Sectoral impact of covid-19: Cascading Risks*

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Abstract

Workers are unequal in the face of the COVID-19 pandemic: Those who work in essential sectors face higher health risk whereas those in non-essential social-consumption sectors face greater economic risk. We study how these health and economic risks cascade into other sectors through supply chains and demand linkages. In the U.S., we find the cascading effects account for about 25-30% of the exposure to both risks. The cascading effect increases the health risk faced by workers in the transportation and retail sectors, and it increases the economic risk faced by workers in the textile and petroleum sectors. We provide sectoral estimates of the health and economic risk for 42 other countries in an online interactive document.

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1 Introduction

The covid-19 pandemic poses great public health and economic challenges to countries around the world. Slowing down the spread of the pandemic requires implementing social distancing measures that disrupt economic activity. At the same time, some activities need to be maintained, which puts workers in these sectors at risk of contracting the virus. How does the workers' exposure to these health and economic risks vary across sectors? Answering that question involves understanding not only how sectors vary in their direct exposure to both types of risks but also in their indirect exposure, through supply chains and demand linkages.

We study the sectors' differential exposure to health and economic risks by focusing on how risk cascades from the two groups of workers particularly hard it by the pandemic. The first group of workers is those working in sectors providing *essential goods and services*, such as health care, food or pharmaceutical products. These workers face a higher health risk than others: at the risk of being infected, workers in those sectors are asked to continuing working to ensure that the population's essential needs are met, even when strict lockdown measures are imposed. The second group of workers is those working in establishments providing services to the public, such as stores, restaurants, or cinemas, which we call *social consumption sectors*. These workers face a higher economic risk than others. Given the high transmission risk associated with social gatherings, these establishments are typically the first ones to be shut down when lockdown measures are taken and the last ones allowed to reopen. Moreover, these establishments are likely to operate at low occupancy, even as government-mandated closings are lifted, both because social distancing reduces the number of customers that they can serve and because customers will avoid these establishments until a vaccine or a treatment becomes available.

We provide sectoral measures of the health risk and economic risk associated with these two groups of workers. The measures account for how risks cascade from the essential and the social consumption sectors to other sectors via supply chains and demand linkages. We find that the cascading effects are large in the U.S., accounting for about 25-30% of the total exposure to each risk. The cascading effect increases the health risk faced by workers in the transportation and retail sectors, and it increases the economic risk faced by workers in the textile and petroleum sectors. Workers in the education sector are spared: they face both lower health and economic risks than others. Our results highlight the key role played by trade and transportation in the transmission of risks. We also provide the measures for each US state. We find that the economic risk is highest in Nevada whereas the health risk is highest in Alaska. We have adapted the methodology for other countries; we provide estimates of the health and economic risk for 43 in an online interactive document (`https://osotimehin.github.io/blog/2020/04/28/cascading-risks.html`).

We use the input-output framework of Leontief (1936), calibrated on data from the World Input-Output Database, to compute the proportion of workers exposed to each type of risk.[1] We adapt the model to incorporate *demand linkages* coming from the complementarity in the households' demand. This feature adds another source of cascading effect, different from the typical one coming from supply chains. We focus on the complementarity between, on the one hand, the consumption of manufacturing goods and on the other hand, the consumption of trade and transportation services, which we calibrate on data from the World Input-Output Database and from the U.S. Bureau of Economic Analysis. By incorporating these demand linkages, we fully account for the central role of trade and transportation in the production network, which has been ignored in the recent input-output literature.[2]

The risk measures are based on the model's employment under different demand scenarios. The health risk is measured as the proportion of workers needed *at the workplace* to maintain the pre-pandemic household consumption in essential goods and services. Our health risk measure is obtained by combining the model's result with the recent indicator of Dingel and Neiman (2020), which gives an upper bound for the proportion of each sector's jobs that can be done at home. The economic risk is measured as the decline in employment induced by a 90% decline in the household demand for social consumption. We assume that the household retail purchases of agricultural, food and chemical products and online purchases are not affected by the shock. We also leave aside shocks to exports and investment.

Note that the measures are not meant to give a precise forecast of the sectoral impact of the pandemic. Rather, we propose indicators of each sector's risk exposure to shed light on how these risks propagate across sectors through supply and demand linkages. Moreover, it should be noted that many factors that could affect each sector's exposure to health and economic risk are missing from our measure. In terms of exposure to health risks, sectors

[1] A key assumption in the Leontief framework is that firms' inputs are perfectly complementary. We believe this assumption is the most adequate for short-run analysis. Complementarity captures the fact that firms need time to reorganize production and change their input mix. Moreover, we show in the Appendix that for demand shocks, a model with some degree of substitution between inputs behave virtually like the Leontief perfect-complementarity model when labor cannot be reallocated across sectors and wages are rigid. This model is based on Osotimehin and Popov (2020).

