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On the economic and health impact of the COVID-19 shock on Italian regions: A value chain approach*

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Abstract

In this work, we evaluate the exposure of Italian regions to the risk associated with the spread of COVID-19 through a two-step value chain approach. First, we estimate the degree of participation of Italian regions in a plurality of value chains linked to consumption, investment and exports. We distinguish between value chains aimed at satisfying essential needs and supply chains activated by needs characterized by a lower level of necessity in line with the restriction measures implemented by the Italian government. Second, we investigate the different levels of contagion risk associated with each value chain and the possibility of reducing it through remote working. An exercise on policy measures implemented by the Italian government during Fall 2020 completes the paper. We find that regions are affected differently by lockdown policies because of their high heterogeneity in the degree of embeddedness within different value chains and because their sectoral contributions to each of them. As a result, Italian regions are associated with very diverse potentials for mitigating contagion risk via remote working practices. Finally, we find evidence that economic and contagion risks positively correlate in non essential value chains, while they are negatively associated in the production of medium-necessity and essential goods and services. In turn, strong lockdowns induce substantially different trade-offs across regions, depending on how regions participate to value chains.

JEL Codes: R15, R10.

Keywords: COVID-19 lockdown, value chains, input-output models, contagion risk, remote working.

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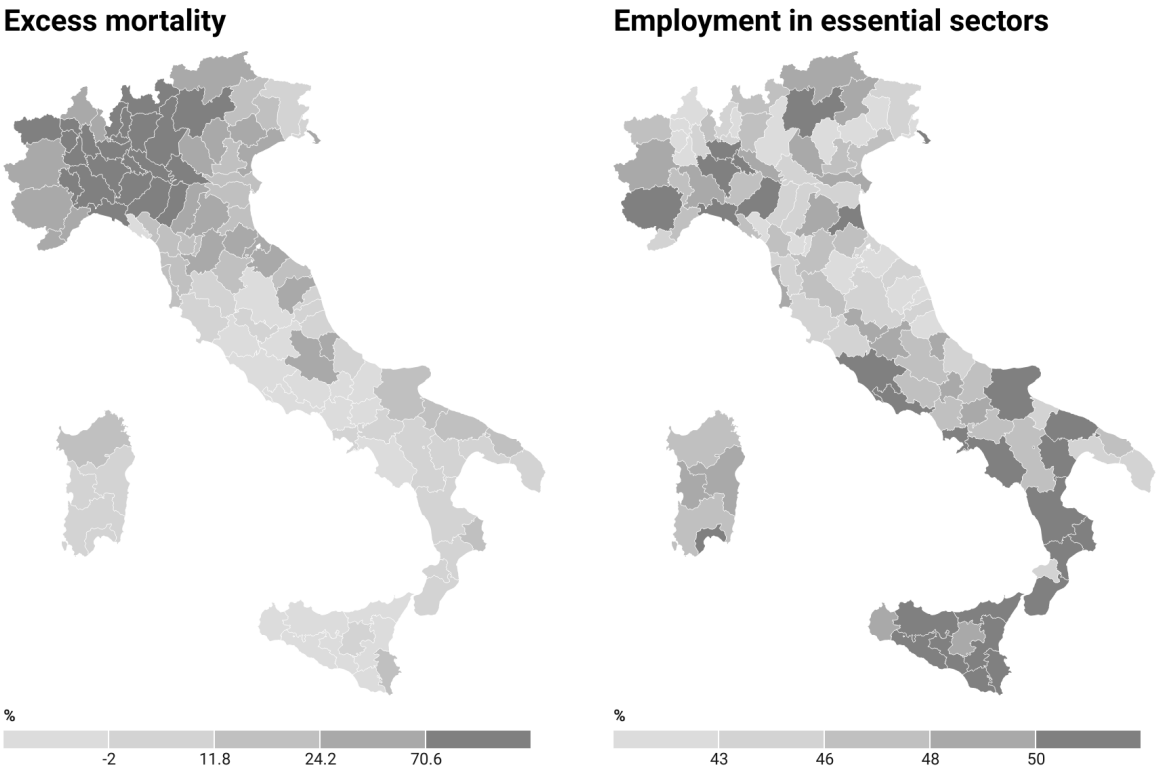
1 Introduction

The health emergency triggered by the COVID-19 pandemic has forced governments around the world to take drastic measures in order to contain the spread of the pandemic, which resulted in large declines in economic activity (IMF, 2020). In Italy, although the government has adopted a nation-wide strategy of mandatory social distancing, the evolution of the most critical epidemiological indicators has shown heterogeneous profiles across regions, possibly due to the fact that daily interactions among individuals are mostly local (Bailey et al., 2020; Glaeser et al., 2020; Conte et al., 2020; Gerritse, 2020; Harris, 2020; OECD, 2020b; Monte, 2020).

The data on excess mortality recorded by ISTAT for the Italian NUTS3 regions in the first 4 months of 2020 are exemplary in this sense (Figure 1; left). These data reveal a divide between the North and the rest of the country. At the same time, different regional profiles do actually emerge, with Lombardy — the NUTS2 region most affected by the epidemic — displaying values far above the national average.

Figure 1: Excess mortality between 1 January and 30 April 2020 compared to the average in the same period of the year recorded between 2015 and 2019 and the weight of employees in local units employed in essential sectors as defined by the National Government. NUTS3 regions.



Also the lockdown did not uniformly affect regional economies. Restrictive measures have exempted firms producing essential goods and services. Moreover, companies relying

more on remote working have been able to partly mitigate the negative effects of those measures (see Dingel & Neiman, 2020; Gourinchas et al., 2020, among the others). Finally, the different the different production specializations of local economies have resulted in heterogeneous economic impacts of containment measures (Figure 1; right) (Barbieri et al., 2020; OECD, 2020b). Indeed, significant regional differences emerged even among southern regions, which are characterized by a higher incidence of workers employed in sectors producing essential goods and services.

Input-output (IO) analyses have extensively been exploited since the onset of the COVID-19 pandemic. Several studies have focused on the exposure of nodes in the production network to demand and supply shocks (Baqaee & Farhi, 2020; Laeven, 2020), with particular regard to the upstream exposure to imports from China (Baldwin & Tomiura, 2020), and on the long-term effects of the crisis on global value chains (Baldwin & Tomiura, 2020; Bonadio et al., 2020; OECD, 2020a). Other studies have instead evaluated the economic and health impacts associated with lockdown and reopening policies (Ferraresi et al., 2020b; Barba Navaretti et al., 2020; Inoue & Todo, 2020; Pichler et al., 2020; Reissl et al., 2021). Finally, a recent stream of works focuses on contagion risk (e.g. Barbieri et al., 2020) and to remote working as a possible mitigation factor (Barbieri et al., 2020; Dingel & Neiman, 2020; Duranti et al., 2020; Boeri et al., 2020).

