Sectoral effects of social distancing

Jean-Noël Barrot, Basile Grassi, and Julien Sauvagnat[1]

March 2020

Work in progress

Abstract

The health crisis caused by the outbreak of the Covid-19 virus has led many countries to implement drastic social distancing rules. By reducing the quantity of labor, social distancing in turn leads to a drop in output which is difficult to quantify without taking into account relationships between sectors. Starting from a standard model of production networks, we analyze the sectoral effects of the shock in the case of France. We estimate that six weeks of social distancing brings GDP down by 5.6%. Apart from sectors directly concerned by social distancing mesures, those whose value added decreases the most are upstream sectors, i.e. sectors most distant from final demand. The same exercise is carried out for other European countries, taking into account national differences in sectoral composition and propensity to telework. Finally, we analyze the economic impact of selectively phasing out social distancing by sector, region or age group.

[1] Jean-Noël Barrot is affiliated with HEC Paris (barrot@hec.fr). Basile Grassi (basile.grassi@unibocconi.it) and Julien Sauvagnat (julien.sauvagnat@unibocconi.it) are affiliated with Bocconi. We thank Hlne Rey and Xavier Ragot for helpful comments.

1 Introduction

The global health crisis caused by the outbreak of the Covid-19 virus has led many countries to implement drastic measures of social distancing. These include shutting down public spaces, restaurants and shops, closing schools, and restricting any economic activity inducing close physical contact between workers. Such restrictions are considered a powerful way of slowing virus propagation and saving human lives. By reducing the quantity of labor, social distancing in turn leads to a drop in output that we explore in this paper.

The economic effects of social distancing rules implemented to curb the spread of the Covid-19 virus depends on the structure of production networks. Modern economies are indeed characterized by the many interdependencies formed by companies in their production processes. These interdependencies are well identified in the literature as facilitating the propagation of non-systemic shocks (Barrot and Sauvagnat, 2016) and their aggregation (Acemoglu et al., 2012; Baqaee and Farhi, 2019), with applications for public policies (Grassi and Sauvagnat, 2019). For a recent review, see Carvalho and Tahbaz-Salehi (2018). We build on the findings of this literature and analyze the effects of social distancing in production networks.

We first calibrate a standard network model, the static version of the general equilibrium model in Long and Plosser (1983) analyzed by Carvalho (2010) and Acemoglu et al. (2012), to the French economy. We use the French Census to determine the share of workers affected by administrative closings and restaurants, and by school closings. We leverage survey data on telework to quantify the share of workers in each sector that remain active despite of confinement. We then show how social distancing disrupts national production through the network of input-output linkages. We estimate that six weeks of social distancing brings GDP down by 5.6%. Apart from the sectors directly concerned by social distancing measures, those whose value added decreases the most are upstream sectors, i.e. sectors most distant from final demand.

The same exercise is carried out for other European countries, taking into account national differences in sectoral composition and propensity to telework. For this, we leverage data on international input-output tables from the "World Input-Output Database" (WIOD, version 16) split into 54 sectors. The estimated fall in GDP ranges from 4.3% (Denmark) to 9.2% (Bulgaria). These differences are partly explained by cross-country differences in sectoral composition, and partly by their workforce propensity to telework.

We finally analyze the economic impact of selectively phasing out social distancing by sector, region or age group. We find the economic benefits of selective phasing out are relatively insensitive to the choice of regions and age groups, but highly sensitive to the choice of sectors.

Our work relates to the recent growing literature on the propagation of shocks in production networks. Recent empirical studies by Barrot and Sauvagnat (2016), Carvalho et al. (2014) and Boehm et al. (2019) exploiting natural disasters for identification confirm that disruptions hitting the production of specific firms spill over to other firms and sectors through input-output linkages. Liu (2019) describes how a network model with distortions can be used in order to assess the effect of industrial policies, and shows that industrial policies that disproportionately target upstream sectors can be welfare-improving. Bigio and La'O (2016), Altinoglu (2018), and Reischer (2019) explore the interaction between financial frictions and the input-output structure of an economy, through the trade-credit relationships between suppliers and customers, and show that credit linkages transmit financial shocks across the economy, amplifying their effects on aggregate output. Recent empirical studies such as Boissay and Gropp (2013), Tor and Schedvin (2015), Costello (2017) and Jorion and Zhang (2009) confirm that liquidity shocks propagate within networks of firms through these trade credit linkages.

We also contribute to a recent stream of new work on the macroeconomic implications of the Covid-19 virus. Berger et al. (2020), Atkeson (2020), Eichenbaum et al. (2020), and Fernando Alvarez and Lippi (2020) incorporate epidemiological SIR or SIER models of contagion in macro models. Veronica Guerrieri and Werning (2020) present a theory of Keynesian supply shocks in which supply shocks may trigger changes in aggregate demand larger than the shocks themselves. Hall et al. (2020) provides insights on the tradeoff between consumption and COVID-19 deaths. Barro et al. (2020) and Correia et al. (2020) study the 1918 Flu Pandemic in the U.S., Greenstone and Nigam (2020) study the implications of social distancing measures whereas Andrew Glover and Ros-Rull (2020) focuses on the distribution effects of the COVID-19. Another line of research focuses on optimal policies in economies hit by an epidemic, such as optimal fiscal policies Faria-e Castro (2020), and optimal quarantine and testing policies Piguillem and Shi (2020); Gollier and Gossner (2020).

The rest of the paper is structured as follows. Section 2 details the construction of the sectoral COVID 19-related labor shocks. Section 3 describes the production network whereas Section 4 presents our model and its calibration. Section 5 presents our results whereas Section 6 offers concluding remarks.

2 Effect of social distancing on the workforce

Administrative closings The decree of March 14, 2020 prohibits certain categories of establishments from opening to the public[2]. Exceptions are granted by the decree of March 15, 2020, and relate in particular to the food and basic necessities trade. To estimate the reduction in active workforce due to administrative closings in each sector, we proceed as follows. Starting from the finest sector classification, the NAF rev. 2 in 732 sector classification, we identify the sectors corresponding to the decree of March 14, 2020, for which we consider that the active workforce is zero. By aggregation, using the number of workers by sector in the 2016 census data available on the INSEE website, we obtain the share of the inactive workforce for each of the 38 sectors of the aggregated NAF rev. 2 classification. The share of the total workforce affected by administrative closings stands at 10.9% and is concentrated in directly affected sectors: hotel and restaurants, arts and leisure, wholesale and retail, social work.

Closures of nurseries, schools, secondary schools and high schools In addition, all nurseries, schools, colleges and high schools were closed from March 16, 2020, in accordance with the decree of March 14, 2020. To estimate the effects on the workforce in each sector, we use data from the census to identify, in each of the 38 sectors of NAF rev. 2, the share of working people with dependent children under 16 and therefore forced into inactivity[3]. The share of the total workforce affected by childcare caused by the closings of nurseries, secondary schools and high schools stands at 13.2%[4], and varies, if we leave aside the sectors concerned by administrative closings and the health sector, from 11.7% (Agriculture) to 19.4% (Pharmaceuticals).

Confinement On the other hand, to prevent the spread of the Covid-19 virus, traffic restrictions are imposed, as well as the strict compliance with a safety dis-

[2]Hearing rooms, conferences, meetings, shows or for multiple use; Sales stores and Shopping centers, except for their delivery and order picking activities; Restaurants and drinking places, except for their takeaway delivery and sales activities, room service in hotel restaurants and bars and contract catering; Dance halls and play rooms; Libraries, documentation centers; Exhibition halls; Covered sports establishments; Museums; Marquees, tents and structures; Outdoor establishments; Educational, educational, training establishments, holiday centers, leisure centers without accommodation.

[3]More specifically, we consider that an active person has dependent children if there is no other inactive person in the household, who could take care of them. If there are several active adults in the household, we consider the drop in activity to be evenly distributed among these adults. We exclude from this calculation those are forced to inactivity because of administrative closings, and health workers whose children are taken care of in the school system.

