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COVID-19 pandemic through the lens of Leontief multipliers for Emerging Economies

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COVID-19 pandemic through the lens of Leontief multipliers for Emerging Economies †

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Abstract:

Coronavirus has been one of the strongest shocks that the World has suffered from in a long time. Its effects tend to dominate the modeling strategists in order to evaluate policy making decisions in terms of economic growth, inflation, or poverty. The discussion in the literature focuses on the nature of the shock, if it is either a demand or a supply shock. I argue that one way to approach this problem is by using input-output tables, based on Leontief multipliers. Following this approach, a shock to one sector, spillover to others by the required intermediate demand for products that are needed for other sectors in order to produce a final good or service. I find that trade and services have higher responses and spread to other sectors which implies a higher order of losses for a Covid shock.

JEL Classification: E01, E37

Key words: Demand and supply shock, Input-output table, Covid

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1. INTRODUCTION

The impact of Coronavirus (Covid-19) over an emerging economy has been under scrutiny in the literature even though there are still a limited amount of data in order to conduct a robust research. How important the change in the economy is, depends on the technique and assumptions made by researchers. The usual approach goes from the identification of a supply shock, a demand shock, or a mix of both. From here, it develops theoretical models and econometric estimations in which the final outcome on growth or inflation can be calculated.

For Eichenbaum et al. (2020) the key is people who cut back on consumption and work to reduce the chances of being infected, and, therefore, reduce the severity of the Covid-19 epidemic shock but exacerbate the size of the associated recession. In contrast, Galindo (2021) evaluates the effectiveness of policy responses to Covid-19 shock with a model in which large and high-risk firms are more affected by the shock and are more responsive to an unconventional monetary policy. On the other hand, Morikawa (2021) finds that the productivity of firms using relief measures (because of the Covid-19 shock) is lower than that of non-user firms prior to the pandemic, suggesting that inefficient firms have been affected seriously.

In terms of how extensive is the impact of the shock, Faisal et al (2021) model the interaction in between fiscal and monetary policy and conclude that fiscal policy has been more effective in boosting economic activity in the short-run, however, in the long-run interest rates rise, investment falls, and inflation rises.[1] On the other hand, Glocker and Piribauer (2021) find that there is a significant degree of heterogeneity in the economic contraction across countries

[1] See Walsh (2010) for a comprehensive review into coordination in between monetary and fiscal policy.

and points out the importance of adverse initial conditions (large contact-intensive service sector) and behavioural changes (increased voluntary spatial distancing).[2]

I take Glocker and Piribauer (2021) idea and suggest a different modeling strategy. Here an input-out table is used in order to measure movements in one sector taking into account its relationship with other sectors. This strategy is based on Leontief multipliers and sheds light on the understanding of how any movement in one sector can be decomposed in a direct and indirect effects over other industries. In other words, a shock to one sector, spreads to others by the required intermediate demand for products that are needed for other sectors in order to produce a final good or service. By using input-output tables, I characterize the new equilibrium in terms of the dynamics implied between demand and supply.

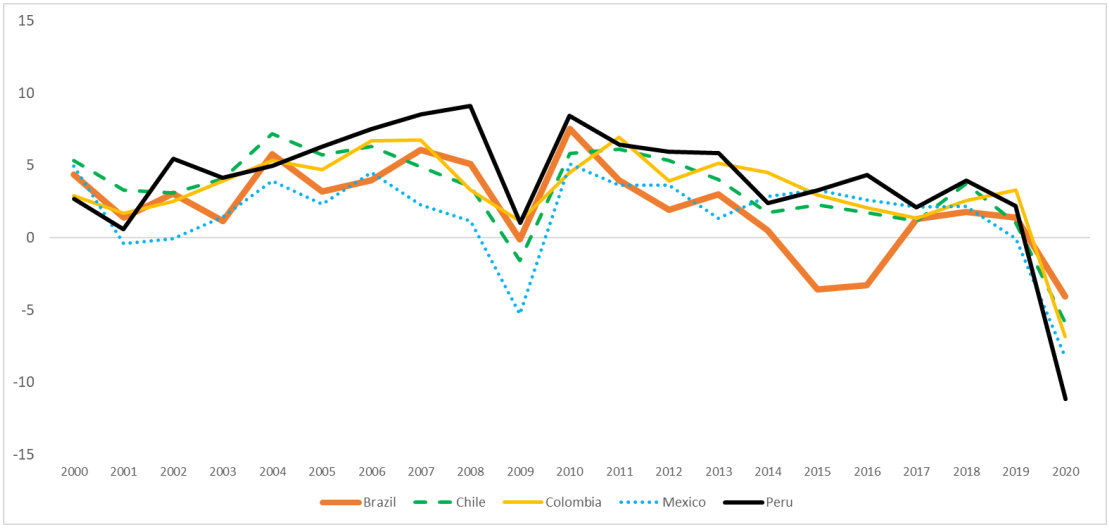
Latin-American countries slow-down production when a crisis arise. The most recent experience is the 2007-2008 international financial crisis. The case of Peru is a clear example of an emerging economy with positive growth rates until the Covid-19 event. While the country takes anti-Covid-19 policy measures in the middle of March, it can be argued that the Covid-19 event begins as early as December of 2019. If so, the effects in terms of GDP are a decrease of around 11 percent, similar to what is recorded in other emerging economies (see Table and Figure 1).