[2] The literature typically assumes that the elasticity between all the components of final demand is higher than one and accounts neither for the heterogeneity in the elasticity of substitution nor for the complementarity between some products.

differ in how extensively and closely their workers interact with other people (and with infected people), which affects the workers' probability to be infected. Sectors also differ in the age and gender composition of their workers which would also affect the each sector's health risk. In terms of economic risks, many dimensions would deserve more attention as well, such as the effect of uncertainty on consumption and investment, business liquidity issues and bankruptcies, and the fall in international trade.[3] Although our analysis does not account for these important effects, we believe our indicators provide a useful perspective on the inequality in the workers' exposure to the health and economic fallout of covid-19.

Our analysis contributes to the literature on input-output linkages (see Carvalho and Tahbaz-Salehi (2019) for a survey). We complement recent work that highlights the importance of accounting for the complementarity in the production process (e.g., Atalay, 2017; Baqaee and Farhi, 2019; Osotimehin and Popov, 2020). In contrast to these papers, we underline here the role played by *demand* complementarity and in particular the critical role played by the trade and transportation sectors. Many papers have investigated the consequences of the covid-19 pandemic. The most closely related paper is Barrot et al. (2020) who use an input-output framework to study the economic impact of covid-19 in France and other European countries. In contrast to them, our objective is not to evaluate the effects on GDP but rather to shed light on the different health and economic risks faced by workers across sectors. Moreover, our focus is different. Whereas Barrot et al. (2020) compute the effects of changes in labor supply on output, we study the effects of changes in final demand on employment. Other recent work, which analyses dimensions that are absent from our analysis, also focus also on the supply side (see for example, Luo and Tsang (2020) and Mejean et al. (2020) for an analysis of the disruption of international supply chains).

2 A measure of sectors' exposure to health and economic risks

We study the inequality across workers in their exposure to the health and economic risk caused by the covid-19 pandemic. We focus on the health risk induced by maintaining essen-

[3] The framework also precludes reallocation across sectors. Anecdotal evidence suggests household will not be able to substitute much between products in the short run. Recent reports of food waste are direct illustration of this limited substitutability. For instance, dairy processing plants that used to sell cheese to restaurants cannot sell their production to retail stores instead because their equipment is designed to package cheese in large 20-pounds bags that are too large for retail customers. See for example "Dumped Milk, Smashed Eggs, Plowed Vegetables: Food Waste of the Pandemic" - The New York April 11 2020 https://www.nytimes.com/2020/04/11/business/coronavirus-destroying-food.htm

tial goods and services and on the economic risk induced by the collapse of the demand for the social-consumption sectors. Workers employed directly in those two groups of sectors are particulary hard it by the pandemic. They are, however, not the only ones that are disproportionately affected by the pandemic, as people working for the suppliers of these sectors, and for the suppliers of their suppliers, and so on, will also be severely affected. Moreover, the risk can also propagate through the complementarity in household consumption. A more complete picture of each sector's exposure to the economic and health risks must hence take into account the cascading effects coming from these two types of sectoral linkages. We describe in this section how we measure the two risks. We highlight the key features of the model and provide the details of the methodology in the Appendix.

Methodology Our model is based on the input-output framework of Leontief (1936), which we calibrate on data from the World Input-Output Database (WIOD, Timmer et al. (2015)). The framework relies on the assumption that the firms' inputs are perfect complements, which we believe is suitable for our analysis. In Appendix C, we show that for demand shocks, a model in which both firms and households can substitute between products virtually behave like the Leontief model in the short-run (under the assumption that wages are rigid and labor cannot be reallocated across sectors).[4]

We differ from standard input-output modeling by explicitly incorporating the demand linkages between trade, transportation and manufacturing products. These demand linkages create additional spillover relative to the standard input-output model in which sectors are connected only through supply chains. We model the household demand for retail and wholesale trade as

$$C_d^{hh} = \sum_i \theta_d^i C_i^{hh}, \tag{1}$$

where d denotes a trade sector (retail or wholesale trade), C_i^{hh} is the household demand for product i and θ_d^i is the distribution margin, with $\theta_d^i > 0$ if i is a manufacturing sector. The demand for transportation includes both transportation margins and the demand for passenger transit:

$$C_{\mathsf{transp}}^{hh} = \sum_i \theta_{\mathsf{transp}}^i C_i^{hh} + C_{\mathsf{passenger}}^{hh}, \tag{2}$$

where C_{transp}^{hh} denotes the household demand for shipping and $C_{\mathsf{passenger}}^{hh}$ its demand for passenger transit services.[5] The trade and transportation margins and the share of passenger

[4] The model is based on Osotimehin and Popov (2020).

[5] Similar equations apply to the demand for retail, wholesale and transportation services implied by exports and investment (without the transit component).

transportation are calibrated using WIOD data and US data from the Bureau of Economic Analysis.

We compute simple measures of the exposure to the health and economic risks that take into account these supply and demand linkages. The measures are calculated using the model's sectoral-employment prediction, under two shutdown scenarios that capture the disproportionate impact of the crisis on the essential and social-consumption sectors. The list of sectors belonging to these two groups is given in Table 2 (in the Appendix).