[4]Sadique et al (2008) obtain a similar proportion based on English data.

tance of one meter between each individual. So that these rules do not lead to the shut down of business, the Minister of Labor asked firms to facilitate remote work as much as possible (telework), and urged companies to bring together their Social and Economic Committee (CSE) to adapt working conditions to health guidelines. In the absence of better data, the share of the active population in each sector likely to continue working at home is estimated using data from the European Community survey on the use of ICT and electronic commerce in businesses carried out by INSEE for Eurostat on a sample of 12,500 companies. This provides, for each sector, the share of employees of companies with more than 10 employees using a portable device provided by the company, connected to the Internet via the network of mobile phones (laptop, smartphone, tablet, etc.) in 2019. This stands at 32%, which is consistent with some recent telework surveys [5]. However, confinementshould lead companies to increase their use of telework. The ICT survey also provides the share of employees of companies with more than 10 employees using a computer (including a portable device) with internet access for professional use (fixed or mobile connection), which averages 62%. We note that this indicator is significantly correlated (correlation = 0.5) with the share of employees in telework in 2017 estimated by DARES[6]. Some sectors being excluded from the survey (agriculture, financial services, public administration), the missing variable is imputed by applying the average ratio between the survey variable and the share of employees in telework estimated by DARES. In the limit case of absolute confinement, only these employees could continue to work, either because they can work at home, or because it is probably easier to reorganize their work environment in accordance with social distancing rules.

Cumulative effect By combining the effect of administrative closings, that of childcare imposed by the closings of nurseries, schools, colleges and high schools, and that of strict confinement allowing only people usually working with a computer to continue to do so, we obtain an overall drop in the active workforce of 52%[7]. The detail by sector is presented in Figure 1. The effect is broken down according to the origin of the shock. In blue, the effect of administrative closings; in red, the additional effect of school closings; and in green, the residual effect of confinement. Unsurprisingly, "arts and leisure" and "hotel restaurants" are the hardest hit, due to administrative closings. Next comes "agriculture" or "business services", where

[5] See for example the 2020 Telework study by Malakoff Humanis, March 2020

[6] DARES Analyses, November 2019, Number 051

[7] This number is remarkably close to estimates by Google of the drop in workplace mobility, -56% relative to baseline in France, see COVID-19 Community Mobility Report as of March 29, 2020

the share of the workforce who does not work on a computer is high. Conversely, “technical activities ”, “ telecommunications ” or “computer services” are relatively spared.

3 Description of the production network

Companies, and consequently the sectors of the French economy, are linked to each other through the network of customer-supplier relationships. There is no data to trace these business-to-business relationships. We therefore rely on the input-output table produced by INSEE, which describes and synthesizes transactions in goods and services in product and branch of activity. Figure 2 shows the structure of the French production network according to the 38 branches of activity of the NAF rev. 2 for 2015. We report the full description of each branch in Table 3.

In the first panel, each column represents the production of a sector. Each row represents the intermediate consumption of a sector, ie the inputs of its production process. In short, the column sectors are the suppliers, the row sectors are the customers. Each box in the table gives the intensity of use by a sector (on the columns) of the input (on the rows) in its production process. The darker the blue, the more quantitatively important the input. We thus verify that for the line (client sector) “hotel restaurants”, the column (supplier sector) “food” is quantitatively important. We note that certain supplier sectors, in columns, contribute significant inputs from a large number of sectors. These are “business services ”, “ consulting”, and “ wholesale and retail ” activities.

In the second panel of Figure 2 are represented the links between sectors. Each point represents a sector, and its size is proportional to the total volume of its inputs. Each line represents a relation between a supplier sector and a client sector, and its width is proportional to the share of the input in the total of the inputs of the client. This graph highlights the chains of links: thus, the “agriculture” sector is an important input of the “food” sector, itself an important input of the “hotel restaurants” sector.

Finally, we report in Table 4 two key network statistics, Bonacich-Katz centrality and upstreamness, for each sector of the economy. The centrality of a sector measures the importance as a supplier to the economy, whereas the upstreamness measures the number of nodes between a given sector and the final demand.

Denoting $(I - \Gamma)^{-1}$ the Leontief inverse of the adjacency matrix Γ, and, β the vector of final demand share β_i, we can write the Bonacich-Katz centrality for each industry i, v_i, as

$$v' = \beta' (I - \Gamma)^{-1} = \beta' + \beta'\Gamma + \beta'\Gamma^2 + \ldots + \beta'\Gamma^k + \ldots, \tag{1}$$

where Γ^k is the power k of the production network adjacency matrix, Γ. In graph theory, the power k of an adjacency matrix records the existence of a path of length k between two nodes. Here the same intuition applies to the terms on the right hand side of equation 1: $\beta'\Gamma^2$ records the contribution of paths of length two between any sector and the final demand, $\beta'\Gamma$ the contribution of paths of length one, and, β' the contribution of paths of length zero that is the direct sales to the final demand. The Bonacich-Katz centrality of sector i, v_i, is the contribution of all the paths of any length from any sector to the final demand. As shown in Table 4, the sector "Construction" has a higher network centrality than "Chemicals", which indicates that "Construction" is overall a more important supplier than "Chemicals" for the economy.

We construct upstreamness of each sector as in Antras et al. (2012). For instance, Iron ore extracted by the "Mining" industry is first transformed in steel by the "Metal" sector, which is then turned into a car by the "Transport Equipment" sector before being sold to final consumers. In that simple example of a vertical economy, the "Mining" sector is upstream to the "Metal" sector, which is itself upstream to the "Transport Equipment" sector.

4 Theoretical Framework

To analyze the effect of social distancing on GDP and on the value added in each sector, we construct a standard model of production networks. Each sector produces a good by using labor and intermediate consumption produced by the other sectors, and by choosing the quantities so as to maximize its profit. Households consume goods produced by sectors[8], and provide a fixed amount of labor to each sectors so as to maximize their utility.

The economy's response to the shock depends on two parameters. The elasticity of substitution between goods drives the responses of household consumption to changes in relative prices. If the elasticity is greater than 1, an increase in the price of a given good leads to a decrease in its share in the household consumption basket, and vice versa. Similarly, the elasticity of substitution between intermediate goods describes the response of sectors to a change in the relative prices of the inputs

[8]In such a closed economy model, household consumption includes public spending, investment and exports

they use. The higher it is, the more a sector can substitute inputs between them. This elasticity is lower when the horizon is short - it can be difficult to quickly substitute inputs between them -, and the level of aggregation is high - it is easier for a company to change supplier, than for a sector to do without with an upstream sector. We rely on the literature to calibrate the elasticity of substitution between final goods at 3, and the elasticity of substitution between intermediate inputs at 0.5. We check that the results are robust to alternative values.

The model is useful for estimating the effect of the supply shock linked to social distancing, and its propagation throughout the production network. It does not take into account international trade[9]. Economic shocks affecting foreign countries with domestic repercussions are not quantified here. Furthermore, the model does not integrate the effect of automatic stabilizers and economic support policies announced in response to the crisis, such as the extension of partial unemployment, the suspension of contributions and tax charges, or the solidarity fund for the self-employed and very small businesses in France. The model also does not integrate the effects of possible demand shocks caused by the health crisis: increased demand for medical and surgical equipment, or the consumption of digital services. The model also ignores possible changes in the structure of consumption (or preference parameters in the utility function) of households linked to the consequences of the outbreak of the virus. Finally, it ignores the amplification effects linked to potential business bankruptcies, the destruction of customer-supplier relationships, and more generally the destruction of companies' relational or organizational capital.

4.1 Model

In this section we describe formally the framework we use to evaluate the economic cost of social-distancing. We then derive the equilibrium equations we use to calibrate and solve this model.

In our framework, there are N goods that are each produced in its sector by a representative firm using sector-specific labor and other industries' goods as inputs for production. There is a representative household that consumes each of the N goods of this economy. She supplies inelastically h_i unit of labor, specific to the sector i. The representative household assumption is intended to capture the behavior of the final demand, that is, the sum of household consumption, government purchases, investment and exports. The representative household maximizes its utility, while firms maximize their profit in a perfectly competitive environment.

[9] The effects of the shock in China on the French economy is studied, for example, by Gerschel et al. (2020)

We denote f_i the quantity of good i consumed and pruchase by the household at price p_i. The GDP of this economy is equal to the sum of the value of the final consumption: $GDP = \sum_i p_i f_i$. The household maximizes its utility that we assume to be of the Constant-Elasticity-of-Substitution (CES) form:

$$C(f_1, \dots, f_N) = \left(\sum_i \beta_i^{\frac{1}{\sigma}} f_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

where σ is the elasticity of substitution between two goods. A value of σ greater than one means that there is substitution. For a value of σ equal to one, the above utility becomes Cobb-Douglas. When σ smaller than one, there is complementarities among the consumption of different goods. When maximizing its utility, the representative household spends a share of its income on good i that depends on the value of the taste parameter β_i and the price of the good i according to:

$$\frac{p_i f_i}{PC} = \beta_i \left(\frac{p_i}{P} \right)^{1-\sigma} . \tag{2}$$

Where $P = \sum_i \beta_i p_i^{1-\sigma}$ is the price index associated to the bundle of goods consumed by the household. Without loss of generality, we normalize this price index to one.