Our work extends these complementary lines of research providing an internally consistent inter-regional framework that accounts for regional heterogeneity in terms of both economic activity and contagion risk. More specifically, we evaluate the exposure of Italian NUTS2 regions to the first wave of the pandemic and to the lockdown measures imposed by the national government, adopting a value chain approach applied at the regional level. Such a perspective appears to be well-suited for a context in which the spread of contagions puts pressure both on the places where consumption takes place, as well as on those where production occurs. Indeed, adopting a inter-regional value chain approach, we can explicitly connect places of consumption with those of production, pinning down the relationships between local final demand and production and employment indirectly activated in different sectors and areas. Furthermore, we combine two indicators capturing the contagion risk of each occupation and the potential for remote working in our analysis to assess the heterogeneous contagion risk along each value chain, and the possible mitigating role of remote working .

Overall, our study provides an ex-post accurate description of the exposure of Italian regions to the economic and health impacts involved in the first wave of the pandemic and in the related lockdown measures, and it develops a policy toolkit to plan geographically-targeted measures to face future surges of contagions.

We find that the heterogeneous degree of embeddedness of Italian regions within different value chains and their different sectoral contributions to each of them translate into diverse health impacts of the COVID-19 shock and heterogeneous potentials for

mitigating contagion risk via remote working practices. More specifically, production and employment value chains show the existence of considerable heterogeneity between Italian regions, especially between northern and southern ones. The former are far more involved in export- and investment-related value chains, whereas the latter are more central in the production of necessary consumption goods and for investment in construction.

Value chains highly differ also in terms of their exposure to the COVID-19 health risk. Employment activated by restaurants and hotels, health and education consumption expenditures displays a higher contagion risk, either because of a high exposure to infections or because of the closeness of interactions among workers or between workers and clients. Furthermore, remote working potential displays high variability across value chains, being lower, among the riskiest, i.e., in those activated by restaurants and hotels and health expenditures. Again, regional patterns reveal heterogeneous within-value chain risk distributions across regions.

A series of regressions reveals that economic and contagion risks are related in a complex way. In particular, economic and contagion risks positively correlate in non essential value chains, while they are negatively associated in the production of medium-necessity and essential goods and services. In turn, tight lockdowns induce substantially different trade-offs across regions, depending on how regions specialize in different value chains.

Finally, we carry out a policy experiment based on geographically-targeted lockdowns aimed at closing specific value chains in regions which were especially hit during the second wave. We show that such closures, while preserving a significant share of workers from infection, exert economic impacts which go beyond targeted regions, due to inter-regional spillovers caused by backward linkages in the closed value chains.

The rest of the paper is organized as follows. In Section 2, we discuss the methodology applied in our analysis. In Section 3, we present the data. Main results are discussed in Section 4. In Section 5 we discuss the results from a policy experiment. Finally, in Section 6, we conclude.

2 Methodology

In this Section, we present our methodology to evaluate the (heterogeneous) involvement of Italian regions in different value chains and their associated economic and contagion risk.

A value chain approach allows to go beyond the analysis of isolated economic sectors by considering that different, but interconnected, sectoral production activities must be jointly activated to satisfy the needs expressed by a community of consumers located in different regions, the investment demand coming from firms, and the demand stemming from foreign markets. Let us take, for instance, consumption value chains. Consumption

needs can be of various types, ranging from nourishment, leisure, all the way to health care services, etc. Firms belonging to different sectors produce goods and services to directly satisfy specific consumer needs (direct activation). At the same time, firms' own production processes require raw materials as well as intermediate products and services provided by other businesses, which do not necessarily belong to the same industry. This gives rise to a second production step (indirect activation). Clearly, the process may be further extended, as firms engaged in the second step also demand intermediate inputs and might activate additional production steps. The value chain associated with a specific consumption need is therefore defined by the set of firms (and sectors) involved in the production process originating from it. As an example, one can consider the clothing value chain, which activates first the firms in the "textile and clothing" sector, and then also agricultural firms (e.g., to cover the demand for wool and cotton), service firms (e.g., transport companies, shops, graphic designers), professional firms (e.g., accountants or lawyers), etc.

In what follows, we propose a four-step procedure to precisely measure (i) the production and employment involved in different value chains, (ii) their spatial distribution across Italian regions, and (iii) the COVID-19 risk that they imply. First, we identify value chains through the IRPET inter-regional input-output matrix (Paniccià & Rosignoli, 2018) embedded in the OECD's ICIO database (see Section 3). Second, we compute the value of direct and indirect gross production associated with each value chain. Third, we estimate the employment content of each value chain. Finally, we measure the contagion risk of each occupation and the potential of reducing this risk through remote working.

Table 1 lists the consumption, investment and export value chains that we analyse in this paper. First, we consider 12 value chains collecting the consumption expenditures for essential and non-essential needs: 1) food and non-alcoholic beverages; 2) alcoholic beverages, tobacco and narcotics; 3) clothing and footwear; 4) housing, water, electricity, gas and other fuels; 5) furnishings, household equipment and routine household maintenance; 6) health; 7) transport; 8) communication; 9) recreation and culture; 10) education; 11) restaurants and hotels; 12) miscellaneous goods and services.[1] To ease the presentation of results, we classify the consumption value chains into three different sets (essential, medium and non-essential), each characterized by a different level of necessity. This classification is consistent with the decisions taken by the Italian government, which halted the production of all non-essentials and allowed firms belonging to essential sectors to continue producing.[2] In particular, essential goods and services are those whose supply

[1]These refer to the 2-digit COICOP classification. The links between the 12 expenditure functions and the goods and services belonging to each of them can be found at the following link: https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Classification_of_individual_consumption_by_purpose_(COICOP).

[2]See the documents released by the Italian government (available only in Italian), e.g., https://www.

had to be guaranteed during the lockdown; non-essential goods and services value chains include sectors exposed to mandatory closures during the first wave of the pandemic; value chains with medium necessity level are those activated by bundles of goods and services expenditures heterogeneously impacted by the mandatory social distancing measures. Beside considering consumption value chains, we also characterise investment value chains, serving the production of investment goods, as well as value chains serving specific export markets. In relation to the investment ones, we distinguish between construction and non-construction investment chains. Finally, with respect to the available 43 export-related value chains we perform two exercises: first, we aggregate them into a single group (cf. Table 1); second, we consider chains serving specific foreign markets that have great relevance for the Italian economy (Germany and the U.S.).[3]

Table 1: List of the examined value chains.

