{array}{ccc} S_{SS}^{-1} & \vdots & 0 \\ \cdots\cdots\cdots & \vdots & \cdots\cdots\cdots\cdots \\ -S_{OO}^{-1} S_{OS} S_{SS}^{-1} & \vdots & S_{OO}^{-1} \end{array}\right]. \tag{5a.1}$$

Sectoral outputs to be produced after input purchases of S-bloc sectors from O have been suppressed will be given by

$$\boldsymbol{x}'|_{SO=0} = \boldsymbol{v}'\boldsymbol{G}|_{SO=0} \tag{5a.2}$$

This vector of outputs can now be compared to sectoral outputs actually observed in the base year, that is, in the absence of the shutdown. Percentage change in sectoral outputs resulting from this component of the pandemic shock can be computed by dividing each element of the vector of differences $\Delta\boldsymbol{x}'|_{SO=0}$ by the corresponding element of the original (i.e., base year) output vector $\boldsymbol{x}'$. Here

$$\Delta\boldsymbol{x}'|_{SO=0} \equiv (\boldsymbol{x}'|_{SO=0} - \boldsymbol{x}') = \boldsymbol{v}'\boldsymbol{G}|_{SO=0} - \boldsymbol{v}\boldsymbol{G} = \boldsymbol{v}'(\boldsymbol{G}|_{SO=0} - \boldsymbol{G}) \tag{5a.3}$$

The second type of effects results from the termination of deliveries of inputs needed to be purchased by sectors in S from others during the shutdown. This interruption can be simulated by counterfactually muting the channel by which O-bloc sectors supply inputs to the shutdown sections of the economy,[7] such that the modified version of the Ghosh inverse, $\boldsymbol{G}|_{OS=0}$ will be given by

$$\boldsymbol{G}|_{OS=0} = \begin{bmatrix} {S_{SS}}^{-1} & \vdots & -S_{SS}^{-1}S_{SO}\underline{S} \\ \cdots\cdots\cdots & \vdots & \cdots\cdots\cdots\cdots\cdots \\ 0 & \vdots & {S_{OO}}^{-1} \end{bmatrix}. \tag{5b.1}$$

Again, these second type of effects can be found in percentage terms by dividing each element of

$$\boldsymbol{x}'|_{OS=0} - \boldsymbol{x}' \equiv \boldsymbol{v}'\boldsymbol{G}|_{OS=0} - \boldsymbol{v}'\boldsymbol{G} \tag{5b.2}$$

by the respective element of $\boldsymbol{x}'$ as before.

Calculation of total cost of the disruption of input–output flows due to the shutdown requires combining sectoral output losses resulting from the silencing of connections between S and O blocs in both directions. This can be achieved by calculating sectoral outputs from equation (3a) after replacing the **G** matrix in (4c) with the following

$$\boldsymbol{G}|_{OS=0\,\text{and}\,SO=0} = \begin{bmatrix} {S_{SS}}^{-1} & \vdots & 0 \\ \cdots\cdots\cdots & \vdots & \cdots\cdots\cdots\cdots\cdots \\ 0 & \vdots & {S_{OO}}^{-1} \end{bmatrix}. \tag{5c.1}$$

where $\boldsymbol{G}|_{OS=0 \text{ and } SO=0}$ is the Ghosh inverse in (4c) with $\boldsymbol{G}|_{SO=0}$ inserted to replace its upper-left corner and $\boldsymbol{G}|_{OS=0}$ inserted to replace its lower-right corner. Thus, total effects on sectoral outputs coming from the shutdown-order–induced interruption of the deliveries of inputs from (to) the S-bloc to (from) the O-bloc sectors can be obtained in percentage terms from

$$(\boldsymbol{x}'|_{OS=0\,\text{and}\,SO=0} - \boldsymbol{x}')\widehat{\boldsymbol{x}}^{-1} = (\boldsymbol{v}'\boldsymbol{G}|_{OS=0\,\text{and}\,SO=0} - \boldsymbol{v}'\boldsymbol{G})\widehat{\boldsymbol{x}}^{-1} = \boldsymbol{v}'(\boldsymbol{G}|_{OS=0\,\text{and}\,SO=0} - \boldsymbol{G})\widehat{\boldsymbol{x}}^{-1} \tag{5c.2}$$

where $\widehat{\boldsymbol{x}}^{-1} = \begin{bmatrix} 1/x_1 & 0 & \cdots & 0 \\ 0 & 1/x_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & 1/x_n \end{bmatrix}$.