Exposure to health risk. We measure the health risk as the proportion of each sectors' pre-epidemic employment needed *at the workplace* to meet the pre-pandemic final demand for essential goods and services. This corresponds to a strict lockdown scenario in which non-essential final demand is shut down. A sector's exposure to the health risk depends not only on the proportion of employment needed but also on whether the work needs to be done at the workplace or can be done at home. Our measure accounts for this dimension using the recent indicator proposed by Dingel and Neiman (2020), which gives an upper bound of the proportion of jobs that can be done from home. We use their sectoral estimates, tele_i, combined with the model's result, to compute our health-risk indicator for every sector:

$$\mathsf{hrisk}_i = (1 - \mathsf{tele}_i)\frac{L_i}{\bar{L}_i},$$

where $\bar{L}_i$ is the pre-pandemic employment in sector i and L_i is the employment required to maintain final demand of essential goods and services.[6] Because of the supply and demand linkages, employment is needed both in essential and in non-essential sectors.

Exposure to economic risk. We measure the economic risk as the proportion of each sectors' pre-epidemic employment not needed after a 90% reduction in the households' demand for social consumption services:

$$\mathsf{ecorisk}_i = \frac{L_i}{\bar{L}_i} - 1,$$

where L_i is the employment in sector i after the collapse in household demand and $\bar{L}_i$ are as defined above. Note that only the household demand declines; the other components of final demand (exports and investment) are assumed to stay constant. Among the social consumptions sectors, the household demand for retail and transportation services are only partially

[6]Workers employed in a sector perform a variety of tasks, out of which a fraction can be performed remotely. Thus even if the fraction of labor needed is less than the ratio $tele_i$, some workers will have to be exposed to health risk.

affected by the shock. We assume that the households' retail purchases of agricultural, food, and chemicals products stay at their pre-pandemic levels, and so do online purchases (to capture the fact that supermarkets, pharmacies and online retailers are allowed to stay open during the shutdown).[7] All these products continue to be delivered to households which is why transportation services are only partially affected. We assume that the transportation services for food, chemical products and products sold online stay at their pre-pandemic levels. Here as well, because of the supply and demand linkages, employment will decline both in social consumption sectors and in other sectors.

Aggregate and regional indicators. The aggregate risk measure is computed by taking the weighted average of the sectoral risk measures:

$$\mathsf{hrisk} = \sum_i (\bar{L}_i/\bar{L})\mathsf{hrisk}_i,$$

where $\bar{L} = \sum_i \bar{L}_i$. We also consider the risk at the regional level s.

$$\mathsf{hrisk}_s = \sum_i (\bar{L}_{si}/\bar{L}_s)\mathsf{hrisk}_i,$$

where $\bar{L}_s = \sum_i \bar{L}_{si}$. The aggregate and regional indicators are defined similarly for the economic-risk indicator.

3 Results

We present here the results of the health and economic indicators for the US. We have adapted the methodology for the 42 other countries of the WIOD. Results for each country are available online at this interactive page: `https://osotimehin.github.io/blog/2020/04/28/cascading-risks.html`.

3.1 Health risk

Our results show that accounting for supply and demand linkages is key to evaluating risk exposure. We estimate that out of the 29% of U.S. workers disproportionately exposed to

[7] We do not capture the expansion of online retail (See for example, "Kayla Yurieff, CNN, Amazon is hiring 75,000 more workers to keep up with demand during pandemic" https://www.cnn.com/2020/04/13/tech/amazon-hiring-coronavirus/index.html). This reallocation towards online retail is likely to be limited in the short run.

health risks during lockdowns, a quarter of these workers are working in non-essential sectors. The decomposition of the aggregate risk by sector is given in Table 1. In addition to showing the large share accounted for by workers in non-essential sectors, the table shows that public service employees and health care workers account for the bulk of the US exposure.

We now turn to the risk faced by workers in each sector. As shown in Figure 1, the health risk is the highest in three sectors providing essential goods and services (agriculture, health and food industry). Exposure in three other essential sectors, chemical, public administration and utilities, is lower but still high, greater than 40%. The last two essential sectors, post and telecommunication and finance, bear a risk of about 20%. To better understand the low exposure of some of these sectors, we decompose the two dimensions of the health risk. In Figure 2, we report the fraction of employment needed (to satisfy the demand for essential goods and services) separately from the fraction of work that can be done from home. Sectors in the south-east quadrant are the most exposed and sectors in the north west quadrant are the least exposed. The figure shows that the financial and post-and-telecommunication sectors are exposed to a lower risk than other essential sectors because work in these sectors can be done from home and not because the sectors are supplying inputs to non-essential services.

Figure 1 also shows the cascading effects coming from supply chains and demand linkages. Workers in non-essential sectors are also at risk since maintaining the consumption of essential goods and services requires maintaining production in other sectors, connected to essential sectors, as well. The most exposed sectors are inland transportation, auxiliary transportation and retail. The indirect effects hence cascade mainly through demand linkages. Least-exposed sectors are education, machinery and material and equipment.