Internal consumption	*Essential*	*Medium*	*Non-essential*
	Food	Communication	Clothing
	Beverages	Housing	Furnishing
	Health	Transport	Recr. & culture
		Education	Restaurants & hotels
			Misc.
Internal investment	Construction investment		
	Other investment		
Exports	Australia, Austria, Belgium, Bulgaria, Brazil, Canada, Chile, China, Cyprus, Czech Rep., Germany, Denmark, Spain, Estonia, Finland, France, UK, Greece, Croatia, Hungary, Indonesia, India, Ireland, Japan, South Korea, Lituania, Luxembourg, Latvia, Mexico, Malta, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Sweden, Turkey, Taiwan, US, Rest of World		

Let us now discuss the different procedures employed to estimate the demand needs activating the different value chains. We disaggregate domestic consumption according to the 2-digits COICOP classification provided by the Regional Accounts database by Italy's National Statistical Office (ISTAT).[4] We then employ the regional *Supply and Use* tables

gazzettaufficiale.it/eli/id/2020/04/11/20A02179/sg.

[3]Our database does not allow us to operate a distinction of investment and export demands on the basis of the level of necessity of the final needs that originated them.

[4]These are: Food and non-alcoholic beverages; Alcoholic beverages, tobacco and narcotics; Clothing

to link the industry flows of the inter-regional input-output database (see Section 3) to the product-based flows of expenditure functions. More precisely, we first consider the flows of bilateral inter-regional exchanges aimed at satisfying the final demand of each region j served by a sector z of each region i in products through the *Make* matrices contained within the *Supply and Use* table of region i. We then employ a "bridge" matrix that maps the bilateral flows in goods and services into the 12 expenditure functions. Finally, we disaggregate the internal consumption of each region into the 12 expenditure functions provided by ISTAT. The disaggregation process satisfies two constraints: (i) the sum of the 12 expenditure functions of the final demand for internal consumption of region j satisfied by sector z of the region i must return the total internal consumption obtained from the initial inter-regional table; (ii) the overall demand for internal consumption of region j must respect the subdivision in the 12 expenditure functions observed in the official National Accounts.

After disaggregating consumption final demand according to the described procedure, we compute the "Leontief" inverse matrix L of the inter-regional input-output table to estimate the supply chains defined as output responses to different demand shocks. Notice that the i-th generic column vector of the Leontief inverse matrix represents the direct and indirect production coefficients resulting from demand addressed to sector i (see, e.g., Miller & Blair, 2009).[5] Once the supply chains have been defined in terms of direct and indirect production coefficients connected to a particular type of final need, we calculate the related regional impacts. Regional activation for different phases of each supply chain was broken down not only in terms of production, but also in terms of employment. To establish the link between production and employment, we consider the ratio between employees and production in each sector.

Finally, the concluding step of our procedure involves the estimation of the risk associated with the spread of COVID-19 contagion along value chains. We consider two indicators for this purpose. The first COVID-19 risk indicator defines contagion risk (CR) as the likelihood of contracting the infection, associated with an occupation. The index returns the maximum value of two risk dimensions (see Barbieri et al., 2020): (i) the exposure to diseases and infections implied by a job's characteristics, and (ii) the degree of physical proximity implied by the same job. The first dimension identifies the pure contagion risk of occupations (e.g., working in the health-care system implies more exposure

and footwear; Housing, water, electricity, gas and other fuels; Furnishings, household equipment and routine household maintenance; Health; Transport; Communication; Recreation and culture; Education; Restaurants and hotels; Miscellaneous goods and services.

[5]Each final need b_j was mapped into a sectoral final demand vector $f_j : \{f_1; f_2; ...; f_i; ...; f_n\}$, where n is the total number of sectors of the inter-regional table. On this basis, we then obtained the supply chain connected to each need j as a weighted average of the columns of L where the weights are given by the elements of f_j. Each different need b_j was then spatially disaggregated into 20 *regional impacts*, in order to separately assess the activation of the national supply chain resulting from each specific type of demand faced by each Italian region.

to diseases and infections than working in the financial services industry). The second one instead captures the riskiness of a job, once contagion has started diffusing. We define high (low) risk occupations as those whose CR indicator is above (below) the average. The second COVID-19 risk indicator defines the remote working potential (RWP) and refers to the possibility of mitigating the risk of contagion by adopting remote workinging when possible. Several proxies have been proposed in the past months to define occupations which can be performed remotely (see e.g. Barbieri et al., 2020; Boeri et al., 2020; Dingel & Neiman, 2020; Duranti et al., 2020). We employ the definition proposed in Duranti et al. (2020) which combines principal component and clustering analyses to identify occupations that can be performed remotely by adopting 21 indicators from the INAPP ICP database and by employing a task-based approach. The indicators aim at capturing the importance of tasks which can (or cannot) be performed remotely and the relevance of in-presence interactions for each occupation. The resulting measure is dichotomous at the occupation scale, taking value 1 in case of jobs which can be performed from home and 0 otherwise.[6] Once we obtain the CR and RWP indexes for each occupation, we cluster employees in sectors and regions by using the Labor Force Survey (provided by ISTAT), and by considering the contagion risk of their occupation as well as the possibility (or absence thereof) of adopting remote working. The riskiest jobs are therefore characterized by a high CR index and a RWP indicator equal to zero (i.e., remote working is not possible). Next, for each sector/region pair, we compute the the share of workers at risk – defined as the ratio between the employees at risk of contagion (both in teleworkable and non-teleworkable occupations) and total employment in the same sector/region combination. Finally, we apply those shares to the total number of employees in any sector/region activated by a given value chain.

3 Data

The methodology discussed in the previous section requires an inter-regional input-output database for the Italian economy embedded in an international database. This is the only way to identify the value chains linked to specific foreign markets. Hence, we transform the IRPET Multi-regional Tables (Paniccià & Rosignoli, 2018) into an inter-regional table and insert it in place of the original Italian table in the ICIO database to get the IRPET-ICIO database.[7] To do so, we rely upon the Italian COEWEB international trade database provided by ISTAT (see Bentivogli et al., 2019, for further details).[8]

The new IRPET-ICIO table shows in *input* (by column), the sector/region contributions of intermediate goods to the generation of production and, in *output* (by row),

[6] The aggregation of occupations at the sector/region level, instead, returns a continuous index bounded over the $[0, 1]$ domain and which we use in our Input-Output simulations.