The household expenditure is constrained by its income which is the sum of its labor income, $\sum_i w_i h_i$ where w_i is the wage in sector i, and the profit of the firms she owns. The total income of the household, which is equal to its expenditure, is equal to the GDP of this economy. Note that in presence of substituability ($\sigma > 1$), following an increasing of the price in sector i, the expenditure share on goods i is decreasing. Indeed, the substitution effect dominates, the household spend less on the good i and more on the other goods in term of its expenditure share. Conversely, in presence of complementarities ($\sigma < 1$), the expenditure share on goods i is increasing. In this case, the income effect dominates and the household spend more of its income on this good. Finally, for the Cobb-Douglas case ($\sigma = 1$), the expenditure share on good i is constant and the substitution and income effects cancelled out exactly.

Each of the N sectors is populated by a representative firm that maximizes profit to produce exactly one of the N goods. We assume that these representative firms are in a perfectly competitive environment and thus take input and output prices as given. In sector i, the representative firm transforms the sector i specific labor h_i and other goods into y_i units of good i according to the following production function:

$$y_i = z_i \left(\alpha_i^{\frac{1}{\theta}} h_i^{\frac{\theta-1}{\theta}} + \sum_{j=1}^{N} \widetilde{\Gamma}_{ij} x_{ij}^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}}.$$

In the above equation, z_i is the total factor productivity (TFP) in this sector, x_{ij} is the ammount of good j used by the sector i in its production process, θ is the elasticity of substitution among inputs of production, and, α_i and $\widetilde{\Gamma}_{ij}$ are parameters that describe the technology available to the firm in sector i. As for the preference of households, the elasticity of substitution θ determines the presence of complementarities and substituabilities among inputs. For $\theta = 1$ the production function nests the Cobb-Douglas case while for $\theta = 0$ the Leontieff case.

Under perfect competition, the representative firm in sector i chooses the level of input, that is, the quantity of labor, h_i, and other goods used as intermediates x_{ij}, in order to maximize its profit. Sovling for the firm's problem implies that the share of expenditure on each inputs is such that:

$$\frac{w_i h_i}{p_i y_i} = \alpha_i z_i^{\theta-1} \left(\frac{w_i}{p_i} \right)^{1-\theta} \tag{3}$$

$$\frac{p_j x_{ij}}{p_i y_i} = \widetilde{\Gamma}_{ij} z_i^{\theta-1} \left(\frac{p_j}{p_i} \right)^{1-\theta} \tag{4}$$

These equations determine the demand of each inputs by the firm in sector i as a function of relative price, TFP, and the technology parameters. It follows that the share of sector i's income spend on the intermediate good j is a function of the relative price of that good and the parameter $\widetilde{\Gamma}_{ij}$. The production network, defined by its adjacency matrix with typical element $\frac{p_j x_{ij}}{p_i y_i}$, is thus determined by technology and prices. Depending on the value of θ, the share of income spend on each inputs can increase of decrease following an increase in the relative price of an input. For $\theta = 1$, the share of expenditure are exactly equals to the parameters $\widetilde{\Gamma}_{ij}$ and is thus independent of prices.

The price charged for each good is, under perfect competition, equal to the marginal cost in the corresponding sector. For the sector i, the marginal cost is a function of the price of labor in this sector w_i, and of the price of the other goods. Indeed, solving for the cost minimization under perfect competition yields:

$$p_i^{1-\theta} = \alpha_i \left(\frac{w_i}{z_i} \right)^{1-\theta} + \sum_{j=1}^{N} \widetilde{\Gamma}_{ij} \left(\frac{p_j}{z_i} \right)^{1-\theta} \tag{5}$$

The price in sector i depends on the price in all other sectors p_j for all j (as long as the parameter $\widetilde{\Gamma}_{ij}$ is non-zero). The above recursive relationship can be solved by rewriting it in matrix form and give the price as a function of technology and wages. This equation is one of the key equilibrium condition of the model. The quantity of each good produced has to be equal to the quantity of goods consumed and used as intermediate inputs – that is, the market clears, $y_i = f_i + \sum_j x_{ji}$. Multiplying this market clearing condition by p_i^θ and using the expression of the demand for inputs in equation 4 together with the final demand 2 yields:

$$\frac{p_i^\theta y_i}{P^\sigma C} = \beta_i p_i^{\theta-\sigma} + \sum_{j=1}^{N} z_j^{\theta-1} \widetilde{\Gamma}_{ji} \frac{p_j^\theta y_j}{P^\sigma C}. \tag{6}$$

The above equation can also be solved in matrix form to gives $\frac{p_i^\theta y_i}{P^\sigma C}$ as a function of technology and preferences and prices. Given the technology parameters, α_i, $\widetilde{\Gamma}_{ij}$ and z_i, the inelastic labor supply in each sector h_i, the equilibrium of this economy is defined by the vector $(\{p_i^\theta y_i, p_i^{1-\theta}\}_{i=1..N}, P^\sigma C)$ that satisfies the system of equations 3, 5, 6, and, the normalization $P = 1$.

4.2 Calibration

In this section, we described how we choose the parameters of this economy. We want our model to be a good quantitative representation of the actual economy. To do so, given the deep parameters σ and θ, we choose the parameters of the model such that some moments computed in the model equalize the same moment of the actual data.

First, we choose the value for σ and θ following Barrot and Sauvagnat (2016) and set $\theta = 0.5$ and $\sigma = 3$. Second, using our data, we compute the final demand as a share of GDP spent on each sector, that is $\frac{p_i f_i}{PC}$, the labor share of income in each sector, that is $\frac{w_i h_i}{p_i y_i}$, the share of income spend on each input, that is the adjacency matrix of the production network $\frac{p_j x_{ij}}{p_i y_i}$. We present the final demand as a share of GDP and total employment for each sector in Table 4.

We choose the $2N + N^2$ parameters β_i, α_i, and, $\widetilde{\Gamma}_{ij}$ to match these $2N + N^2$ moments of the data. To do so, we search the parameter space such that the right-hand side of equations 2, 3 and 4 are equal to the data moments $\frac{p_i f_i}{PC}$, $\frac{w_i h_i}{p_i y_i}$, and, $\frac{p_j x_{ij}}{p_i y_i}$ respectively. Information on the calibrated parameters can be found in Table 1.

5 Results

5.1 Effect of social distancing on GDP

The model makes it possible to estimate the effect of social distancing on the value added of each sector, the weighted sum of which forms GDP. The results are presented for a period of 6 weeks. The estimated fall in annual GDP is -5.6%[10] . We decompose this number according to the origin of the shock, and present the result in Table 2. Administrative closings cause a decrease of 0.9%. When we add the closings of nurseries, colleges and high schools, the drop is 2.5%. The residual difference, ie 3.1 percentage points, is explained by confinement.

The model makes it possible to estimate the impact of the shock separately for each sector. Figure 4 shows the effect of six weeks of social distancing on annual value added growth in each sector. The effect is broken down according to the origin of the shock. In blue, the effect of administrative closings; in red, the additional effect of school closings; and in green, the residual effect of confinement. The drop varies from -8.8% to -4.1% depending on the sector. Among the sectors most affected, are some of those directly impacted by social distancing measures, such as "arts and leisure" (-7.7%) and "hotel restaurants" (-6.8%). However, among the most affected sectors are also several upstream sectors, i.e. those most distant from final demand, such as "mining" (-8.8%), and "technical activities" (-7.6%), "consulting" (-6.2%) or "utilities" (-6.0%). Thus, if the downstream sectors seem more directly disturbed by administrative closings in terms of active workforce, upstream sectors suffer most significantly in terms of value added.

5.2 Extension to other European countries

We next analyze the effect that social distancing would have on other European countries, taking into account only national differences in sectoral composition, and in the telework propensity. It is therefore assumed that all countries take the same decisions on administrative closings, closings of schools and confinement[11]. The structure of the production network in 54 branches is obtained from the "World Input-Output" database (WIOD, version 2016), which provides for each country the 2014 input-output table. The propensity of each sector in each country to telework

[10] This estimate is higher than that presented by INSEE in its Conjoncture Point of March 26, 2020 from contemporary shock data, which finds 3% for a month of social distancing, and to that presented by the OFCE in its Policy Brief of March 30, 2020. This difference can be explained by the fact that the model does not take into account automatic stabilizers and support policies .

[11] All countries in the sample closed their schools, but not all of them imposed administrative closings and confinement.

comes from the community survey on the use of ICT and electronic commerce in businesses described above.

The results are presented in Figure 5. The GDP drops on average by 6.6% in the sample, for six weeks of social distancing [12]. The fall in GDP ranges from 4.3% (Denmark) to 9.2% (Bulgaria). These differences are partly explained by the sectoral composition, and partly by the propensity to telework, as shown in Figure 8 which shows the correlation[13] between propensity to telework and decline in GDP.