3.2 Economic risk

Accounting for supply and demand linkages is important to assessing economic risk as well. We estimate that 21% of U.S. workers are disproportionately exposed to the economic risk caused by the shutdown of social consumption. Almost a third of these workers are in sectors indirectly exposed. The decomposition of the aggregate risk by sector is given in Table 1. The table shows that workers in hotel and restaurants and in retail account for the bulk of the US exposure. We also report the economic risk associated with the shutdown of retail stores only. This result shows that the retail industry plays a central in the cascade effects. Sectors linked to the retail industry, mostly through demand linkages, account for the majority of the indirect exposure.

How does the exposure to economic risk vary across sectors? Figure 3 shows that, as expected, the economic risk is high in the sectors' directly affected by the shutdown, such as hotels and restaurant, or other social and personal services. Workers in retail and inland transportation face a substantially lower risk than hotels-and-restaurants workers (about 30-40% vs 70%). Recall that retail services are only partially affected by the demand shock since the demand for online retail and for the retail of food and chemicals are assumed to stay constant. Inland transportation is affected even less because the transportation of commodities continues even if passenger transit is shut down. The strongest cascade effects are experienced by the textile and the petroleum industries. The least-affected sectors are health, public administration, construction, and education.

3.3 Which U.S. states are the most exposed?

The state economic and health risk indices, computed using each state's industry employment shares as weights, are presented in Figure 4. Most states have similar exposure to economic risk. Nevada and Hawaii stand out on the high side and District of Columbia on the low side. Nevada bears a high economic risk because it has a large share of workers employed in hotels and restaurants, while the District of Columbia has disproportionately a large employment share in Public Administration and Defence and a comparatively lower share in retail.

Health risk disparities are larger, with about 10 percentage points (corresponding to a 40% difference) between the least and most exposed states. Nevada is here too an outlier. Its health risk is low both because the health risk of the hotels-and-restaurants sector is low and because it has a small share of workers in health care. At the other end of the spectrum is Alaska. Alaska's high health risk is due to its significantly higher than average employment share in Public Administration and Defense and a lower than average employment share in Renting of Equipment and Other Business Activities, a sector with low health risk.

4 Conclusion

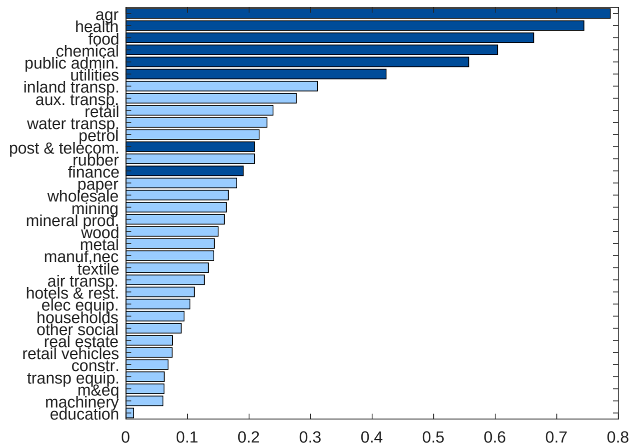
Workers face disparate exposure to health and economic risks from the COVID-19 pandemic. We find that a substantial portion of this exposure is indirect, cascading from essential and social-consumption sectors through supply chains and demand links. Taking into account the indirect exposure generated by the linkages across sectors is important to fully understand the distributional consequences of the pandemic and the effects of policies taken to mitigate its consequences. Our results also shed light on the critical role played by the trade and transportation industries. These sectors, which have been overlooked in recent input-output literature, deserve more attention as they may also play a key role in the transmission of

Table 1: Decomposition of the aggregate risks (in percents)

Health risk		Economic risk	(a)	(b)
Total	28.9	Total	20.7	9.7
Indirect	7.7	Indirect	6.0	4.6
Agr.	1.1	Hotels & rest.	6.0	-
Food	0.7	Land transp.	0.4	-
Chemical	0.3	Air transp.	0.1	-
Utilities	0.3	Other social & pers.	3.0	-
Post & telecom.	0.2	Retail vehicles	1.1	1.1
Finance	0.7	Retail (excl. vehicles)	4.1	4.0
Public admin.	8.7			
Health	9.1			