Obviously, costs of shutting down certain sectors to slow down the spread of COVID-19 are not limited to losses resulting from the discontinuation of input–output transactions between shutdown sectors and the others. They also include the drop in the value-added (i.e., the wage receipts and capital earnings going to factors of production employed) in the covered sectors. In other words, a complete shutdown implies that the owners of the primary factors of production employed in the covered sectors will not be compensated for their productive services over the shutdown period.[8] Thus, the first k elements corresponding to the sectors in bloc S in the original (or base year) value-added vector $\boldsymbol{v}' = [v_1, v_2, v_3, \ldots, v_k, v_{k+1}, \ldots, v_n]$ should be replaced with 0's after the shutdown yielding $\boldsymbol{v}_s' = [0, 0, 0, \ldots, 0, v_{k+1}, \ldots, v_n]$ as the post-shutdown value-added vector.

One can now find the effects of the elimination of value-added payments due to the cessation of production in the shutdown sectors upon all sectoral outputs by using equation (3b). Defining the $\Delta\boldsymbol{v}'$ term in equation (3b) as the difference between the post-shutdown value-added vector $\boldsymbol{v}_s'$ and the initial value-added vector $\boldsymbol{v}'$, the resulting difference vector $\Delta\boldsymbol{v}_s'$ will be $\Delta\boldsymbol{v}_s' = \boldsymbol{v}_s' - \boldsymbol{v}' = [-v_1, -v_2, -v_3, \ldots, -v_k, 0, 0, 0, \ldots, 0]$. Substituting this and the original Ghosh inverse in equation (4c) yields

$$\Delta\boldsymbol{x}' = \Delta\boldsymbol{v}_s'\boldsymbol{G} \tag{6}$$

which can be expressed in *percentage* terms by the product $\Delta\boldsymbol{x}'\,\widehat{\boldsymbol{x}}^{-1}$ as before.

Simulation experiments and numerical results

In this section, we illustrate the use of the methodology described above in measuring the costs to the Turkish economy of shutting down different sectors to fight COVID-19. As in many other countries, tourism and related service sectors were on top of the list and included the following (identified by *CPA*, *2008 Codes*): (i) Accommodation and food services (*I*), (ii) travel agency, tour operator, and other reservation and related services (*N79*), (iii) creative arts; entertainment; library, archive, museum, and other cultural services; gambling and betting services (*R90-R92*), (iv) sporting services and amusement and recreation services (*R93*), and (v) Other personal services (*S96*).[9]

To assess the economywide costs of sectoral shutdowns, we use the latest available data on transactions between different sectors (see Appendix for a full list) of the Turkish economy as reported in the 2012 input–output table published by TurkStat. The data for the $1 \times n$ value-added vector $\boldsymbol{v}'$ also come from the original transactions matrix and include payments to labor and capital, as well as imports, for each sector. In 2012, the five sectors listed above together accounted for roughly 4.27 percent of GDP at market prices in 2012.[10]

We run four simulation experiments to observe economywide costs of shutdowns in the relevant sectors and to decompose these costs into output effects resulting from the interruption of these sectors' sales of inputs to and purchases of inputs from other sectors, as well as from the idling of factors of production in the shutdown sectors. The experiments are described below:

1. In the first experiment, we look at economywide losses in sectoral outputs resulting from the disruption of deliveries *from* the shutdown sectors *to* the other sectors that need inputs. Thus, this experiment simulates the scenario where deliveries of inputs to other sectors are discontinued due to the suspension of production in the sectors ordered to shut down. Mathematically speaking, the experiment amounts to comparing $\boldsymbol{x}'|_{SO=0}$—the post-shutdown vector of sectoral outputs found from equation (5a.2) by muting the flows of inputs from all sectors in *S*-bloc to those in *O*-bloc—to $\boldsymbol{x}'$, the vector of initial (pre-pandemic) outputs.
2. In the second experiment, sectoral output losses result from the plummeting to the ground of input purchase orders placed *by* the shutdown sectors. Thus, this experiment focuses on the effects of termination of input shipments *from* other sectors *to* the sectors where production activity is suspended due to the shutdown. The resulting effects from the disturbance of input–output flows through this second channel are captured by calculating sectoral output losses from equation (5b.2).
3. The third experiment combines the first two scenarios to find out the total effects of the shutdown coming from each broken channel of connections between *S* and *O* blocs due to the shutdown. In mathematical terms, this experiment amounts to finding sectoral output losses from equation (5c.2).
4. The final experiment realistically considers sectoral shutdowns as policies that lead not only to a disruption of *all* intermediate input transactions between the sectors that are shut down and the rest of the economy, but also the disruption of payments to labor, capital, and to the rest of the world in the affected sectors. In this experiment, we halt receipts of wages by workers and rents, profits, and interest earnings by the owners of capital installed in the covered sectors, as well as payments to foreign companies that supply imports, as a complete shutdown would require. In mathematical terms, this experiment is equivalent to finding $\Delta\boldsymbol{x}'$ from equation (6).

Numerical results we obtained using the 2012 input–output transactions table for the Turkish economy are presented in Tables 1 and 2.

Table 1. Decomposition of sectoral output effects of the shutdown by experiments: *S*-bloc sectors (%).

Sectoral CPA Code	Activity descriptions of sectors shut down	Share in Gross output/Factor income	Deviations of sectoral outputs from actual base year values under			
			Exp. 1	*Exp. 2*	*Exp. 3*	*Exp. 4*
I	Accommodation and food services	2.54/3.09	−0.28	−46.86	−46.98	−53.29
N79	Travel agency, tour operator and other reservation services, and related services	0.55/0.40	−0.58	−47.69	−47.97	−52.61
R90-92	Creative arts; entertainment; library, archive, museum, and other cultural services; gambling and betting services	0.41/0. 69	−0.34	−21.44	−21.51	−78.74
R93	Sporting services and Amusement and recreation services	0.26/0.27	−0.43	−53.29	−53.52	−46.94
S96	Other personal services	0.37/0.39	−0.46	−55.92	−56.18	−44.32
Percentage share of the bloc in total gross output/factor income (column sum)		4.13/4.84	—	—	—	—

Table 2. Decomposition of the effects of shutdown on sectoral outputs by experiments: Mean percentage errors (MPEs) for sector groups in *O*-bloc (%).

Sectoral CPA Code	Activity descriptions of sectors	Share in Gross output/Factor income	Deviations of sectoral outputs from actual base year values under			
			Exp. 1	*Exp. 2*	*Exp. 3*	*Exp. 4*
A01-A03 and B	Primary goods (agriculture, forestry, fisheries, mining, and quarrying)	8.96/9.63	−0.280	−0.133	−0.281	−0.147
C10-C33 and F	Manufacturing, and construction	44.84/26.33	−0.473	−0.221	−0.475	−0.252
D35 and E36-E39	Utilities and related products, sewerage and waste disposal	5.02/2.79	−0.275	−0.128	−0.275	−0.147
G45-G47	Wholesale and retail trade	8.51/12.55	−1.342	−0.638	−1.361	−0.706
H49-H53	Transportation and support services for transportation, postal and courier services	7.84/9.34	−1.016	−0.479	−1.033	−0.539
J58-J63	Publishing services, broadcasting, telecom and computer support services	2.10/3.00	−2.395	−0.964	−2.510	−1.436
K64-K66 and L68 B	Financial services, insurance and related services, legal and managerial services, Real estate services	7.41/13.41	−1.001	−0.464	−1.014	−0.538
M69-M75 and S95	Technical and scientific services	2.40/3.47	−1.746	−0.819	−1.798	−0.930
*N*77-N78, *N*80-N82, O84 P85, Q86, Q87-Q88, S94, and T	Other services	8.76/14.59	−1.473	−0.697	−1.506	−0.778
MPEs for all sectors with output share **<** share in factor receipts[a]			−1.070	−0.505	−1.087	−0.567
MPEs for all sectors with output share **>** share in factor receipts[b]			−0.885	−0.388	−0.914	−0.498
	Total economywide *loss* in gross outputs (%)		0.628	2.173	2.501	4.748

[a] Primary goods (second row), wholesale and retail trade (fifth row), and all other services (Rows 6–10).

[b] Manufacturing and construction (third row) and utilities and related services (fourth row).