[7] See https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm.

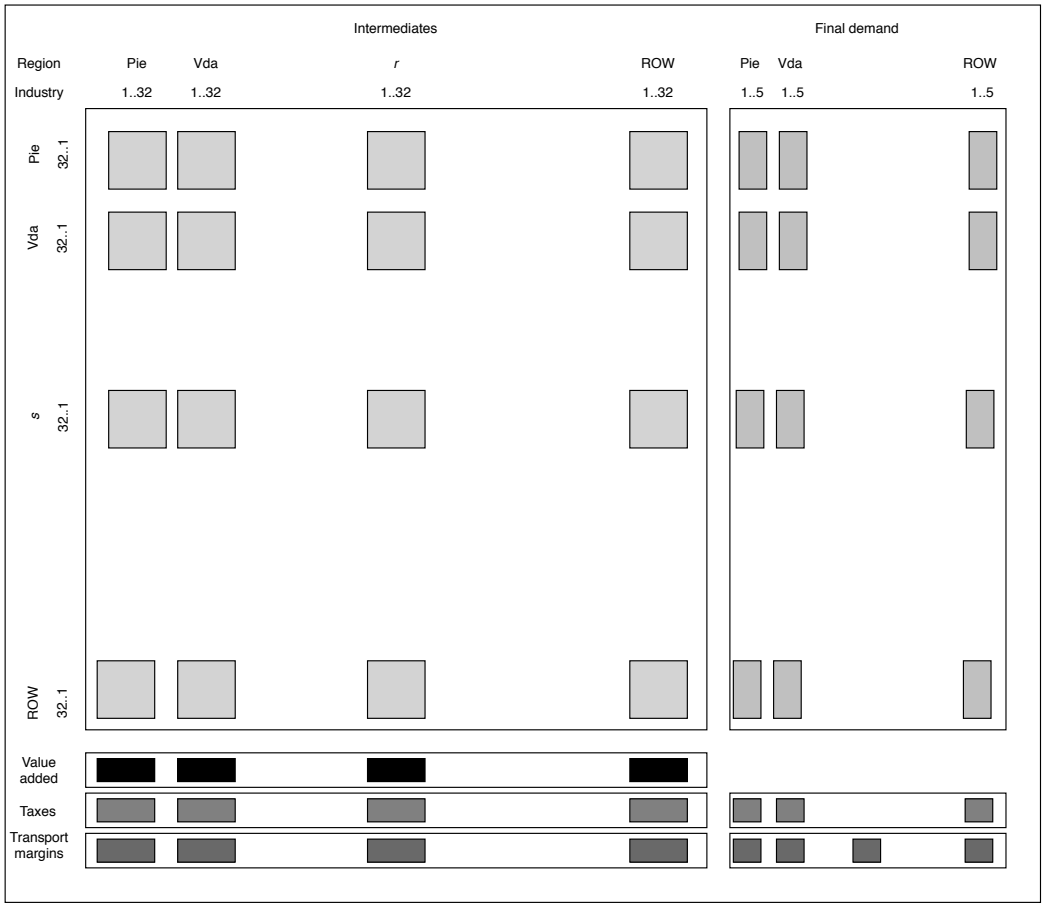
[8] http://www.coeweb.istat.it/.

the sector/region destination of the obtained production.[9] The structure of the table of interest is represented in Figure 2, where the square matrix at top left denotes the flows of intermediate goods and services, while the rectangular matrices at the top right denote trade in final goods. For each sector and region, the difference between the value of production and intermediate consumption (by column) yields an aggregate which is the sum (at the sectoral level) of value added at basic prices, net taxes and transport margins (cf. the black rectangles in Figure 2). The accounting structure of the model can be summarized by the following identity, for each sector j and geographical area r:

$$\sum_{s=1}^{N}\sum_{i=1}^{M} x_{ij}^{sr} + y_j^r + tax_j^r + TTM_j^r \equiv \sum_{s=1}^{N}\sum_{i=1}^{M} x_{ij}^{rs} + \sum_{s=1}^{N} fd_j^{rs}$$

where N is the number of geographical areas, M is the number of sectors,[10] x denotes intermediate inputs, y is value added at basic prices, fd stands for final demand, tax are indirect net taxes and TTM are trade transport margins.

Figure 2: The IRPET-ICIO Table



[9]The reference year for the IO table is 2015. This is the latest release of the OECD ICIO database, and the most recent available in order to perform an inter-regional-international analysis as the one carried out in this work.

[10]The IRPET-ICIO Table contains 32 sectors for each geographical area. Sectors are listed in Table A.1 in the Appendix.

We recover employee data at the sector/region level via the ISTAT Regional Accounts.[11] To match sectors in the IRPET-ICIO table to those in the Regional Accounts, one can either merge sectors or split them according to the production shares computed from the table. To compute the CR and the RWP indicators, we rely upon the ICP database provided by INAPP.[12] For any 5-digit occupation, the database returns a set of characteristics, in the form of scores, based upon a survey submitted to 16 thousand employees. Finally, we link occupation-based indices to employment at a sector/region scale through the ISTAT Labor Force Survey.[13] This allows us to connect 3-digit occupations to the number of employees in each sector/region combination.[14]

4 Regional Exposures to Different value chains

We begin with an evaluation of the production and employment exposure of Italian regions to different consumption, investment and export value chains (cf. Section 4.1). This allows us to quantify the economic risk faced by each region with respect to the lockdown measures implemented in the face of the COVID-19 pandemic. The obtained results can then be exploited in Section 4.2 to estimate the share of the workforce facing the highest risk of being exposed to the COVID-19 contagion. Finally, we perform a battery of regressions to study the possible relationships between economic and contagion risks (see Section 4.3).