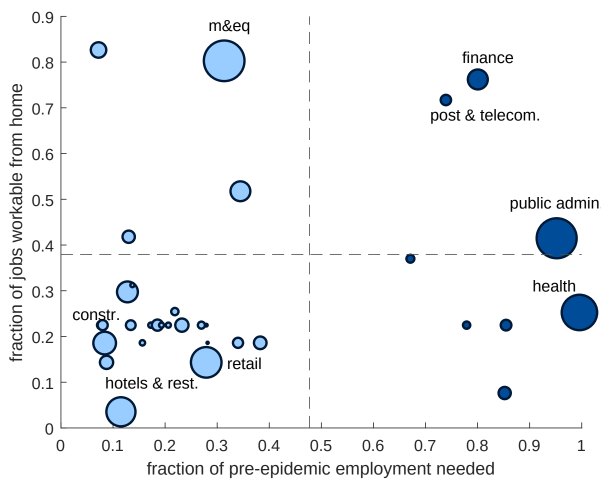
Note: The table shows the decomposition of the two risks into the indirect exposure component ("indirect") and the direct exposure broken down by sectors. The economic risk is measured under two scenarios: (a) when the demand shock affects all social consumption sectors, and (b) when the shock only affects retail (including retail of vehicles). Each sector's contribution to the economic-risk exposure is computed as ($\mathsf{ecorisk}_i \times \bar{L}_i / \bar{L}$). The contribution to the health-risk exposure is computed similarly.

Figure 1: Exposure to health risk



Note: Health risk is measured as proportion of sector's workers needed to maintain and who cannot work from home. Essential sectors in dark blue. Light sectors are direct or indirect suppliers to essential sectors.

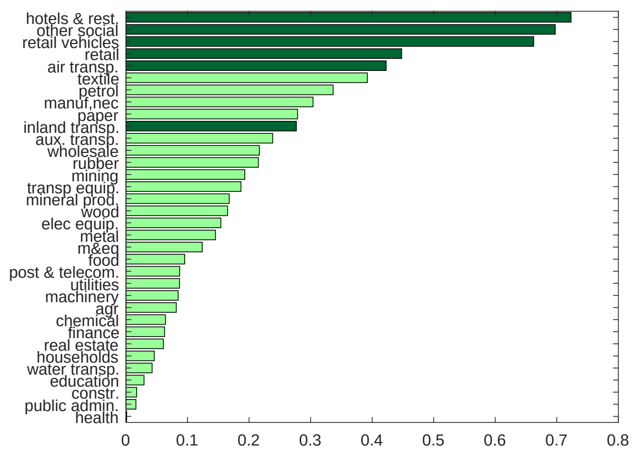
Figure 2: The two components of the health risk exposure



Note: Essential sectors in dark bars. Sectors in the south-east quadrant are at higher risk. The dash lines show the US average of the two components.

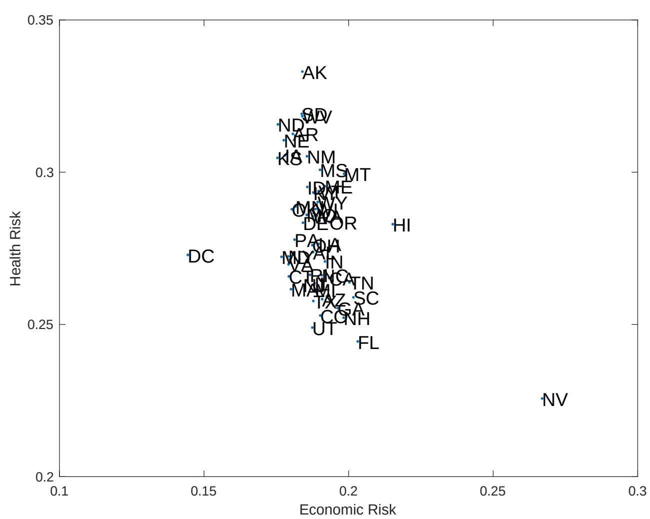
other shocks.

Figure 3: Exposure to economic risk



Note: Economic risk measured as the decline in employment following a 90% reduction in household demand for social consumption. Dark green bars are the social-consumption sectors. Light green bars are the sectors not directly affected by the shock.

Figure 4: Health and economics risk across U.S. states



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APPENDIX

A Methodology

Supply chains. We use the input-output framework of Leontief (1936) to compute how changes in final demand cascade across sectors. Each sector's product is used either by final users or as an input by other domestic firms:

$$p_i Q_i = p_i C_i + \sum_j p_i X_{ji} \; \forall i = 1, ..., n,$$

where Q_i is the gross output of sector i, p_i its price, C_i its use by final users, and X_{ji} its use by sector j. Note that final use C_i is composed of the demand from households, C_i^{hh}, as well as investment and exports.

This system of equations can be rewritten in matrix form:

$$\boldsymbol{q} = \boldsymbol{c} + \boldsymbol{M}'\boldsymbol{q},$$

with $q_i = p_i Q_i$, $c_i = p_i C_i$, and $M_{ij} = (p_j X_{ij})/(p_i Q_i)$. Hence, gross output is given by

$$\boldsymbol{q} = (\boldsymbol{I} - \boldsymbol{M}')^{-1}\boldsymbol{c}, \tag{A.1}$$

with $\boldsymbol{I}$ the identity matrix. The matrix $(\boldsymbol{I} - \boldsymbol{M}')^{-1}$ is called the total requirement matrix. The first column of the matrix gives how many dollars of each sector's product is required to produce one dollar of final output of the first sector's product.