Combined share of the five sectors that were instructed to terminate productive activity as part of the fight against COVID-19 together exceeded four percent of the total value of the gross outputs of all sectors and reached 4.84 percent of total payments to factors of production in the base year (GDP at factor cost). Simulation results reported in the table decompose the effects of this termination of productive activity on the shutdown sectors themselves. For three of these sectors (I, N79, and R90-R92), the effect causing the largest contraction in sectoral outputs is coming from discontinuation of factor payments, as simulated under Experiment 4 (53.29, 52.61, and 78.74 percent, respectively). For the remaining two (R93 and S96), it arises from the interruption of two-way transactions in inputs, as simulated under Experiment 3. For all five sectors, by far the smallest effects on sectoral outputs are inflicted by their post-shutdown failure to deliver inputs needed by other sectors (Experiment 1). This is in line with expectations, since tourism and related sectors that were shut down typically serve to final demand rather than intermediate input demand by companies in other sectors.

Table 2 and Figures 1 and 2 show decomposition of the effects that the shutdown inflicts upon the other sectors under each experiment scenario. The numbers reported in the last two rows of the table are mean percentage errors (MPEs) calculated for groups of sectors using the deviations of individual sectors' gross outputs from actual base year values under each experiment. Perhaps, the most striking result is the relatively larger size of output effects on service sectors in all four experiments, as compared to sectors producing primary and manufactured goods, as well as utilities and construction. To be more precise, sectors whose shares in total factor incomes exceed their shares in total gross output (by the numbers in the third column of Table 2) get affected visibly more than sectors whose shares in total factor incomes are lower than their respective shares in total gross output. Most service sectors fall into the first category while almost all manufacturing sectors and construction etc. fall into the latter category. Given that many of the service sectors in the first group have also experienced significant contractions in demand in the aftermath of COVID-19 outbreak, it would be appropriate to view the pandemic as a shock primarily hitting service sectors whether they have received the shutdown orders or not.

The last row in Table 2 indicates that *total cost* of shutting down the five sectors due to the pandemic may reach 7.249 percent of total gross output when we consider the output losses resulting from disruption of two-way input–output flows simulated under Experiment 3 (2.501 percent) *together with* the drop in total factor incomes in the shutdown sectors as simulated under Experiment 4 (4.748 percent). Naturally, these numbers point to *annual* losses, and they must be discounted accordingly with duration of shutdowns lasting shorter than a year. It could be argued, therefore, that the almost complete shutdown of these sectors alone for nearly 3 months in the first round must have led to the loss of at least about 1.8 percent of the total gross output in the Turkish economy. Given the current size of the Turkish economy, this translates to more than 13 billion US dollars, a huge amount even by overlooking the effects of tourism on current account, foreign exchange reserves etc.[11]

Concluding remarks

Many countries around the world have introduced legally enforceable measures to partially or completely restrict productive activity in certain sectors to curb the spread of COVID-19 epidemic. Anti-pandemic measures were particularly severe in a number of service sectors such as tourism and related services, airlines and other modes of passenger transportation, dining, and entertainment services, and often included large-scale or complete shutdowns. The shutdown orders issued by governments not only stopped productive activity in the covered sectors but also caused severe contractions in output and employment in sectors that sell/purchase inputs to/from sectors that have been shut down. Given the huge costs associated with these measures, deciding which sectors to shut

Figure 1. Decomposition of the effects of shutdown on different sector groups (%) and MPEs.

down and for how long is arguably the most important problem facing the governments all around the world now. This makes the provision of theory- and evidence-based feedback to this policy-making process a (if not *the*) top priority item in the research agenda of the economics profession. Well-designed approaches for systematic measurement of possible output and job losses to result from