Roughly speaking, information on GDP shows the direct effect of Covid on each productive sector i.e. does not take into account any spillover effect between each other. The interaction between sectors is key for calibrating deep parameters that govern over important relationships at the time of recommending policy measures. Using an input-output table for 55 industries, I intend to uncover which sectors have the major impact on the Peruvian economy because of the Covid-19 scenario. Based on Leontied multipliers, this strategy takes into account the

[2] It is worth mentioning the work of Kantur and Ozcan (2021) who find that the pandemic inflation (based on the consumption during the first lockdown) is higher than the official inflation rate, suggesting a behavioral change in consumption, but, in the reopening period, the difference between inflation rates is no-significant, suggesting no changes in habits of consumption.

equilibrium between supply and demand at the time of constructing an input-output table (see Elias et al, 2018; and, Mustafin et al, 2018).

FIGURE 1 – GDP IN LATIN-AMERICAN COUNTRIES



NOTE: GROWTH RATES OF GDP, AT CONSTANT PRICES IN NATIONAL CURRENCY.
SOURCE: WORLD ECONOMIC OUTLOOK DATABASE, IMF.

TABLE 1 – GDP FOR THE PERUVIAN ECONOMY

	Particip. 1/	Real terms 2/			Var. % 3/	
	%	2018	2019	2020	2019	2020
Agriculture	5.4	28642	29553	29959	3.2	1.4
Fishing	0.3	2449	1831	1879	-25.2	2.6
Petroleum and minning	12.2	66587	66528	57577	-0.1	-13.5
Manufacturing	12.8	70979	69779	60761	-1.7	-12.9
Electricity and water	1.9	9860	10248	9619	3.9	-6.1
Construction	5.9	31619	32139	27721	1.6	-13.7
Trade	10.5	55430	57120	47990	3.0	-16.0
Services	42.1	220838	229733	207756	4.0	-9.6
GDP		**534665**	**546161**	**485633**	**2.2**	**-11.1**

NOTES: THE COMPONENT OF TAXES IS NOT INCLUDED IN THE ESTIMATION OF THE GDP. IF SO, PARTICIPATION DOES NOT ADD TO 100%.
1/ PARTICIPATION IS WITH RESPECT TO THE VALUES IN 2019, 2/ IN MILLIONS OF SOLES OF 2007, AND 3/ WITH RESPECT TO SIMILAR PERIOD OF THE PREVIOUS YEAR.
SOURCE: NATIONAL INSTITUTE OF STATISTICS OF PERU (INEI).

The rest of this paper is organized as follows: Section 2 describes the relationship between an input-output table and Leontief multipliers; Section 3 presents the idea of shocks in the

context of Leontief multipliers; Section 4 discusses the limits and caveats for this approach; and, Section 5 presents the main conclusions.

2. INPUT-OUTPUT TABLES AND LEONTIEF MULTIPLIERS

In this paper, I use the input-output table for Peru for the year 2016 which is the table with the most reliable information.[3] I depart from a 365 activities for 101 industries that follows the Standard Industrial Classification (SIC), and build a consistent matrix that is 55x55 which is required for estimating Leontief multipliers. Even though most conventional tables describe 54 industries, I decompose the industry of Hotels and Restaurants, given Restaurants' higher linkage with other industries.