Demand linkages. In addition to accounting for supply chains, we account for the complementarity between the demand for retail trade, wholesale and transportation, and the demand for manufacturing goods.

The household demand for retail and wholesale trade is

$$c_d^{hh} = \sum_i \theta_d^i c_i^{hh}, \tag{A.2}$$

where d denotes a distribution sector (retail trade or wholesale trade), c_i^{hh} is the value of household demand for product i and θ_d^i is the distribution margin, with $\theta_d^i > 0$ if i is a manufacturing sector. The demand for transportation includes both transportation margins and the demand for passenger transit:

$$c_{\mathsf{transp}}^{hh} = \sum_i \theta_{\mathsf{transp}}^i c_i^{hh} + c_{\mathsf{passenger}}^{hh}, \tag{A.3}$$

where c^{hh}_{transp} denotes the household demand for shipping and $c^{hh}_{\mathsf{passenger}}$ its demand for passenger transit services.

Similar equations can be written for the other components of final demand, exports and investment (without passenger transportation). The final demand for the trade and transportation sectors is of the form

$$c_d = \sum_i \bar{\theta}^i_d c_i, \tag{A.4}$$

where $\bar{\theta}^i_d$ is the average margin across the different final uses.

Health risk measure. We measure the exposure to the health risk as the proportion of workers needed *at the workplace* to maintain the final use of essential goods and services to its pre-pandemic level.

1. We compute the vector of final output, $\boldsymbol{c}$, when the demand for essential goods and services only is maintained. Final demand is set equal to the prepandemic level for all essential sectors. All the non-essential sectors' final demand is set to zero, except for retail, wholesale and transportation. Although these three sectors are not essential sectors, their services are required to ensure the delivery of essential goods. We compute their final use from equation (A.4) (under the assumption that $\bar{\theta}^i_d$ is identical across sectors i) where c_i is nonzero only for essential products.

2. We use equation (A.1) to compute the gross output required in all the sectors to produce the vector of essential final demand .

3. Assuming that labor productivity is constant, the proportion of pre-pandemic employment needed is equal to the ratio of the gross-output to its pre-pandemic level.

4. Finally, we adjust the measure by subtracting the proportion of the employment needed that can be done from home using the Dingel and Neiman (2020) measure, as described in Section 2.

Economic risk measure We measure the exposure to the economic risk as the decline in employment following a 90% decline in the household demand for sectors providing social consumption. We assume that investment and exports remain constant and that the shutdown only affect the households' final demand c^{hh}_i. We take into account the critical role of the retail sector. The demand for manufactured goods is proportional to trade services (equation (A.2)), therefore the shutdown of stores disrupts the demand for manufactured goods, which in turn affects the demand for wholesale and transportation services.

Note that we consider that the retail sector is only partially affected by the demand shock. The retail sales of agricultural, food, and chemical products are spared from the shutdown, capturing the fact that foods stores and pharmacies remain open, and so are online retailers. This smaller demand shock leads to a smaller demand shock for transportation and wholesale trade.

The pre-pandemic variables are denoted $\overline{q}$, $\overline{c}$ and $\overline{c}^{hh}$.

1. We compute the vector of final demand, $\boldsymbol{c}$, following the drastic demand shock. Final demand does not collapse to the same extent in all sectors.

   (a) For social-consumption sectors except retail, wholesale trade and transportation, final demand is:
   $$\frac{c_i}{\overline{c}_i} = -0.9\frac{\overline{c}_i^{hh}}{\overline{c}_i} + 1.$$

   (b) For retail trade, final demand is
   $$\frac{c_{\mathsf{rtrade}}}{\overline{c}_{\mathsf{rtrade}}} = -0.9(1-\phi_{\mathsf{rtrade\_open}})(1-\phi_{\mathsf{rtrade\_online}})\frac{\overline{c}^{hh}_{\mathsf{rtrade}}}{\overline{c}_{\mathsf{rtrade}}} + 1$$
   where $\phi_{\mathsf{rtrade\_open}} = \overline{c}^{hh}_{\mathsf{rtrade\_open}}/\overline{c}^{hh}_{\mathsf{rtrade}}$ denotes the share of retail trade services for the procurement of agricultural, food, and chemical products, and $\phi_{\mathsf{rtrade\_online}} = \overline{c}^{hh}_{\mathsf{rtrade\_online}}/\overline{c}^{hh}_{\mathsf{rtrade}}$ denotes the share of online retail trade services.