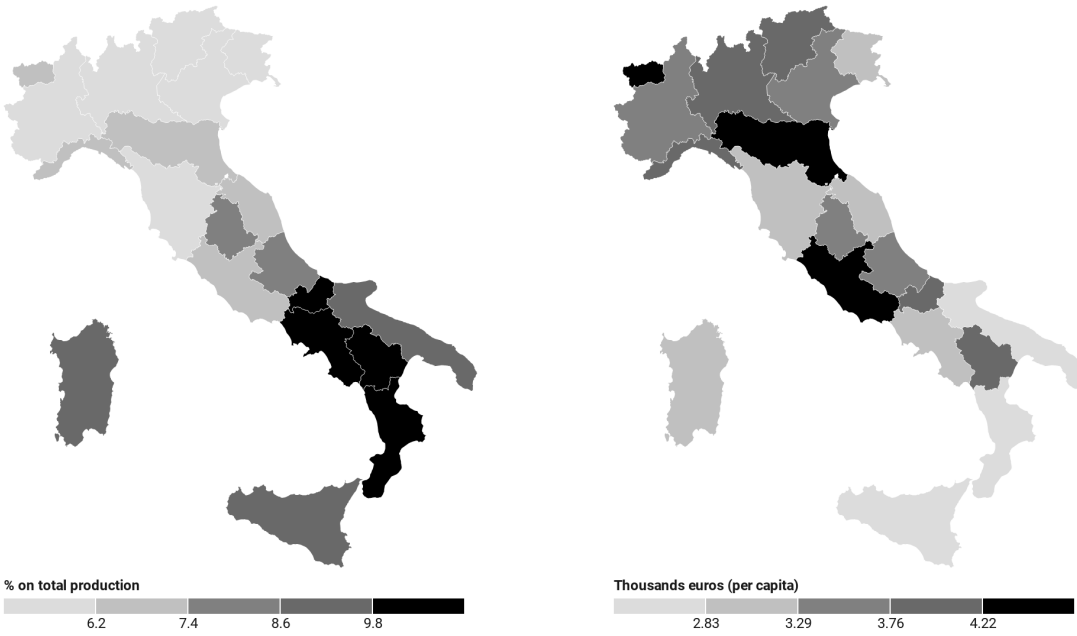
4.1 Economic Exposures

Before providing a detailed picture of the regional involvement in the different value chains, we consider some relevant and distinctive production networks. In particular, we study subsets of supply chains characterized by different economic fortunes during the lockdown which took place in Italy in Spring 2020. To represent the consumption value chains which have not been directly affected by the restriction measures, we consider the food and non-alcoholic beverages value chain. Conversely, in order to consider sectors strongly affected by the mobility restrictions, we analyse the value chains activated by clothing consumption, and by accommodation and restaurants expenditures. Finally, we also study the export value chains related to the U.S. and German markets.

Figure 3 displays the output activated by the food value chain both as a percentage of total regional production and in per capita terms. In % terms, southern regions are characterized by a stronger involvement in this supply chain. When moving from specializations

[11] http://dati.istat.it/.
[12] See https://www.inapp.org/it/dati/ICP for details.
[13] https://www.istat.it/it/archivio/8263.
[14] In order to obtain reliable information for each sector at the regional scale we linked data from 2016, 2017 and 2018.

Figure 3: Regional production activation by Italy's internal consumption of food and non-alcoholic beverages. % of regional output (left) and output per capita (right)



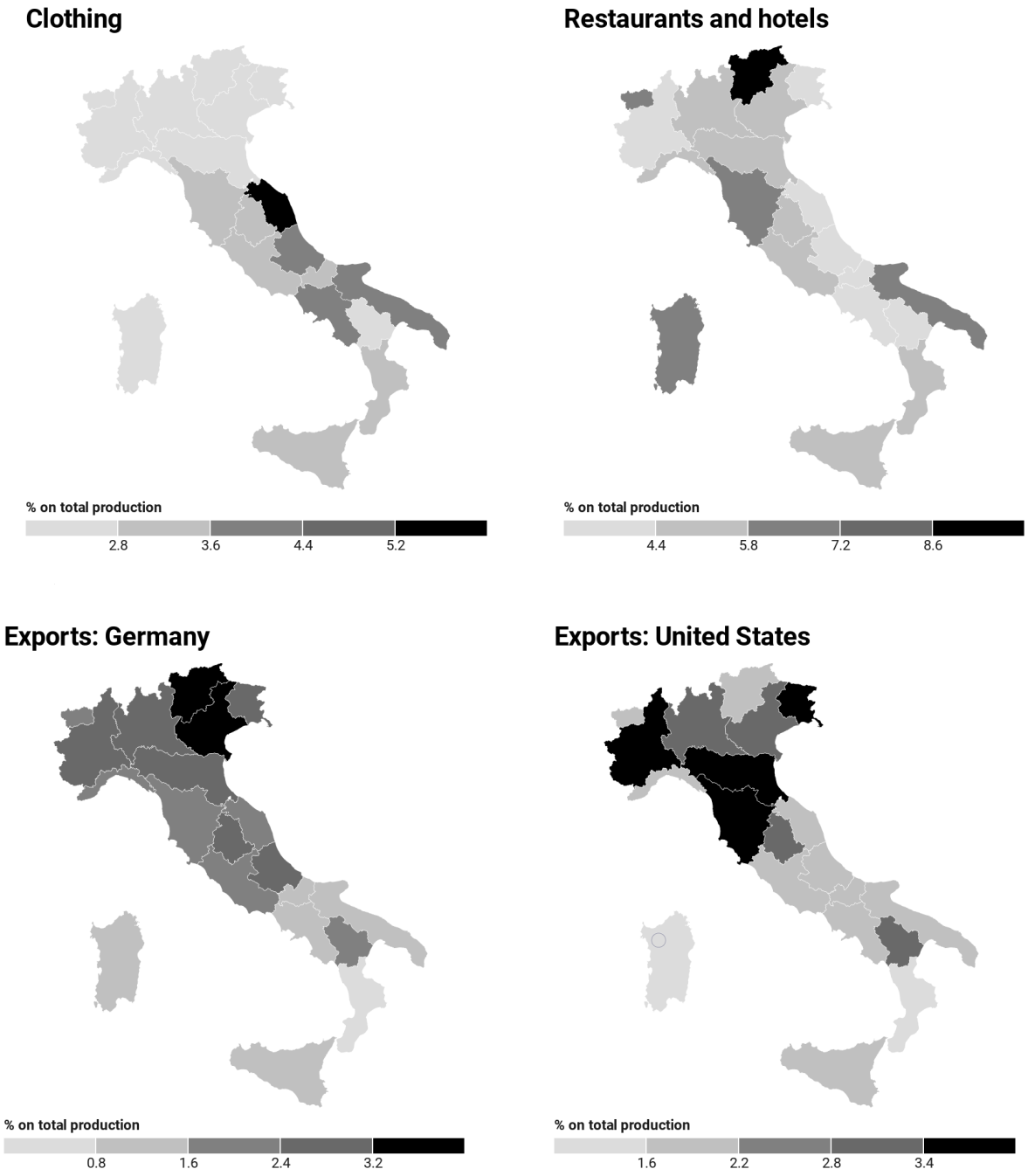
to per capita output, Lazio and some northern regions, especially Emilia-Romagna and Lombardy, become the most relevant. This might signal a structural weakness of industrial sectors in the South, suggesting that the North is more oriented toward higher value added segments in the supply chain.