5.3 Progressive phasing out of social distancing

Phasing out of social distancing is anticipated to be implemented progressively. The model allows us to predict the marginal effect on GDP that phasing out would have on each sector, region or age group, taken in isolation. We consider each sector (or region, or age group) one after the other assuming that social distancing is lifted after 4 weeks instead of 6, and we measure the effect on marginal on GDP. We then normalize the implied GDP in euros by the number of released workers, which gives an approximation of the marginal benefit per worker of phasing out social distancing. The results are presented in Figure 3-7. The effect on GDP (Panel A) varies by a factor of 4 across sectors and across regions, but is relatively stable by age group. The marginal effect per worker (Panel B) is stable by region and age group, but varies very strongly by sector.

These results must be interpreted with caution, and within the limits of the model's assumptions. They correspond to the effect of the decline in the workforce linked to social distancing and do not take into account international trade or public policies undertaken to support the economy. They describe the supply side response at the sectoral level and make it possible to identify the most affected sectors. They do not in any way challenge the importance of social distancing, which is well identified by the medical literature as an effective means of slowing down the epidemic propagation, whose human, social and economic costs are considerable.

6 Concluding remarks

The health crisis caused by the outbreak of the Covid-19 virus has led many states to take drastic measures of social distancing. By reducing the amount of work, these measures in turn lead to a drop in value added and output which is difficult to

[12] We note that France undergoes a drop in GDP of 5.4%, very close to the 5.6% estimated above from 38 sectors, instead of 54.

[13] A 10 percentage points increase in telework propensity increases GDP by 1%.

quantify without taking into account relationships between sectors. Starting from a standard model of production networks, we analyze the sectoral effects of the shock in the case of France. We estimate that six weeks of social distancing brings GDP down by 5.6%. Apart from the sectors directly concerned by social distancing measures, those whose value added decreases the most are upstream sectors, i.e. sectors most distant from final demand. The same exercise is carried out for other European countries, taking into account national differences in sectoral composition and propensity to telework. Finally, we analyze the economic impact of selectively phasing out social distancing by sector, region or age group.

Our work highlights that input-output analysis has important implications for understanding the propagation of epidemics in production network, and their associated overall macroeconomic impact. In this vein, an important question relates to assessing the welfare effects of partial job insurance policies. If high replacement rates depress labor supply, this is likely to disrupt production not only within affected sectors. Indeed, this will also affect production and therefore prices and output in downstream and upstream sectors. A natural extension of our work will be to study the macroeconomic effects of sector-specific job insurance policies.

References

Acemoglu, D., V. M. Carvalho, A. Ozdaglar, and A. Tahbaz-Salehi (2012, 09). The network origins of aggregate fluctuations. *Econometrica 80*(5), 1977–2016.

Altinoglu, L. (2018). The origins of aggregate fluctuations in a credit network economy. *Working Paper*.

Andrew Glover, Jonathan Heathcote, D. K. and J.-V. Ros-Rull (2020). Health versus wealth: On the distributional effects of controlling a pandemic. *Working Paper*.

Antras, P., D. Chor, T. Fally, and R. Hillberry (2012). Measuring the upstreamness of production and trade flows. *American Economic Review Papers and Proceedings*.

Atkeson, A. (2020). What will be the economic impact of covid-19 in the us? rough estimates of disease scenarios. *NBER Working Paper*.

Baqaee, D. R. and E. Farhi (2019). Networks, barriers, and trade. *Working Paper*.

Barro, R., J. F. Ursua, and J. Weng (2020). The coronavirus and the great influenza pandemic: Lessons from the "spanish flu" for the coronavirus's potential effects on mortality and economic activity. *NBER Working Paper*.

Barrot, J.-N. and J. Sauvagnat (2016). Input Specificity and the Propagation of Idiosyncratic Shocks in Production Networks. *The Quarterly Journal of Economics 131*(3), 1543–1592.

Berger, D., K. Herkenhoff, and S. Mongey (2020). An seir infectious disease model with testing and conditional quarantine. *Working Paper*.

Bigio, S. and J. La'O (2016, April). Financial frictions in production networks. Working Paper 22212, National Bureau of Economic Research.

Boehm, C. E., A. Flaaen, and N. Pandalai-Nayar (2019). Input linkages and the transmission of shocks: Firm-level evidence from the 2011 tohoku earthquake. *Review of Economics and Statistics 101*(1), 60–75.

Boissay, F. and R. Gropp (2013). Payment defaults and interfirm liquidity provision. *Review of Finance 17*(1853–1894).

Carvalho, V. M. (2010). Aggregate fluctuations and the network structure of intersectoral trade. mimeo.

Carvalho, V. M., M. Nirei, and Y. Saito (2014, June). Supply Chain Disruptions: Evidence from the Great East Japan Earthquake. Discussion papers 14035, Research Institute of Economy, Trade and Industry (RIETI).

Carvalho, V. M. and A. Tahbaz-Salehi (2018). Production networks: A primer. *Annual Review of Economics*.

Correia, S., S. Luck, and E. Verner (2020). Pandemics depress the economy, public health interventions do not: Evidence from the 1918 flu. *Working Paper*.

Costello, A. M. (2017). Credit market disruptions and liquidity spillover effects in the supply chain. *Working Paper*.

Eichenbaum, M. S., S. Rebelo, and M. Trabandt (2020). The macroeconomics of epidemics. *Working Paper*.

Faria-e Castro, M. (2020). Fiscal policy during a pandemic. *Working Paper*.

Fernando Alvarez, D. A. and F. Lippi (2020). A simple planning problem for covid-19 lockdown. *Working Paper*.

Gerschel, E., A. Martine, and I. Mejen (2020, 3). Propagation of shocks in global value chains: the coronavirus case. *IPP Policy brief* (53).

Gollier, C. and O. Gossner (2020). Group testing against covid-19. *Working Paper*.

Grassi, B. and J. Sauvagnat (2019, 12). Production networks and economic policy. *Oxford Review of Economic Policy 35*(4), 638–677.

Greenstone, M. and V. Nigam (2020). Does social distancing matter? *Working Paper*.

Hall, R. E., C. I. Jones, and P. J. Klenow (2020). Trading off consumption and covid-19 deaths. *Working Paper*.

Jorion, P. and G. Zhang (2009). Credit contagion from counterparty risk. *Journal of Finance 64*(2053–2087).

Liu, E. (2019, 08). Industrial Policies in Production Networks. *The Quarterly Journal of Economics 134*(4), 1883–1948.

Long, J. B. J. and C. I. Plosser (1983, February). Real Business Cycles. *Journal of Political Economy 91*(1), 39–69.

Piguillem, F. and L. Shi (2020). The optimal covid-19 quarantine and testing policies. *Working Paper*.

Reischer, M. (2019). Finance-thy-neighbor: Trade credit origins of aggregate fluctuations. *Working Paper*.

Tor, J. and E. V. Schedvin (2015). Trade credit and the propagation of corporate failure: an empirical analysis. *Econometrica 83*(1315–1371).

Veronica Guerrieri, Guido Lorenzoni, L. S. and I. Werning (2020). Macroeconomic implications of covid-19: Can negative supply shocks cause demand shortages? *Working Paper*.

Tables and figures

Table 1
Baseline Calibration

Parameters	Value	Descrption
σ	3	Barrot and Sauvagnat (2016)
θ	0.5	Barrot and Sauvagnat (2016)
N	36	# of sectors
α_i		median
β_i		median
$\widetilde{\Gamma}_{ij}$		median
$\widetilde{\Gamma}$		density of the network $\widetilde{\Gamma}$

Table 2
Effect of 6 weeks of social distancing on GDP

	Administrative closings	Administrative closings + School closings	Administrative closings + School closings + Confinement
GDP growth	-0.9%	-2.5%	-5.6%

Figure 1
Decrease in active workforce caused by social distancing measures

This figure shows the effects of social distancing measures on the workforce by sector (in %). Blue bars represent the decline in the active workforce due to administrative closings. Red bars, the additional effect linked to school closings. Green bars, the residual effect related to confinement.