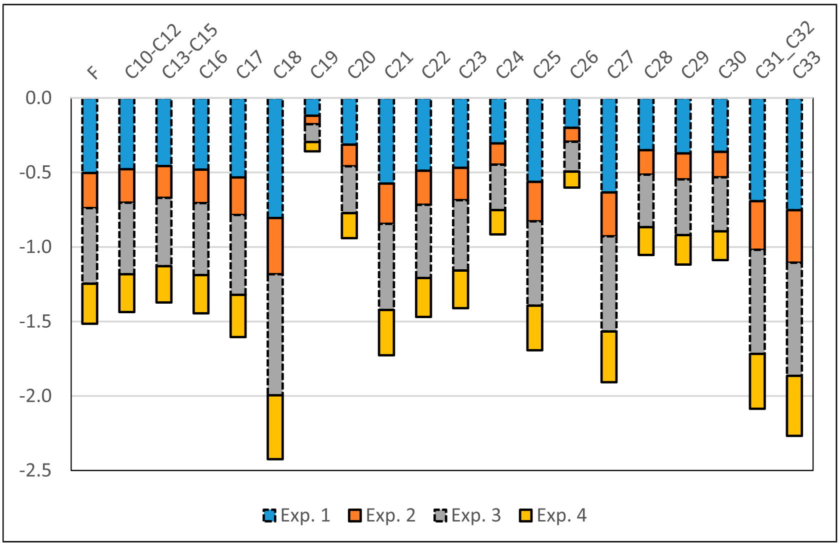

Figure 2. Decomposition of the effects of shutdown on manufacturing and construction sectors (%).

sectoral shutdowns are much needed indeed for informed decision making by policy makers who are burdened by the tough task of striking a balance between public health and economic costs of the pandemic. The issue is particularly important for tourism economists, as sectors supplying travel, accommodations, and related services are on top of the list of sectors considered for shutdowns.

This article proposed a novel methodology with a very low computational burden to assess economic costs of sectoral shutdowns introduced to control the spread of COVID-19 (and other epidemics), in terms of the losses in sectoral outputs and the contraction of GDP by using a supply-driven input–output (IO) model. Our framework allowed for a decomposition of the effects of sectoral shutdowns into direct and indirect losses resulting from broken input–output linkages due to i) suspension of the delivery of inputs to other sectors and ii) termination of the demand for inputs produced by these sectors, as well as due to the interruption of factor payments to the owners of factors of production employed in the sectors ordered to shut down.

Our innovative use of the supply-driven input–output framework has made our methodology ideal for the measurement and sectoral decomposition of economywide costs of pandemic-induced shutdowns, enabling governments to make informed choices in designing virus containment policies. To illustrate, we have applied this methodological framework on Turkey, where tourism and related service sectors have been partially or completely closed down several times, for weeks or even months at a time. In our application, we carried out four simulation experiments using the most recent input–output data. Our findings revealed that shutting down five sectors considered in the study could cost as high as 7.25 percent of total gross output on an *annual* basis, exceeding 50 billion US dollars in lost output and factor incomes. This total should obviously be discounted accordingly with the actual durations of shutdowns lasting less than a year, but it remains true that shutdowns create a huge cost.

Output and income losses experienced by tourism and related service sectors themselves are particularly large, but there is little that the affected industries could do about them. A shutdown order ceases all activity, making it impossible to serve to an alternative customer base. This is the reason why domestic tourism could not easily emerge as an alternative to international tourism, for example. A nationwide shutdown often requires that all hotels be shut down, all airports be closed, transportation services to different destinations be canceled, curfews be imposed, etc. affecting all travelers regardless of their nationality. As such, shutdowns are difficult to be dealt with through managerial strategies or destination policies. The best bet for the stakeholders of tourism ecosystems everywhere seems to be campaigning/lobbying for rapid vaccination of the citizenry so as to uplift domestic tourism activity at least.

While very useful for measuring output losses caused by complete shutdowns quickly and reasonably accurately, our technique has a few limitations. First, input–output models do not allow for the effects of shorter or longer shutdowns to be distinguished, due to their static nature. In other words, drops in sectoral outputs resulting from *each* week of a shutdown turn out to be the same regardless of whether the shutdown lasted for 2 weeks or 12 weeks. In reality, sectors that can no longer sell to those that received shutdown orders may find substitutes (alternative purchasers) when shutdowns last longer. Still, this lack of the possibility of adjustment to the duration of shutdown in our methodology is not likely to make a difference in results that is significant enough for policy makers to reconsider their decisions. Second and perhaps more importantly, the input–output framework does not allow for employment losses in sectors that supply inputs to shutdown sectors to be accounted for endogenously.[12] Thus, additional output losses resulting from the reductions in employment after each period of shutdown may not be estimated directly using our framework alone. Finally, inherent limitations of input–output data may lead to some shortcomings in the measurement of effects. In addition to typically anachronistic nature of data used in input–output analyses, classification of sectors within a country's input–output table may not match well with the coverage of businesses that are shut down, causing underestimation of actual effects. The transportation sector in the Turkish table is a case in point: it clusters passenger transportation activities that have been covered under some of the COVID-19 shutdowns, together with cargo transportation that has never been covered.