We then consider the supply chains activated by internal consumption expenditures for clothing and restaurants & hotels (see the top panels of Figure 4). Consumption of clothing mostly activates center and southern regions, with Marche displaying the highest degree of involvement in the value chain. In absolute terms, the Marche are characterized by the highest values, together with Tuscany, Lombardy, Lazio and Veneto. Furthermore, as Lombardy and Lazio represent the largest national markets, they are also characterized by a high activation of commercial services along the value chain, whereas regions such as Marche and Tuscany especially contribute in terms of manufacturing production. Restaurant and hotel expenditures tend to activate production in the whole country, but they mainly expose few specific regions such as Trentino-Südtirol, Tuscany, Apulia and Sardinia where tourism plays an important role in the local economy. Again, focusing on absolute values allows regions such as Lombardy and Lazio to emerge as important economic actors (see Figure A.1 in the Appendix).

Moving to the export-related value chains, we find that regional exposures vary as shown by the bottom panels of Figure 4. Exports to the German market significantly activate all the northern and center regions, while exports to the United States mostly trigger the North of Italy and Tuscany. In terms of per capita production (see Figure

A.1 in the Appendix), Lombardy clearly emerges as the core region for Italian production serving German and U.S. demand.

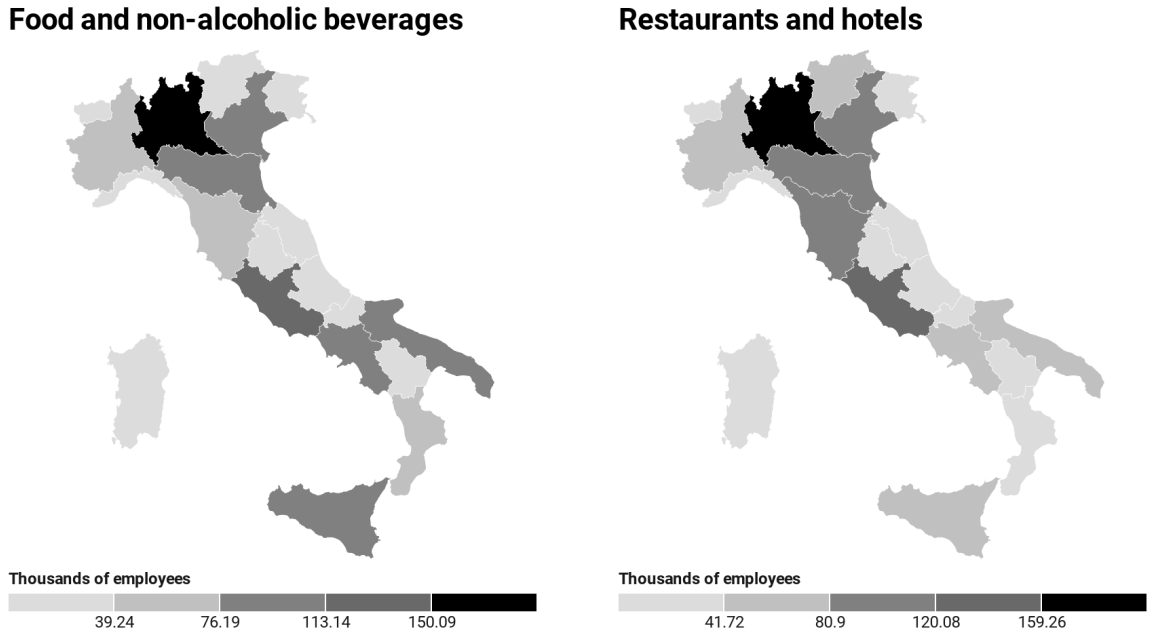
Figure 4: Regional production activation by Italy's internal consumption of clothing and hotels and restaurants and exports to Germany and United States.



Does production activation linearly map to employment activation? To answer this question, we investigate the relevance of the different value chains in activating Italian regions in terms of employment. We focus on two consumption value chains characterized by opposite dynamics during the lockdown period. Namely, the production network

activated by expenditures on food and non-alcoholic beverages and the one related to expenditures on hotels and restaurants (Figure 5). In both cases, Lombardy turns out to be the region with the highest activation in absolute terms, with almost 200 thousand employees involved in each of the two value chains. Workers in Lazio, Emilia-Romagna and Veneto are also strongly activated by both value chains. Finally, employment in southern regions is particularly stimulated by the food production network, while Tuscany employees are strongly activated by expenditures for hotels and restaurants.

Figure 5: Regional employment activation by Italy's internal consumption of food and non-alcoholic beverages and for restaurants and hotels.



We now move one step forward by studying the exposure to the mobility restrictions introduced by the Italian government on the 12 value chains activated by the different consumption needs, as well as on investment and total export production networks. We also group the 12 consumption value chains according to the degree of necessity of goods and services involved in production. More precisely, using the classification of "needs" employed by the Italian government during the first lockdown phase, we analyse the embeddedness of the Italian regions in three clusters of consumption-related value chains: consumption expenditures in essential goods and services, consumption expenditures in goods and services characterized by a medium degree of necessity, consumption expenditures for other goods and services (see Section 2 and the top panel of Table 1).

Let us consider production value chains first. The main results for each of the 12 consumption value chains are reported in Table 2, while those for the clustered consumption-related, investment-related and export-related value chains are reported in Table 3. The analyses of consumption value chains show that southern regions are more specialized, rel-

Table 2: Production activation in the 12 value chains activated by consumption expenditures