The starting point for estimating Leontief multipliers is recognizing the equilibrium in between supply and demand in the input-output table:

$$Total\ supply\ = Total\ demand$$

This equality also implies that different sectors use each other products, in the form of an intermediate demand i.e. goods for any industry may be used as inputs (for other industries or activities) or as final goods (for example, households or firms):

$$Total\ supply = Intermediate\ demand + Final\ demand$$

[3] The tables for 2017 and 2018 have either preliminary or estimated information.

The Leontief method captures most technological relationships in the intermediate demand, or demand in between industries. So that, a matrix with technological coefficients would reproduce the intermediate demand with only information on total supply.

Let *X* be a vector of the total supply in the economy for different industries, and *Y* be the final demand of those produced goods. A fraction of the total production for each industry is demanded in between industries i.e. it is intermediate demand. This relationship can be represented as:

$$X = A\,X + Y \tag{1}$$

where *A* is the matrix of technological coefficients. When *A* multiplies *Y*, it gives back a vector with the intermediate demand.[4]

With some matrix algebra, the total supply of the economy can be obtained from its final demand, based on the following relationship:

$$X = (I - A)^{-1}\,Y \tag{2}$$

$$X = B\,Y \tag{3}$$

where I is the identity matrix and $\boldsymbol{B = (I - A)^{-1}}$ is the matrix of total requirements for the economy.

[4] For the estimation of the matrix *A*, see Appendix A.

3. EQUILIBRIUMS AND SHOCKS

Equation (3) basically introduces the idea of a new equilibrium given a shock, in the sense that any change in any component of the final demand (vector *Y*) translates into a change in all components of total supply in the economy (vector *X*) through matrix *B*. In turn, changes in *X*, gives back a new set of values for *Y*, ceteris paribus the relationship between *X* and *Y*.

The key for understanding this process is matrix *A*. This matrix consolidates the relationship between industries because it departs from the intermediate demand that is required for the final production of a good or a service.

For the Covid-19 scenario, this implies a forecast in which the forecaster does not have any prior about a virus that would hit the economy (in this case, the whole World). In terms of timing, the previous remark implies a prediction exercise around December 2019 by an institution that is used to provide forecasts on regular basis and a reasonable level of industries. In this case, I use the forecast made by the Central Bank of Peru, that is publically available on its web page under the name of Inflation Report for December 2019.

The remaining of the exercise is to record the observed behavior for different industries during 2020 and compare with the forecast made in 2019. The difference between the two values is considered the direct effect of Covid in that industry. Here I also estimate the relationship between supply and final demand which is used in the following step.

For calculating the indirect effect, I estimate the total supply of the economy based on the observed forecast for each industry in 2019, then I input the observed value in 2020 of an industry and afterwards generate a new vector of total supply. Using the relationship between total supply and final demand in the previous step, I calculate a new final demand for each industry. The total value of the final demand for all industries is considered here as the indirect

effect, given the reaction on the supply side to a new demand in an industry, and ceteris paribus the effect on all other industries and the relationship between total supply and final demand.

Table 2 presents results for this contra-factual experiment for most affected industries. Trade is the most affected sector. The loss is important in either direct or indirect effect. Here the heavy linkage with all other sectors is key for understanding this result and helps to explain why this sector is the only one to have an indirect effect that is bigger than the direct effect. The result on Trade is related to the initial conditions described in Glocker and Piribauer (2021).[5]

Regarding direct effect, the most affected industries are Trade, Mining, and Transportation. While mining companies have to stop/reduce operations because of the virus, the indirect effect seems to be lower relative to other sectors. The provision of services for transportation also suffered important losses, in special those in the air traveling and it is important to notice that here there is a clear link with the distribution of goods by ground transportation.

TABLE 2 – DIRECT AND INDIRECT EFFECT BY SECTOR

Code	Standard Industrial Classification	Effect
	Top 3 sectors with most direct effect	
38	Trade	
4	Minning	2.1
39	Transportation	2.0
		1.6
	Top 3 sectors with most indirect effect	
38	Trade	2.8
40.2	Restaurants	0.5
39	Transportation	0.4
	Top 3 sectors with most effect	
38	Trade	4.9
4	Minning	2.2
39	Transportation	2.0

NOTES: MEASURE AS A PERCENTAGE OF THE 2019 GDP.

[5] See Appendix B for the effects for each sector.

Regarding indirect effects, Trade, Restaurants, and Transportation are the sectors with the most impact. The reduction in the provision of this services are clearly associated with the reduced demand on the side of most industries.