Given that the disease also triggers sizable contractions or expansions in demand for the outputs of other sectors than those that are shut down, suggestions for future research include a CGE analysis of the economywide impact of shutdowns. Unlike the input–output framework that only permits measurement of supply-side or demand-side shocks at a time, a CGE model allows for interactions between supply and demand sides of the economy—and hence, the analysis of the effects of simultaneous, pandemic-induced shocks to sectoral supplies and demands. It would therefore be useful to repeat extended versions of simulation experiments here with a CGE model similar to the one used by Van Heerden and Roos (2021), as well. A particularly interesting modeling exercise would be to estimate the effects of shutdowns by using our methodology and by solving a CGE model based on the same input–output data and compare results.

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Notes

1. The drop in international arrivals in January 2021 is 87 percent (UNWTO, 2021a).
2. Some small countries such as Seychelles, Israel, Chile, Bahrain, UAE have already immunized almost all their citizens. Some areas with larger populations such as the UK, the US and the EU have also made significant progress in that direction but many others including China and India may not finish vaccinating their populations until the end of 2022. Consequently, there still is considerable uncertainty as to when normal life will resume, with no need remaining for shutdowns and lockdowns.
3. Following the end of the second nationwide shutdown covering some of the listed sectors in March 2021, the government issued partial shutdown orders differing in severity and sectoral coverage to remain in effect in different provinces which soon after were extended to cover all cafes, restaurants etc. across the country.
4. Another multisectoral model constructed to study total economic costs of COVID-19 by placing a special emphasis on tourism is Yang, Zhang, Chen (2020) where the authors use a Dynamic Stochastic General Equlibrium (DSGE) model that distinguishes two sectors: tourism and the rest.
5. Carter (1965) took the US input-output table and solved the demand-side model by assuming a complete lack of linkages between agricultural and non-agricultural sectors to see if the deviations between resulting values of sectoral outputs under this counterfactual scenario and their actual values would be considerably large. Carter's analysis was partial in the sense that he only suppressed non-agricultural sectors' demand for inputs produced by agricultural sectors, rather than considering a two-way lack of input-output linkages as in Sayan and Demir (1998).
6. It can be shown that this is equivalent to counterfactually setting ${}^{SO}b_{ij} = 0 \; \forall \; i \in \{1, 2,..., k\}$ and $j \in \{k+1, k+2,..., n\}$ so as to turn B_{SO} into a matrix with 0's everywhere.
7. Once again, it can be shown that this is equivalent to counterfactually setting ${}^{OS}b_{ij} = 0 \; \forall \; i \in \{k+1, k+2,..., n\}$ and $j \in \{1, 2,..., k\}$ so as to convert B_{OS} into a matrix with 0's everywhere.
8. We do not consider the possibility of a continuation of payments to primary factors of production during the shutdown due to the imposition of a firing ban, union power, unemployment insurance and other government operated schemes etc. So, the counterfactual scenario we consider may be taken to represent the upper bound for the magnitude of effects spreading across sectors through input-output linkages.
9. Services of airlines and intercity passenger buses have also been suspended for a while but the sectoral classification in the Turkish input-output table does not allow for distinguishing passenger transportation from cargo transportation in the "Air transportation" sector (*H51*), and from cargo transportation and pipelines in the case of "Land transportation" sector (*H49*). We thus considered only those sectors completely shut down first from mid-March to early June –and in later rounds.
10. GDP at market prices is equal to total factor income plus indirect taxes (net of subsidies) on products.
11. Additional rounds of shutdowns have also been introduced since (in November 2020 to cover all dining, entertainment and sports/recreation services, and in May 2021 covering the entire hospitality sector).
12. It is possible to make some inferences about employment losses by combining results from input-output models with output elasticities of demand for labor as in, for example, Taymaz (2020). For direct estimation of employment losses caused by shutdowns, see, for example, Bauer and Weber (2021).

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