	Household consumption related value chains											
Region	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Piedmont	6%	2%	2%	9%	2%	2%	5%	1%	3%	0%	4%	4%
Aosta Valley	7%	2%	2%	14%	2%	2%	4%	1%	3%	0%	6%	3%
Lombardy	6%	2%	2%	7%	3%	1%	5%	1%	3%	0%	5%	5%
Trentino Südtirol	6%	2%	2%	9%	2%	1%	4%	1%	3%	0%	10%	3%
Veneto	6%	2%	2%	8%	3%	1%	5%	1%	3%	0%	5%	4%
Friuli Venezia Giulia	5%	1%	2%	8%	3%	2%	5%	1%	3%	0%	4%	7%
Liguria	7%	2%	2%	11%	2%	2%	7%	1%	3%	0%	5%	4%
Emilia-Romagna	7%	2%	2%	8%	2%	2%	4%	1%	3%	0%	5%	4%
Tuscany	6%	2%	3%	9%	2%	2%	5%	1%	3%	0%	6%	4%
Umbria	8%	2%	3%	10%	3%	2%	5%	1%	3%	0%	5%	5%
Marche	7%	2%	6%	9%	3%	2%	5%	1%	3%	0%	4%	4%
Lazio	7%	2%	3%	9%	3%	1%	5%	2%	4%	0%	5%	6%
Abruzzo	8%	2%	4%	10%	3%	1%	5%	1%	3%	0%	4%	4%
Molise	11%	3%	3%	12%	3%	2%	5%	1%	3%	1%	3%	4%
Campania	11%	3%	4%	10%	3%	2%	6%	1%	3%	0%	3%	4%
Apulia	9%	3%	4%	13%	2%	2%	6%	1%	3%	0%	6%	4%
Basilicata	10%	3%	2%	8%	3%	1%	6%	0%	2%	0%	4%	3%
Calabria	10%	3%	3%	15%	3%	2%	6%	1%	3%	0%	5%	4%
Sicily	9%	3%	3%	14%	2%	2%	9%	1%	3%	0%	5%	4%
Sardinia	9%	3%	2%	11%	2%	2%	7%	1%	3%	0%	6%	3%

(1): Food and non-alcoholic beverages; (2): Alcoholic beverages, tobacco and narcotics; (3): Clothing and footwear; (4): Housing, water, electricity, gas and other fuels; (5): Furnishings, household equipment and routine household maintenance; (6): Health; (7): Transport; (8): Communication; (9): Recreation and culture; (10): Education; (11): Restaurants and hotels; (12): Miscellaneous goods and services.

Table 3: Production activated by different value chain groups as a percentage of total regional production

Region	*value chain group*					
	(1)	(2)	(3)	(4)	(5)	(6)
Piedmont	9%	15%	16%	6%	8%	34%
Aosta Valley	10%	18%	17%	12%	6%	18%
Lombardy	9%	14%	18%	6%	8%	35%
Trentino Südtirol	9%	14%	21%	11%	7%	21%
Veneto	9%	14%	17%	7%	7%	35%
Friuli Venezia Giulia	9%	14%	18%	6%	7%	31%
Liguria	11%	20%	16%	7%	7%	24%
Emilia-Romagna	11%	14%	16%	6%	7%	34%
Tuscany	9%	16%	19%	7%	6%	30%
Umbria	12%	17%	19%	8%	6%	22%
Marche	11%	16%	20%	7%	7%	26%
Lazio	11%	17%	20%	8%	8%	18%
Abruzzo	12%	16%	16%	10%	6%	23%
Molise	16%	18%	16%	10%	6%	14%
Campania	15%	17%	17%	8%	6%	15%
Apulia	13%	20%	19%	8%	5%	15%
Basilicata	14%	15%	15%	12%	7%	22%
Calabria	15%	22%	18%	9%	4%	5%
Sicily	14%	24%	17%	7%	4%	9%
Sardinia	13%	20%	17%	8%	4%	16%

(1): Essential goods and services; (2) Goods and services of medium necessity; (3) Other goods and services; (4) Construction investment; (5) Other investment; (6) Exports

atively to northern and center ones, in food, housing and in transport related production networks due to the presence of car maker plants and of fuel-processing industries (see Table 2). More generally, northern regions are much less involved in internal consumption value chains, with few exceptions (e.g. Liguria in the housing and transport-related value chains and Trentino-Südtirol in hotels and restaurants-related production network). Regions in the center of Italy instead display intermediate degrees of embeddedness. It is finally important to notice that, notwithstanding the existence of relevant specialization patterns for some value chains (e.g., columns 1, 4, 11), the activation of some other chains cut across all regions almost equally indicating a lower degree of regional specialization (e.g., columns 2, 8, 10).

Regional heterogeneity emerges also when we focus on consumption-related production networks clustered according the different levels of necessity. In particular, value chains linked to goods and services characterized by essential and medium-level necessity are particularly relevant in activating production in southern regions (see Table 3). A more geographically homogeneous pattern emerges when one focuses on goods and services characterized by a lower degree of necessity.

In the same table, the analysis of investment value chains shows that construction investment is far more important in southern regions and in few small northern regions. Conversely, all the networks related to all other types of investment, and those more related to the production of high value added products (e.g., machine tools), contribute more strongly to total production of the northern regions.

The main difference between the North (and part of the Center) vis-à-vis the South of Italy concerns the importance of foreign demand in activating internal production. Exports activate around one third of total production in the largest regions of the North, as well as in Tuscany and Marche in the Center. For the rest of the country, instead, export value chains mobilize less than one fourth of total production. This pattern sheds lights on the impact that the lockdowns imposed by relevant trade partners (e.g., France, Germany and the U.K.) could have on northern regions with respect to southern ones. In this respect, the regional production systems of many Italian regions partially rely on external demand with relevant implications for the mobility of workers at risk.

When one considers the absolute-value measures of activation, such as the number of employees (see Tables 4 and 5), the central role of Lombardy emerges in all value chains, especially for what concerns the export-related network, wherein Lombardy employs more than one million workers (see Table 5). Most regions of the North and some of the Center (notably Tuscany and Marche relatively to their size) are also highly embedded in the export value chains. The central and southern regions are instead mostly involved in internal consumption value chains. Sicily stands out in this sense, but also Lazio and Campania display similar features. Finally, most employees working for consumption value chains are involved in providing food, hotels and restaurants and transport services

(Table 4).

To sum up, production and employment value chains show the existence of considerable heterogeneity across Italian regions, especially along the North-South axis. Northern regions are far more involved in export- and investment-related value chains, whereas southern ones play an important role in the production of necessary consumption goods and for investment in construction. This heterogeneity may have led to a differentiated impact of the lockdown measures imposed in March by the Italian government. The increasing spread of the pandemic that took place both in Italy and in many foreign trade partners since Fall 2020 might be reflected in heterogeneous economic impacts of the second wave across Italian regions according to the different lockdown measures and degrees of specialization (see Reissl et al., 2021).