   (c) For transportation services, final demand is
   $$\frac{c_{\mathsf{transp}}}{\overline{c}_{\mathsf{transp}}} = -0.9\left[\phi_{\mathsf{passenger}} + (1-\phi_{\mathsf{passenger}})(1-\phi_{\mathsf{transp\_open}})(1-\phi_{\mathsf{rtrade\_online}})\right]\frac{\overline{c}^{hh}_{\mathsf{transp}}}{\overline{c}_{\mathsf{transp}}} + 1$$
   where $\phi_{\mathsf{transp\_open}} = \overline{c}^{hh}_{\mathsf{transp\_open}}/\overline{c}^{hh}_{\mathsf{transp}}$ denotes the share of transportation services for the procurement of agricultural, food, and chemical products, and $\phi_{\mathsf{passenger}} = \overline{c}^{hh}_{\mathsf{passenger}}/\overline{c}^{hh}_{\mathsf{transp}}$ denotes the share of passenger transit.

   (d) For wholesale trade, final demand is
   $$\frac{c_{\mathsf{wtrade}}}{\overline{c}_{\mathsf{wtrade}}} = -0.9(1-\phi_{\mathsf{wtrade\_open}})(1-\phi_{\mathsf{rtrade\_online}})\frac{\overline{c}^{hh}_{\mathsf{wtrade}}}{\overline{c}_{\mathsf{wtrade}}} + 1,$$
   where $\phi_{\mathsf{wtrade\_open}} = \overline{c}^{hh}_{\mathsf{wtrade\_open}}/\overline{c}^{hh}_{\mathsf{wtrade}}$ denotes the share of wholesale trade services for the procurement of agricultural, food, and chemical products.

(e) For all manufacturing goods except agricultural, food and chemical products, final demand is

$$\frac{c_i}{\bar{c}_i} = -0.9(1 - \phi_{\mathsf{rtrade\_online}})\frac{\bar{c}_i^{hh}}{\bar{c}_i} + 1$$

(f) Final demand is equal to the sector's pre-pandemic level for all other sectors.

2. We use equation (A.1) to compute the gross output implied by the new vector $\boldsymbol{c}$.

3. Assuming that labor productivity is constant, the employment loss is equal to the ratio of the decline in gross output relative to the pre-pandemic level.

B Data and calibration

All data used in the calibration are publicly available. The main dataset is the World Input Output data (WIOD, 2016 release), available at http://www.wiod.org.

Input-Output data. To calibrate the input-output parameters (the elements of matrix $\boldsymbol{M}$), the pre-pandemic final demand and the household consumption share, $\bar{c}_i^{hh}/\bar{c}_i$, we use data from the WIOD for 2014 (latest year available), aggregated according to classification given in Table 2. The input-output parameters are computed as the value of domestic intermediate inputs over gross output (at basic prices). The pre-pandemic final demand is computed as the sum of Final consumption expenditure by households, Final consumption expenditure by non-profit organisations serving households, Final consumption expenditure by government, Gross fixed capital formation, and Changes in inventories and valuables and Exports. The household consumption share is equal to sum of the Final consumption expenditure by households, Final consumption expenditure by non-profit organisations serving households, and Final consumption expenditure by government, divided by total final demand.

Transportation and trade margins. To calibrate $\phi_{\mathsf{rtrade\_open}}, \phi_{\mathsf{wtrade\_open}}, \phi_{\mathsf{transp\_open}}$, we use US data on transportation and trade margins (after redefinition) published by the BEA for 2012 (latest available year) in the Industry Economic Accounts. We apply these margins to all the countries of the sample. To calibrate $\bar{\theta}_i^d$, we impute average margins from the WIOD data (using equation (A.4) and under the assumption that the margins are identical across sector i).

Table 2: List of sectors

		Essential	Social Cons
AtB	Agriculture, Hunting, Forestry and Fishing	×	
C	Mining and Quarrying		
15t16	Food, Beverages and Tobacco	×	
17t19	Textiles and Textile Products; Leather and Leather Products		
20	Wood and Products of Wood and Cork		
21t22	Pulp, Paper, Paper , Printing and Publishing		
23	Coke, Refined Petroleum and Nuclear Fuel		
24	Chemicals and Chemical Products	×	
25	Rubber and Plastics		
26	Other Non-Metallic Mineral		
27t28	Basic Metals and Fabricated Metal		
29	Machinery, Nec		
30t33	Electrical and Optical Equipment		
34t35	Transport Equipment		
36t37	Manufacturing, Nec; Recycling		
E	Electricity, Gas and Water Supply	×	
F	Construction		
50	Sale and Repair of Motor Vehicles; Retail Sale of Fuel		×
51	Wholesale Trade and Commission Trade, Except of Motor Vehicles		
52	Retail Trade, Except of Motor Vehicles and Motorcycles		×
H	Hotels and Restaurants		×
60	Inland Transport		×
61	Water Transport		
62	Air Transport		×
63	Other Supporting and Auxiliary Transport Activities		
64	Post and Telecommunications	×	
J	Financial Intermediation	×	
70	Real Estate Activities		
71t74	Renting of M&Eq and Other Business Activities		
L	Public Admin and Defence; Compulsory Social Security	×	
M	Education		
N	Health and Social Work	×	
O	Other Community, Social and Personal Services		×
P	Private Households with Employed Persons		

Online trade. For the share of online trade, $\phi_{\mathsf{rtrade\_online}}$, we use the estimate of the U.S Census 2017 Annual Retail Trade Survey (9.1%).