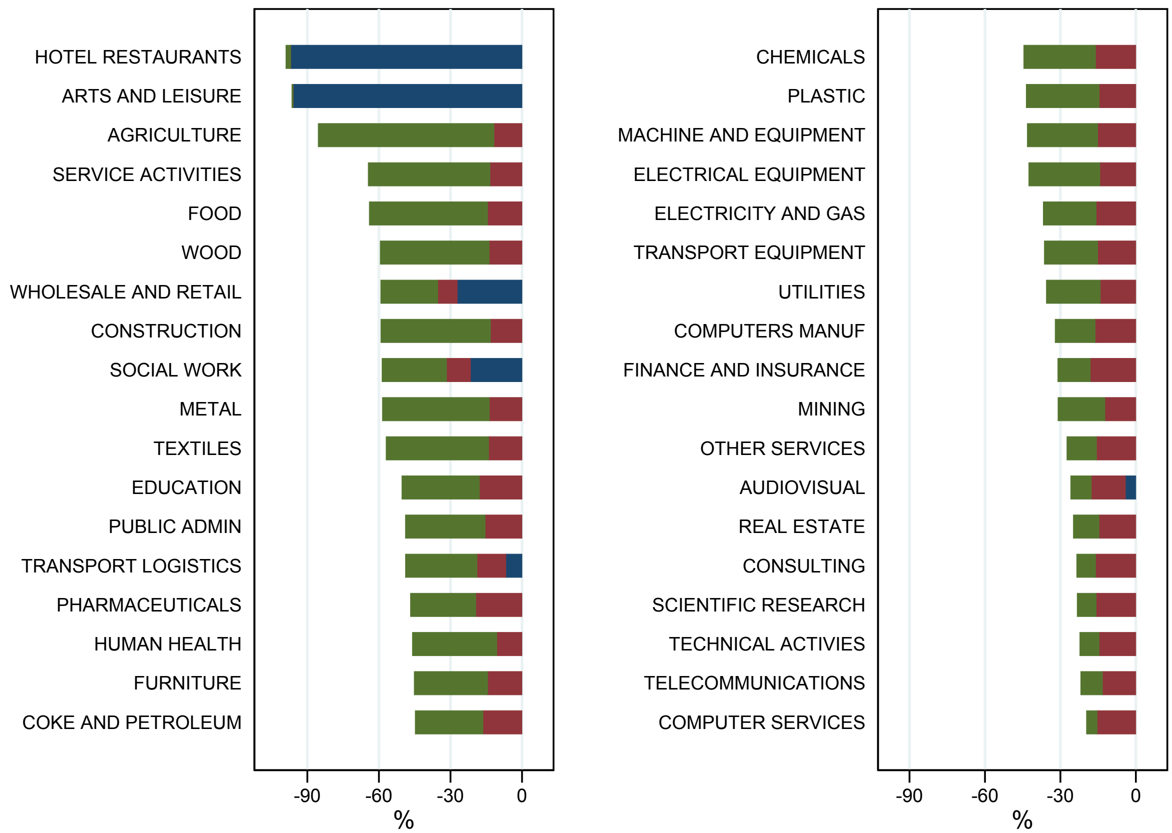


Figure 2
The French production network

This figure shows the structure of the French production network according to the 38 branches of activity of the NAF rev. 2. In the first panel, each column represents the production of a sector. Each line represents the intermediate consumption of a sector. In the second panel, each point represents a sector, and its size is proportional to the total volume of its inputs. Each line represents a relation between a supplier sector and a client sector, and its width is proportional to the share of the input in the total of the inputs of the customer.

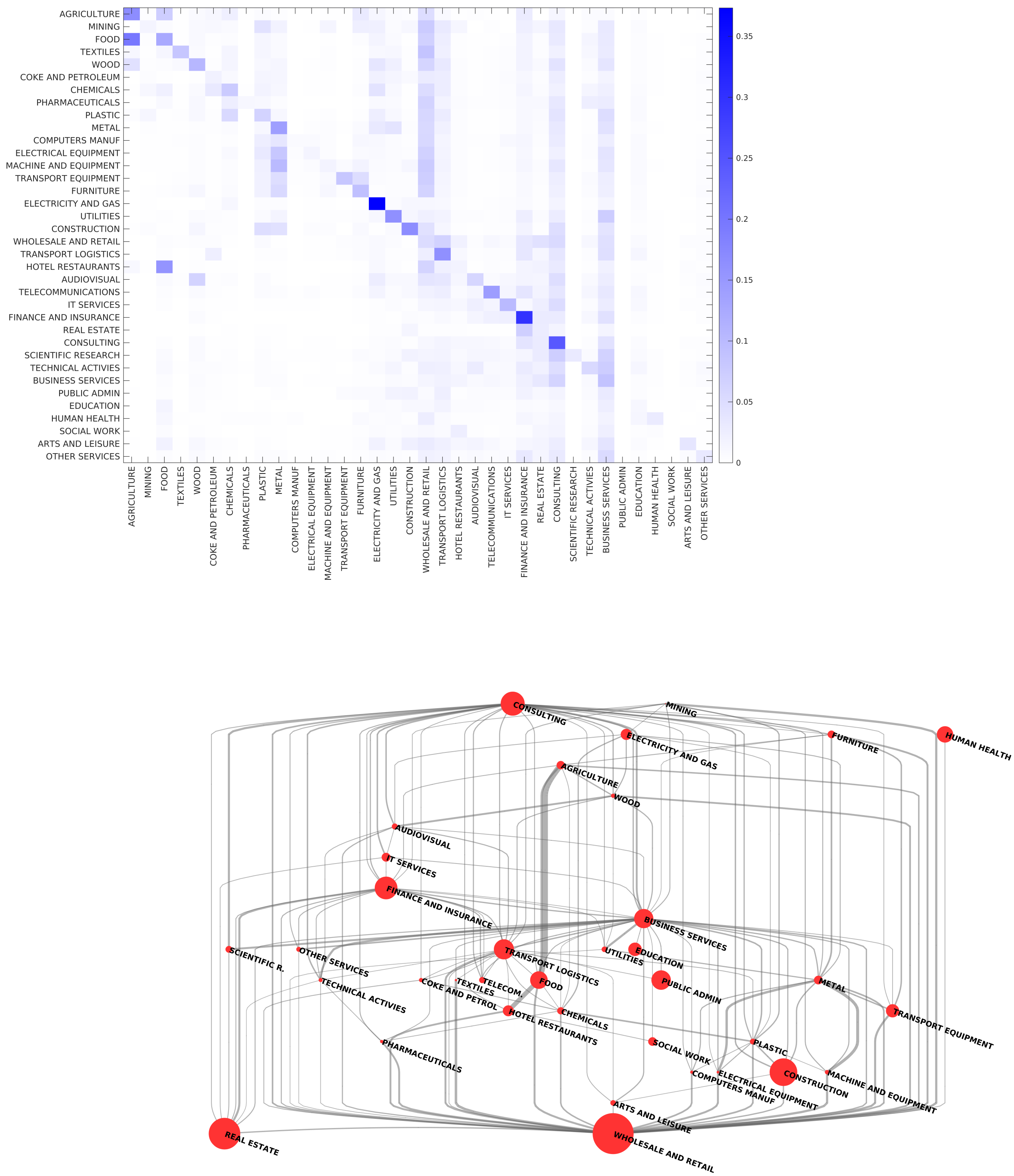
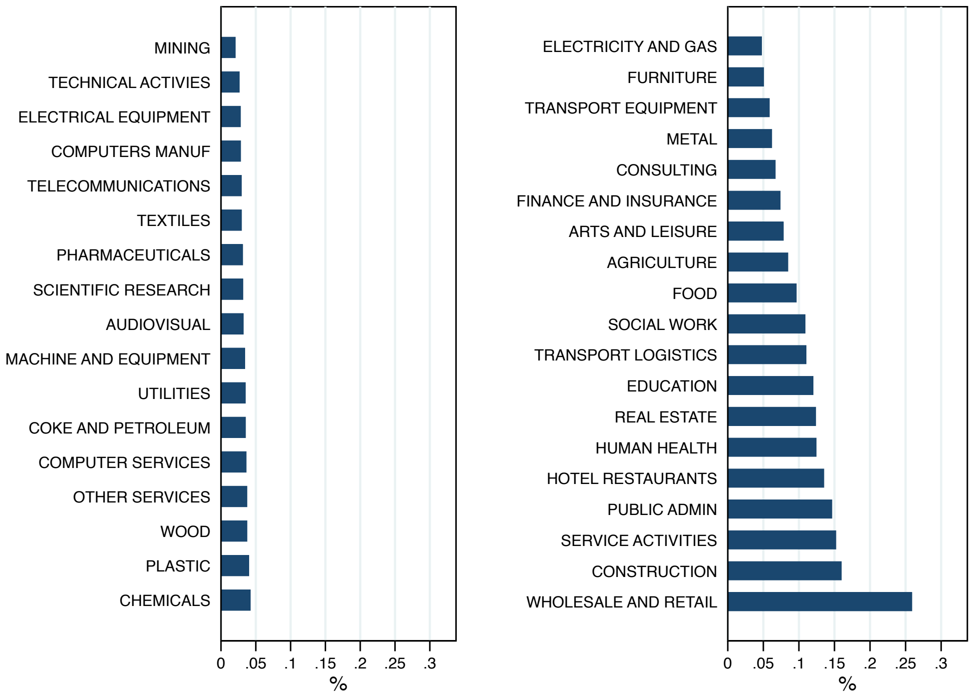


Figure 3
Effect on GDP of differentiated phasing out by sector

This figure shows the effects on GDP of phasing out social distancing in each sector individually, after 4 weeks instead of 6.