Either for modeling or for analysis, the indirect effect must get most attention, because it is how a shock may channel through the economy. Table 3 presents how much impact it is in each sector, measure as the percentage of the total indirect effect. For Trade, Transportation and Financial Services clearly take most of the effect. This opens the discussion of sectors that affect other sectors that are also highly linked. The spread and the multiplying effect seem to be associated with the ability of complementing each other such as Trade and Transportation, and vice-versa.

TABLE 3 – LINKAGE OF THE INDIRECT EFFECT

Code	Standard Industrial Classification	Effect
	Trade	
39	Transportation	22.8
43	Financial services	14.7
41	Telecomunications	9.1
	Others	53.5
	Restaurants	
1	Agricultural	27.9
15	Beberages	17.9
5	Meat processing	14.4
	Others	39.8
	Transportation	
38	Trade	27.5
22	Oil refination	11.4
43	Financial services	8.8
	Others	52.2

NOTES: MEASURE AS A PERCENTAGE OF THE TOTAL INDIRECT EFFECT.

In Restaurants, the indirect effect is more related to their suppliers. This is a service that stop for some months, and slowly re-open. By not demanding their usual inputs, other industries focused on alternative markets, and by doing so, cope with the negative shock. In the case of Transportation, Trade appears as the most impacted activity. This complementarity re-inforce each other, and develops into the source of spillover to the economy as a whole.

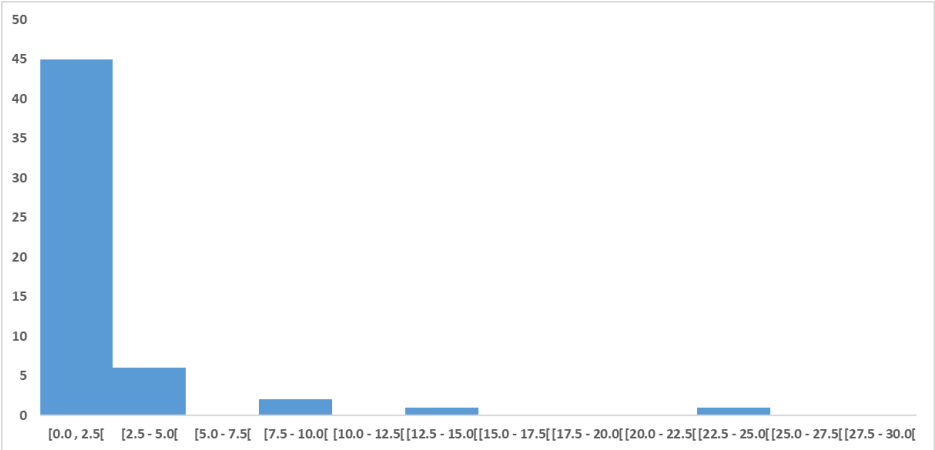
Figure 2 basically presents histograms that shows the dispersion given by industries. In the case of Trade, 51 out of 55 industries obtain a reduction in between 0 and 5 percent of the total indirect effect. This result of concentration also repeats for Restaurants and is similar for the case of Transportation (50 out of 55).

In terms of modeling, these results suggest that either the distinction between tradable/non-tradable and durable/non-durable goods has to be incorporated at the time of modeling design. While thinking of Covid-19, the provision of services, in general, has a higher indirect impact. Also important to keep in mind that the transactions have to be considered as a part of the set of assumptions for general equilibrium and dynamics in the economy.