Sectoral employment. The sectoral employment data is obtained from the WIOD Socio-Economic Account (2016 release). We use the number of persons engaged in 2014 (latest year available). For state-level sectoral employment, we use employment data from the BEA (Table SAEMP25N Total Full-Time and Part-Time Employment by NAICS Industry). We use a crosswalk from NAICS to ISIC and then from ISIC to the WIOD classificatioon.

Work-from-home Indicator. We use the workable from home index computed by Dingel and Neiman (2020), computed on the US, that we apply to all countries. The indicator shows the fraction of employment in each sector that can be *potentially* done from home, inferred from the characteristics of the occupations in the sector. Note that the indicator does not measure whether these activities are being *effectively* done at home during the lockdown. We use their benchmark indicator (employment-weighted).

C A short-run version of Osotimehin and Popov (2020)

Assuming perfect complementarity in production and no substitution possibilities in the household demand as in Leontief (1936) may seem like a stark assumption. We show here that this framework is suitable for our analysis. For demand shocks, a model with substitution possibilities in production and demand behave like the Leontief model in the short-run.

In Osotimehin and Popov (2020)), we consider a static multi-sector model with input-output linkages (which can be thought of as the steady state of a richer dynamic model). In the model, both firms and households can substitute between products. We find that in the short-run, under the assumption of sticky nominal wages and no labor reallocation across sectors, the model behaves like the Leontief model when subjected to demand shocks.

In the model, in each sector a representative firm produces goods with a constant-returns-to-scale production function

$$Q_i = A_i \left[(1-\alpha_i)^{1-\sigma}(B_i L_i)^{\sigma} + \alpha_i^{1-\sigma} X_i^{\sigma}\right]^{\frac{1}{\sigma}}, \tag{C.1}$$

where B_i is the labor-augmenting productivity component, A_i is the Hicks-neutral productivity component, and L_i is the labor input. The intermediate-input bundle is given by

$$X_i = \left(\sum_j v_{ij}^{1-\rho} X_{ij}^{\rho} \right)^{\frac{1}{\rho}}, \tag{C.2}$$

where X_{ij} is the quantity of intermediate goods from sector j used by sector i. We impose $\alpha_i \in [0,1)$, $v_{ij} \in [0,1]$, and $\sum_{j=1}^{n} v_{ij} = 1$ for all $i = 1, ..., n$, $\rho \in (-\infty, 1)$ and $\sigma \in (-\infty, 1)$. Final output (consumption) is an aggregate of the goods from the different sectors,

$$Y = \prod_{i=1}^{n} \beta_i^{-\beta_i} \prod_{i=1}^{n} C_i^{\beta_i}, \tag{C.3}$$

with $\beta_i \in [0,1]$, $\sum_{i=1}^{n} \beta_i = 1$. Finally, we assume that firms charge exogenous sector-specific markups μ_i over marginal costs. The prices p_i are given by

$$(p_i/w) = A_i^{-1} \mu_i \left[(1-\alpha_i) B_i^{\frac{\sigma}{1-\sigma}} + \alpha_i \left[\sum_{j=1}^{n} v_{ij} \left(p_j/w\right)^{-\frac{\rho}{1-\rho}} \right]^{\frac{1-\rho}{\rho} \frac{\sigma}{1-\sigma}} \right]^{-\frac{1-\sigma}{\sigma}}, \tag{C.4}$$

and final consumption by

$$C_i = \beta_i / (p_i(1 + \tau_{Ci})Y, \tag{C.5}$$

where w is the wage and τ_{Ci} is the demand shock, which we assume takes the form of a distortion on the households' first-order condition and P is the effective price level given by:

$$P = \prod_i \left[p_i(1 + \tau_{Ci})\right]^{\beta_i} \tag{C.6}$$

Under the short-run assumptions, we can see from equation (C.4) that prices are fixed at their pre-shock level. Together with the constant returns to scale assumption, this result implies that the ratios X_{ij}/Q_i and L_i/Q_i are constant like in the Leontief model.

All the sectors have zero distortion before the shock and only the affected sectors experience a distortion after the shock. For all the affected sectors we have:

$$1 + \tau'_{Ci} = \frac{\bar{C}_i}{C'_i} \frac{\bar{P}\bar{Y}}{P'Y'},$$

where bars denote pre-shock values and primes denote after-coronavirus shock values. Then plugging in the production function (C.1) and the price level (C.6), equation (C.5) shows an equilibrium of the model is that the final demand stays to its pre-shock level in the sectors not affected by the shock, as assumed in our analysis.

If the products produced by the direct or indirect suppliers to the affected sectors cannot be used for final use, this is the only equilibrium. We have computed all other equilibria of the model and find that the difference from the Leontief equilibrium is quantitatively negligible even when products produced by the suppliers of the affected sectors can be used for final use.