Panel A: % of GDP



Panel B: euros per released worker

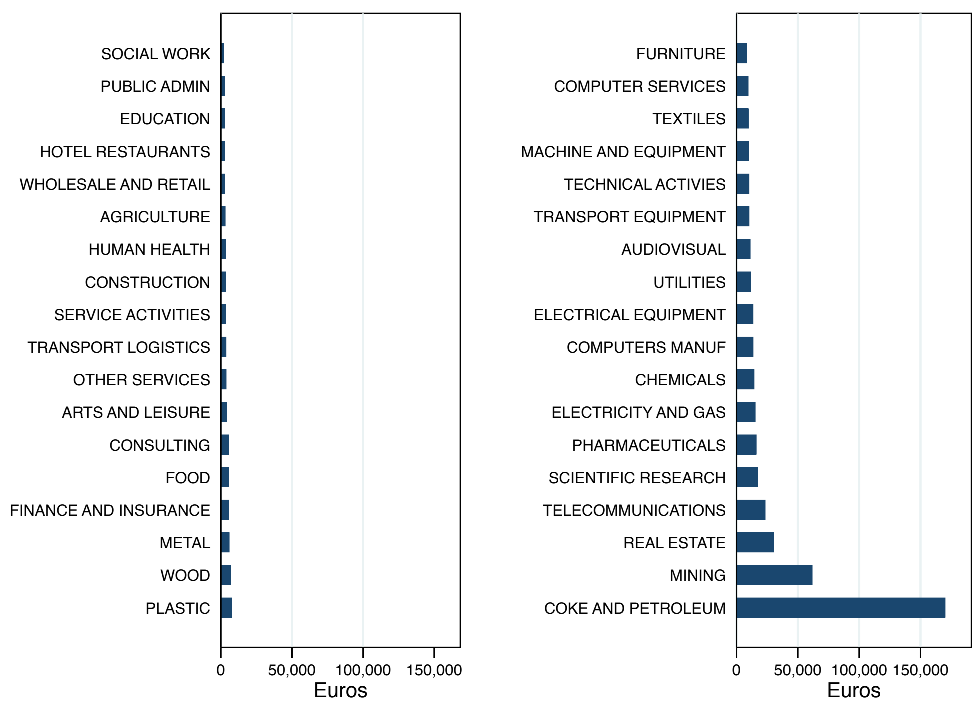


Figure 4
Value added growth for 6 weeks of social distancing (%)

This figure shows the effects of social distancing on value added growth for each sector (in %). Blue bars represent the decline in the active workforce due to administrative closings. Red bars, the additional effect linked to school closings. Green bars, the residual effect linked to confinement.

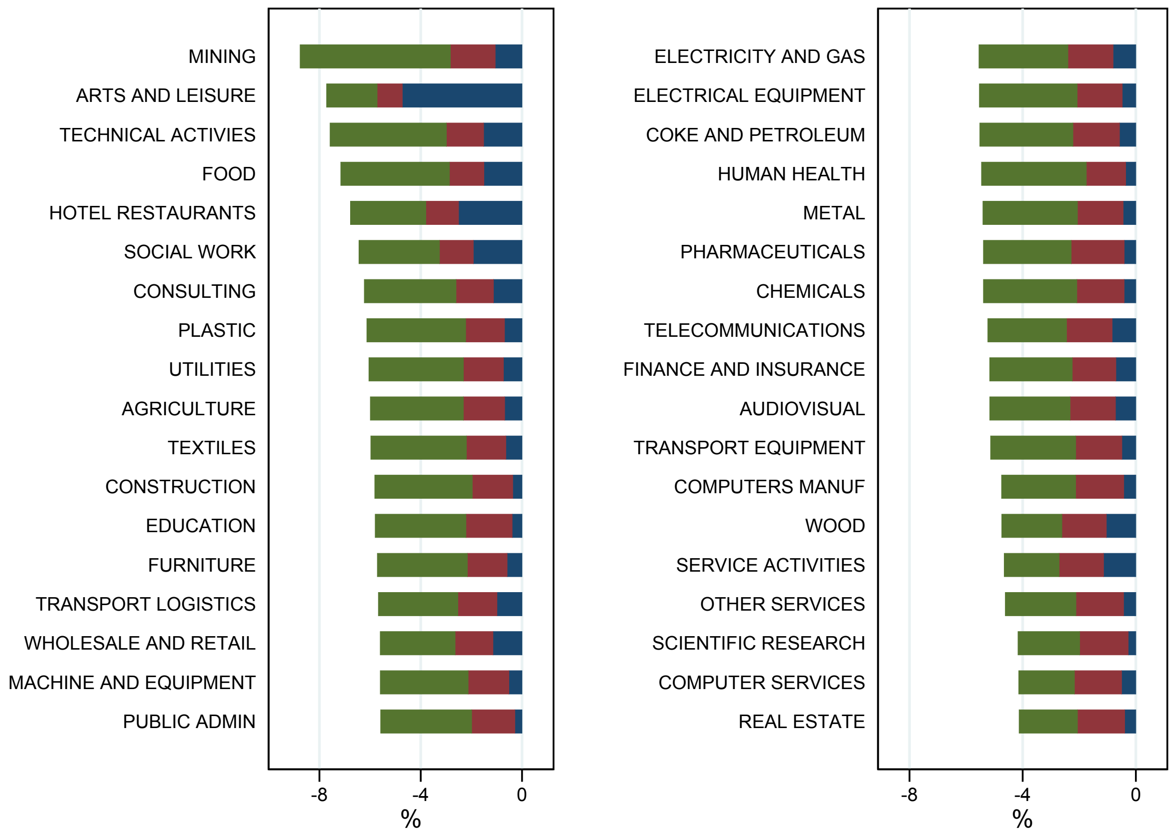


Figure 5
GDP drop by country for 6 weeks of social distancing

This figure shows the effects of social distancing on the GDP growth of European countries (in %). We assume that all countries apply the same restrictions, and that social distancing is in place for 6 weeks in each country. Only the sectoral composition and the propensity to telework vary.