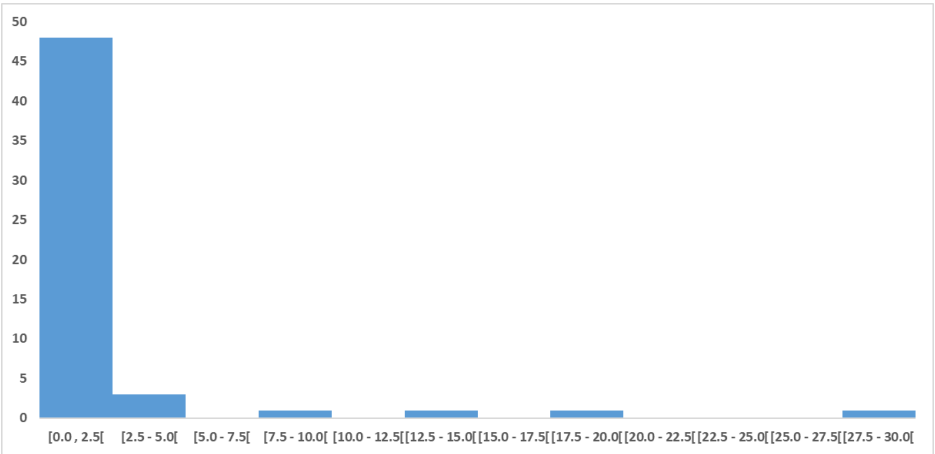
In line with Tian (2021), input-output linkages facilitate the understanding of expectations-driven fluctuations. For Tian (2021), signals about yet-to-be-realized aggregate (macro) and idiosyncratic (micro) fundamentals in the future affect current equilibrium outcome through chains of input needs when inputs require time to build. It is clear the importance on these chains and here I characterize how firms respond differently to a common signal, specifically for Trade and Services (result that is related to that in Glocker and Piribauer, 2021). For Tian (2021) the network structure into an input-output table determines the magnitude of signal-induced aggregate fluctuations which I intent to capture through Leontief multipliers.

FIGURE 2 – SPREAD TO OTHER SECTORS

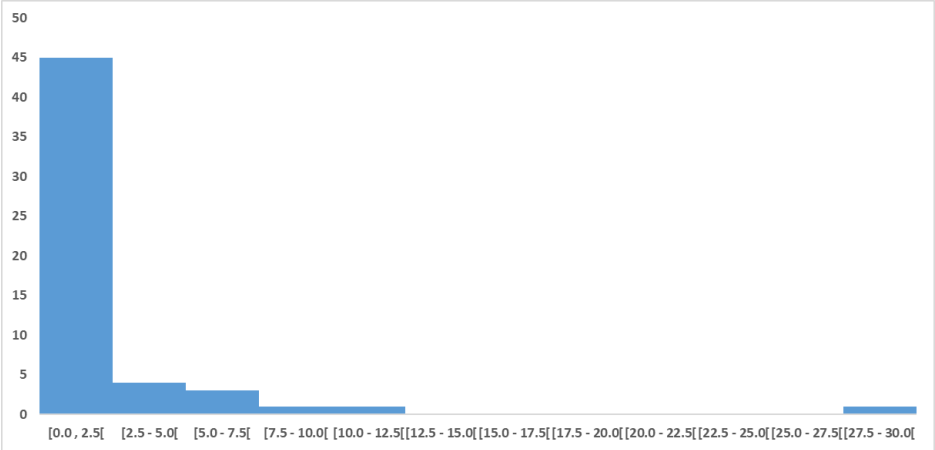
a. Trade



b. Restaurants



c. Transportation



4. CAVEATS AND LIMITS

This strategy has a number of critics and limitations. Most of those are related to the design and the availability of the needed information. Here I provide some.

First at all, the time-frequency is in annual terms. Most conclusions that are obtained in these particular frameworks, clearly limit the scope of those because the effects of Covid-19 may last beyond 2020. I argue that the initial effect is the key for understanding the adaptation process on the side of the industries and the recovery of the economy under an eventual vaccination of most of the population.

Then it is important to consider how stable the relationships are between industries in 2016 (the most up-to-date input-output table that is available) and in 2020 (a year with possible structural changes). This critic is also related to the availability of information i.e. the input-output table for 2020, to follow this strategy which might be available in 2023. Even though the impact is strong in some sectors, here I point out to technological relationships that would be difficult to break, even during a crisis. This paper provides a stepping-stone for moving forward in this way of thinking, and eventually confirm how reliable this strategy is for counter-factual exercises.

The use of GDP as a proxy for final demand is also important to be mentioned. The subtraction of the intermediate demand from the total supply is usually considered added value, and that is GDP. However, GDP considers net exports, and final demand considers the external demand for domestic products (exports). The limits here are more on the side of tradable goods, but still it keeps the results robust for the provision of services and for non-tradable goods. Some caution has to be taken at the time of using these results for calibrating general equilibrium models.

5. CONCLUSIONS

The Covid-19 event of 2020 leaves important lessons in terms of value added for industries. This research contributes to the view about sectors that were impacted the most, taking into account the net of industrial relationships. Similar than Glocker and Piribauer (2021), I find that Trade and services such as Restaurants and Transportation are the most affected by the Covid-19 shock, basically because of the highly links within these activities.