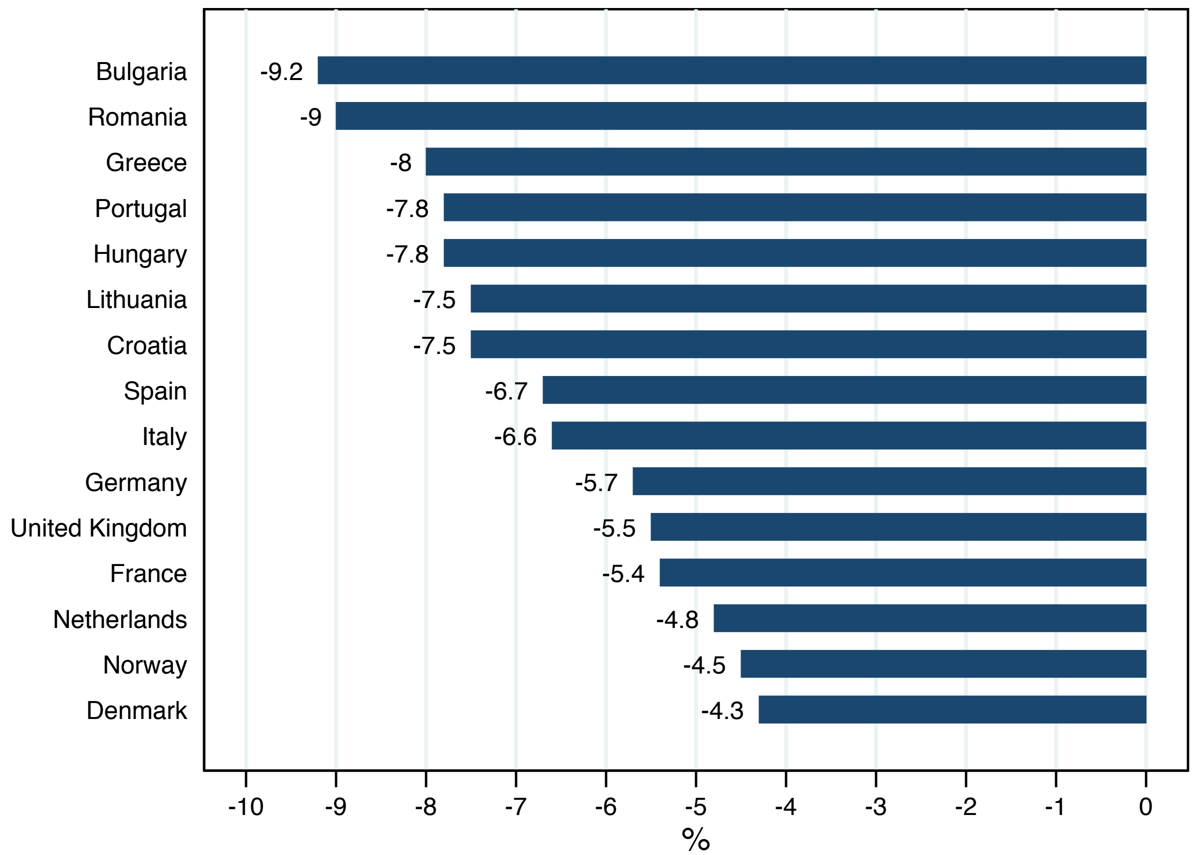
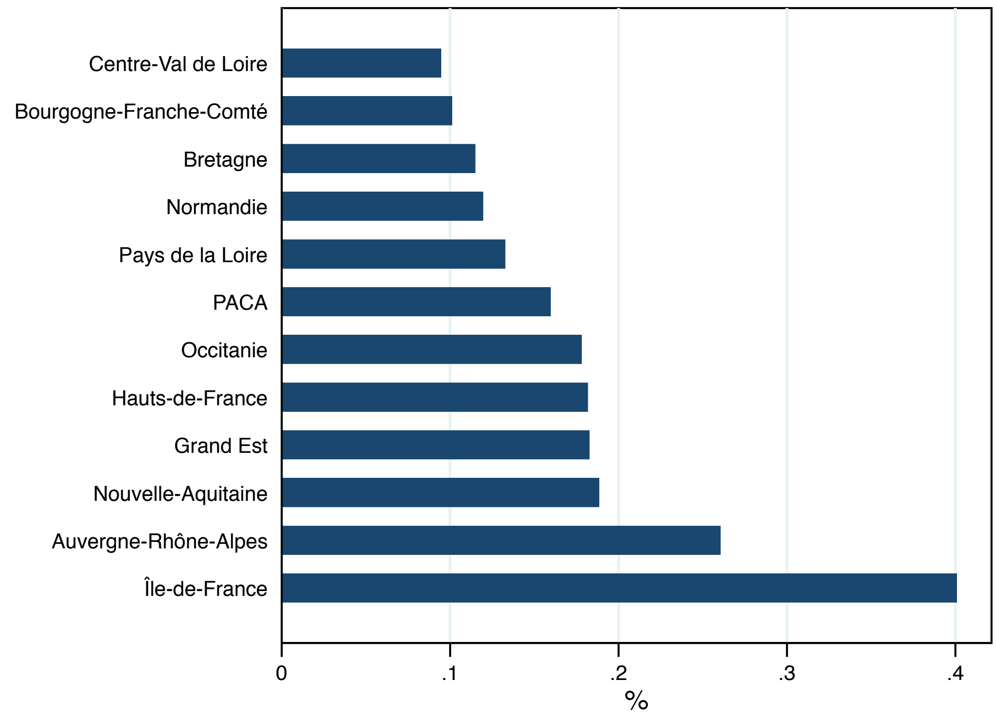


Figure 6
Effect on GDP of differentiated phasing out by region

This figure shows the effects on GDP of phasing out social distancing in each region individually, after 4 weeks instead of 6.

Panel A: % of GDP



Panel B: euros per released worker

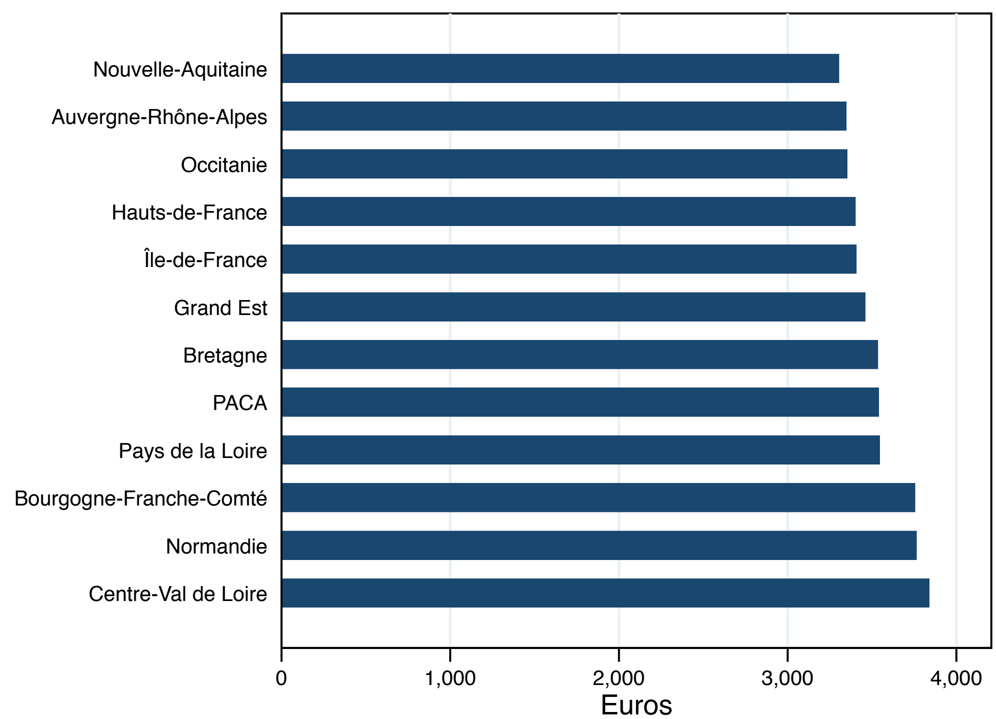
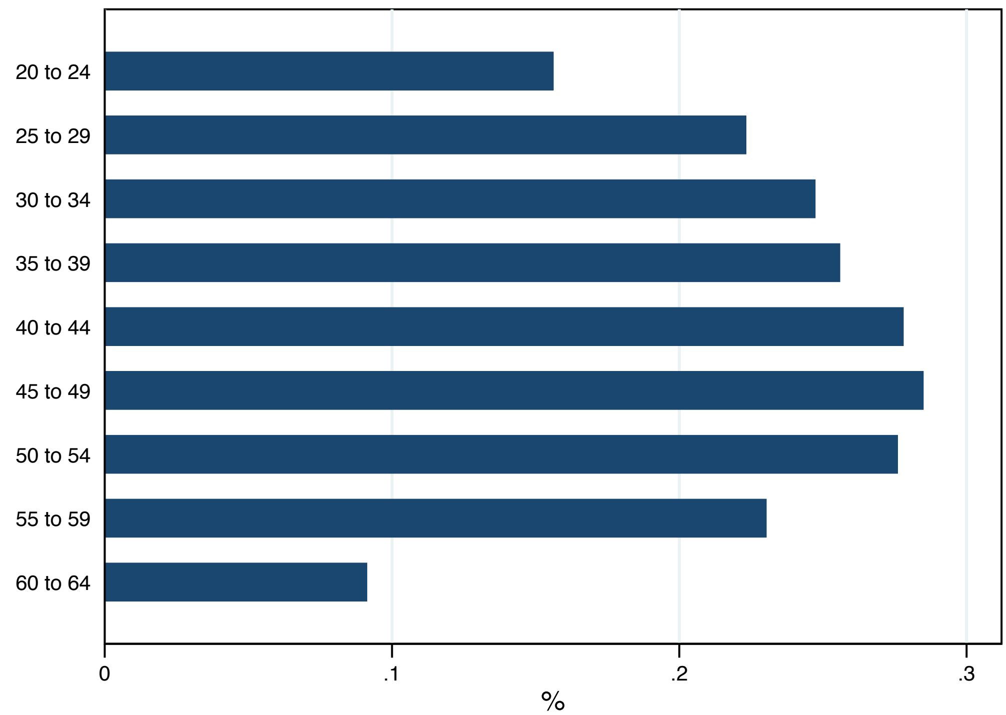


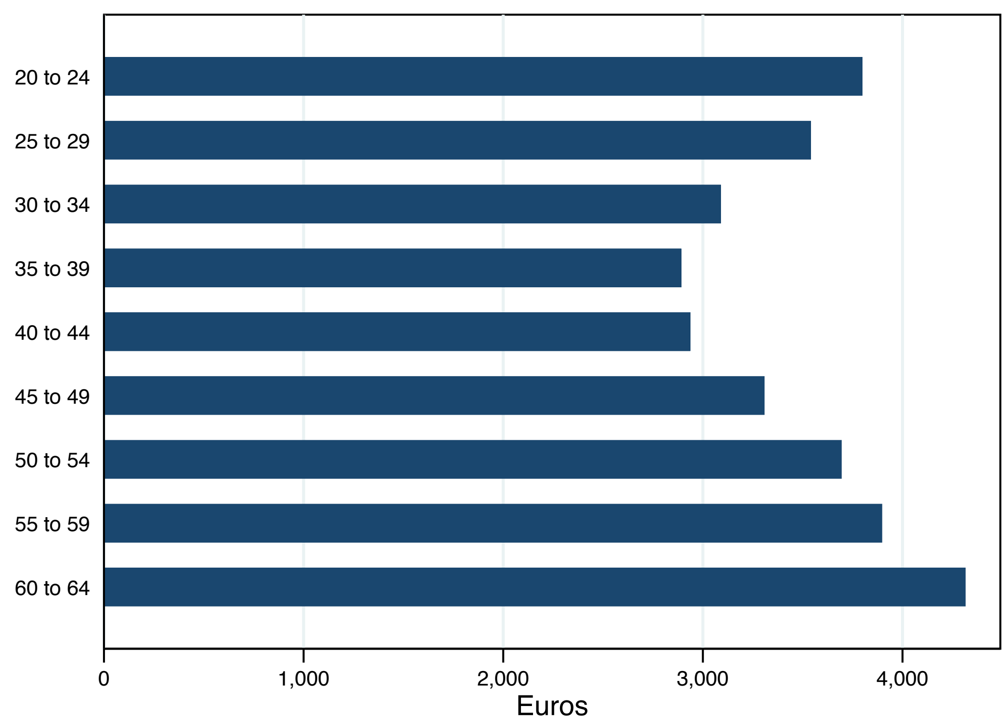
Figure 7
Effect on GDP of differentiated phasing out by age group

This figure shows the effects on GDP of of phasing out social distancing in age group individually, after 4 weeks instead of 6.

Panel A: % of GDP



Panel B: euros per released worker



Appendix

Table 3
List of Sectors

CODE A38	ACRONYM A38	DESCRIPTION A38
AZ	AGRICULTURE	agriculture, forestry and fishing
BZ	MINING	mining and quarrying
CA	FOOD	manufacture of food products, beverages and tobacco products
CB	TEXTILES	manufacture of textiles, wearing apparel and leather products
CC	WOOD	manufacture of wood and paper products, and printing
CD	COKE AND PETROLEUM	manufacture of coke and refined petroleum products
CE	CHEMICALS	manufacture of chemicals and chemical products
CF	PHARMACEUTICALS	manufacture of basic pharmaceutical products and pharmaceutical preparations
CG	PLASTIC	manufacture of rubber and plastics products, and other non-metallic mineral products
CH	METAL	manufacture of basic metals and fabricated metal products, except machinery and equipment
CI	COMPUTERS MANUF	manufacture of computer, electronic and optical products
CJ	ELECTRICAL EQUIPMENT	manufacture of electrical equipment
CK	MACHINE AND EQUIPMENT	manufacture of machinery and equipment n.e.c.
CL	TRANSPORT EQUIPMENT	manufacture of transport equipment
CM	FURNITURE	manufacture of furniture; other manufacturing; repair and installation of machinery and equipment
DZ	ELECTRICITY AND GAS	electricity, gas, steam and air conditioning supply
EZ	UTILITIES	water supply; sewerage, waste management and remediation activities
FZ	CONSTRUCTION	construction
GZ	WHOLESALE AND RETAIL	wholesale and retail trade, repair of motor vehicles and motorcycles
HZ	TRANSPORT LOGISTICS	transportation and storage
IZ	HOTEL RESTAURANTS	accommodation and food service activities
JA	AUDIOVISUAL	publishing, audiovisual and broadcasting activities
JB	TELECOMMUNICATIONS	telecommunications
JC	IT SERVICES	computer programming, consultancy and related activities; information service activities
KZ	FINANCE AND INSURANCE	financial and insurance activities
LZ	REAL ESTATE	real estate activities
MA	CONSULTING	legal and accounting activities; activities of head offices; management consultancy activities; architecture and engineering activities; technical testing and analysis
MB	SCIENTIFIC RESEARCH	scientific research and development
MC	TECHNICAL ACTIVITIES	advertising and market research; other professional, scientific and technical activities; veterinary activities
NZ	BUSINESS SERVICES	administrative and support service activities
OZ	PUBLIC ADMIN	public administration and defence; compulsory social security
PZ	EDUCATION	education
QA	HUMAN HEALTH	human health activities
QB	SOCIAL WORK	social work activities
RZ	ARTS AND LEISURE	arts, entertainment and recreation
SZ	OTHER SERVICES	other service activities

Table 4
Sector characteristics and network statistics

Column (1) reports sector names. Column (2) presents the final demand (the sum of household consumption, government purchases, investment and exports) as a share of GDP spent on each sector. Column (3) reports employment in each sector as a fraction of total employment in the economy. Column (4) reports the upstreamness of each sector as in Antras et al. (2012), Column (5) reports the Bonacich-Katz centrality of each sector. These statistics are computed using data from Insee 2015 Symmetric domestic input-output table (SIOT) level A38 (Billion euros).

(1)	(2)	(3)	(4)	(5)
Secteur	Sector Characteristics		Network Statistics	
	Final Demand	Employment	Upstreamness	Network Centrality
AGRICULTURE	2.7%	1.1%	2.09	0.032
MINING	0.1%	0.0%	2.43	0.002
FOOD	2.3%	4.6%	1.52	0.070
TEXTILES	0.4%	0.5%	1.43	0.007
WOOD	0.8%	0.4%	2.27	0.015
COKE AND PETROLEUM	0.0%	0.9%	1.69	0.015
CHEMICALS	0.5%	1.9%	1.47	0.027
PHARMACEUTICALS	0.3%	1.0%	1.04	0.011
PLASTIC	1.0%	0.7%	2.04	0.021
METAL	1.5%	1.3%	1.91	0.033
COMPUTERS MANUF	0.5%	0.9%	1.09	0.010
ELECTRICAL EQUIPMENT	0.4%	0.7%	1.28	0.008
MACHINE AND EQUIPMENT	0.7%	1.3%	1.25	0.015
TRANSPORT EQUIPMENT	1.3%	4.6%	1.14	0.052
FURNITURE	1.1%	1.7%	1.59	0.029
ELECTRICITY AND GAS	0.7%	1.4%	2.36	0.043
UTILITIES	0.7%	0.6%	2.17	0.020
CONSTRUCTION	6.5%	8.4%	1.35	0.112
WHOLESALE AND RETAIL	12.8%	11.8%	1.46	0.167
TRANSPORT AND LOGISTICS	5.1%	3.6%	1.92	0.080
HOTEL RESTAURANTS	4.0%	3.0%	1.48	0.042
AUDIOVISUAL	0.9%	1.3%	1.75	0.022
TELECOMMUNICATIONS	0.5%	1.0%	2.05	0.022
IT SERVICES	1.6%	2.2%	1.61	0.034
FINANCE AND INSURANCE	3.5%	2.7%	2.36	0.091
REAL ESTATE	1.4%	10.1%	1.37	0.128
CONSULTING	4.4%	2.5%	2.40	0.097
SCIENTIFIC RESEARCH	0.7%	2.4%	1.03	0.025
TECHNICAL ACTIVITIES	1.0%	0.3%	2.33	0.014
BUSINESS SERVICES	5.7%	2.0%	2.28	0.077
PUBLIC ADMIN	9.8%	7.8%	1.00	0.078
EDUCATION	7.7%	4.4%	1.26	0.053
HUMAN HEALTH	7.1%	6.2%	1.06	0.065
SOCIAL WORK	7.6%	3.3%	1.00	0.033
ARTS AND LEISURE	1.6%	1.7%	1.20	0.020
OTHER SERVICES	3.0%	1.3%	1.40	0.017
Moyenne	2.8%	2.8%	1.64	0.044
Min	0.0%	0.0%	1.00	0.002
Max	12.8%	11.8%	2.43	0.167

Figure 8
Cross-country correlation between telework and GDP change

This graph shows the correlation between the share of persons employed using computers with access to Internet and the change in GDP (in %) across 15 European countries.