This result on the provision of services considers direct and indirect effects and suggests that the spread of the shock is heterogeneous among productive sectors. As suggest in Tian (2021), the reinforcement between services makes the effect to be stronger for a particular group of activities. The absent in the provision of the service in Restaurants would limit the amount of required Transportation for either mobilizing customers or supplying products.

In terms of modeling, this result also suggests the use of tradable and non-tradable sectors or durable and non-durable goods, given the importance of trade and services for understanding the Covid-19 shock.

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APPENDIX A

To estimate matrix *A*, let us define matrix *DI* that includes all 55 intermediate demands from all industries in the economy. Then,

$$DI = A\,Z \tag{A.1}$$

$$A = DI\,(Z)^{-1} \tag{A.2}$$

where *Z* is a matrix of the total supply in the economy.

Rather than using a vector with the sum of all intermediate demand in the economy, the idea here is to use all relationships by considering each individual demand in each industry in the form of a matrix. In order to do so, vector *X* becomes matrix *Z* by recognizing that the total supply in each sector is any produced amount but zero for other sectors i.e. it is a diagonal matrix with the total production in the diagonal and zero otherwise.

APPENDIX B

TABLE B.1 – DIRECT AND INDIRECT EFFECT BY SECTOR

Code	CIIU	Effect		
		Direct	Indirect	Total
1	Agricultural	0.2	0.0	0.2
2	Fishing	0.1	0.0	0.1
3	Petroleum	0.1	0.0	0.1
4	Minning	2.0	0.2	2.2
5	Meat processing	0.1	0.1	0.2
6	Fish processing	0.0	0.0	0.0
7	Fishmeal industry	0.0	0.0	0.0
8	Fruits processing	0.0	0.0	0.0
9	Oil based on vegetables and fruits	0.0	0.0	0.0
10	Milk industry	0.1	0.0	0.1
11	Milling and bakery	0.1	0.0	0.2
12	Sugar industry	0.0	0.0	0.0
13	Other food products industry	0.1	0.0	0.1
14	Elaboración de alimentos preparados para animales	0.0	0.0	0.0
15	Beberages	0.1	0.0	0.1
16	Textiles	0.0	0.0	0.0
17	Clothing	0.1	0.0	0.2
18	Leather	0.1	0.0	0.1
19	Wood products	0.0	0.0	0.0
20	Paper	0.0	0.0	0.0
21	Printing	0.0	0.0	0.0
22	Oil refination	0.2	0.0	0.2
23	Chemical products	0.0	0.0	0.0
24	Cleaning products	0.1	0.0	0.1
25	Drugs and pharmaceutical products	0.1	0.0	0.1
26	Plastic products	0.0	0.0	0.0
27	Glass products	0.0	0.0	0.0
28	Iron and steal industry	0.0	0.0	0.0
29	Jewelry	0.1	0.1	0.2
30	Metak products	0.1	0.0	0.1
31	Informatic and electronic products	0.1	0.0	0.1
32	Machinery and equipment	0.2	0.0	0.2
33	Products for transportation	0.2	0.0	0.2
34	Furniture	0.1	0.0	0.1
35	Other manufacturing industries	0.1	0.0	0.1
36	Electricity and water	0.2	0.0	0.2
37	Construction	1.2	0.2	1.4
38	Trade	2.1	2.8	4.9
39	Transportation	1.6	0.4	2.0
40.1	Hotels	0.4	0.1	0.4
40.2	Restaurants	1.3	0.5	1.8
41	Telecomunications	0.1	0.0	0.1
42	Other information services	0.0	0.0	0.0
43	Financial services	0.4	0.1	0.5
44	Insurance services	0.2	0.0	0.1
45	Servicio inmobiliario y alquiler de vivienda	0.8	0.0	0.8
46	Servicios profesionales, científicos y técnicos	0.1	0.0	0.1
47	Rental cars	0.1	0.0	0.1
48	Travel agencies	0.0	0.0	0.0
49	Managing services	0.1	0.0	0.1
50	Defense	0.0	0.0	0.0
51	Education	0.7	0.1	0.8
52	Health	0.5	0.1	0.6
53	Social services	0.1	0.0	0.1
54	Other personal services	0.5	0.1	0.6

NOTES: MEASURE AS A PERCENTAGE OF THE 2019 GDP.