4.2 Contagion Risk and Mitigation

The COVID-19 pandemic impacts firms both via the effect that lockdown measures have on job creation and production and through the effect of the spread of the virus, e.g. during daily home-work commuting or by working in presence. This results in heterogeneous risk and costs experienced by employees working in different regions/sectors. On the one hand, workers employed in the health system and in value chains providing essential goods and services (e.g., related to the supply of food and beverage, as well as medical equipment and pharmaceutical products; see also Section 4.1) do not experience the monetary costs of lockdown measures, but face higher risk of contracting the infection, especially when remote working is not feasible. On the other hand, employees in value chains providing non-essential goods and services under lockdown are sheltered from the health risk of the pandemic but experience a drop in income and have to rely on government income assistance even in the case in which they could in principle work remotely, if their firm decides to shut down production due to a substantial fall in demand, shortages of intermediate inputs or liquidity and solvency problems (see Demmou et al., 2021; Gourinchas et al., 2020; Guerini et al., 2020). It is thus of paramount importance to assess contagion risk and the potential for mitigating it by resorting to remote working in the different value chains under analysis.

We first assess, for some specific regional value chains, the share of employees at higher-than-average risk of contracting COVID-19 (see Section 2 for a formal definition). We then remove the employees who could work from home according to our estimates in order to assess the mitigating impact of remote working. Table 6 reports for each region and value chain the number of employees activated, the share of workers at above-average risk of contracting COVID-19 and, among the latter ones, the share of workers performing tasks which are more likely to be executed from home (a proxy of the risk reduction entailed by remote working).

Table 4: Thousands of employees in the 12 value chains activated by consumption expenditures

	Household consumption related value chains											
Region	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Piedmont	70	20	29	48	46	32	82	12	29	16	72	70
Aosta Valley	2	1	1	2	1	1	1	0	1	0	4	1
Lombardy	187	54	88	122	129	75	220	33	81	39	198	220
Trentino Südtirol	19	6	7	10	8	8	14	2	8	4	45	12
Veneto	77	21	35	36	36	33	68	11	28	19	103	58
Friuli Venezia Giulia	18	5	7	9	10	11	16	2	7	3	18	21
Liguria	25	7	8	16	9	10	27	4	8	3	31	18
Emilia-Romagna	94	28	35	48	52	36	81	11	33	17	96	77
Tuscany	60	17	36	30	23	23	53	8	23	11	83	45
Umbria	15	5	7	7	6	5	11	2	5	2	14	10
Marche	26	7	26	13	19	10	25	3	8	5	24	23
Lazio	123	37	51	84	80	37	122	32	54	17	127	124
Abruzzo	26	8	14	13	13	7	21	2	6	3	19	16
Molise	6	2	2	3	3	2	4	0	1	1	3	3
Campania	109	31	42	43	29	22	64	13	21	14	59	42
Apulia	84	25	35	45	33	19	58	6	16	9	64	45
Basilicata	12	4	3	5	4	3	8	1	2	2	7	5
Calabria	49	15	12	19	16	10	26	3	7	4	26	21
Sicily	100	31	29	51	40	23	79	8	19	11	69	54
Sardinia	30	9	8	14	8	9	19	3	8	4	31	12

(1): Food and non-alcoholic beverages; (2): Alcoholic beverages, tobacco and narcotics; (3): Clothing and footwear; (4): Housing, water, electricity, gas and other fuels; (5): Furnishings, household equipment and routine household maintenance; (6): Health; (7): Transport; (8): Communication; (9): Recreation and culture; (10): Education; (11): Restaurants and hotels; (12): Miscellaneous goods and services.

Table 5: Thousands of employees activated by different value chain groups

Region	*value chain group*					
	(1)	(2)	(3)	(4)	(5)	(6)
Piedmont	122	158	246	77	101	402
Aosta Valley	4	4	8	4	2	8
Lombardy	316	413	717	222	262	1.065
Trentino Südtirol	32	30	80	35	24	91
Veneto	132	135	259	99	96	621
Friuli Venezia Giulia	34	31	62	22	23	140
Liguria	43	50	74	25	29	144
Emilia-Romagna	158	157	292	90	109	468
Tuscany	100	101	209	66	53	399
Umbria	25	22	42	18	12	78
Marche	43	46	100	28	29	111
Lazio	197	254	436	136	144	304
Abruzzo	41	39	69	39	21	72
Molise	9	8	12	7	3	8
Campania	162	134	193	91	59	302
Apulia	128	118	193	74	45	128
Basilicata	19	15	21	15	8	22
Calabria	73	52	83	38	17	28
Sicily	153	149	210	74	43	99
Sardinia	48	39	67	29	14	97

(1): Essential goods and services; (2) Goods and services of medium necessity; (3) Other goods and services; (4) Construction investment; (5) Other investment; (6) Exports

Let us consider again the two paradigmatic value chains of food and non-alcoholic beverages vis-à-vis hotels and restaurants (see 4.1). At the aggregate level, they both activate more than a million employees across Italy, with some remarkable differences in terms of regional embeddedness (the former chain is more concentrated in southern regions, the latter is more homogeneous). Results in Table 6 suggest that two sources of heterogeneity stand out. On the one hand, both contagion risk and the potential for remote working differ widely. Expenditures for hotels and restaurants activate riskier tasks which can hardly be performed from home. On the other hand, interesting regional differences seem to arise in both value chains. The shares of workers at risk in the two value chains range from 35% (Calabria) to 53% (Aosta Valley and Sardinia) in the food supply chain, and from 66% (Calabria) to 84% (Aosta Valley) in the hotels and restaurants one. Furthermore, the potential of mitigating risk via remote working is higher in the food supply chain, oscillating between 24% (Lombardy) and 13% (Molise and Sardinia), while in the hotel and restaurant network, the values are much lower, i.e., between 13% in Emilia-Romagna, Umbria and Tuscany and 7% in Calabria. A further interesting pattern suggests the existence of a North-South divide in the share of employees that can work

Table 6: Employment at risk and risk reduction potential from remote working in value chains activated by food and non-alcoholic beverages expenditures and hotels and restaurants expenditures

Region	*Food & beverages*			*Restaurants & hotels*		
	Employees	at risk	but can telework	Employees	at risk	but can telework
Piedmont	70	48%	19%	72	78%	9%
Aosta Valley	2	53%	15%	4	84%	12%
Lombardy	187	45%	24%	198	74%	12%
Trentino Südtirol	19	48%	19%	45	78%	9%
Veneto	77	48%	20%	103	81%	12%
Friuli Venezia Giulia	18	49%	18%	18	77%	9%
Liguria	25	52%	15%	31	82%	11%
Emilia-Romagna	94	47%	21%	96	75%	13%
Tuscany	60	46%	22%	83	78%	13%
Umbria	15	46%	20%	14	77%	13%
Marche	26	49%	16%	24	78%	8%
Lazio	123	45%	23%	127	72%	14%
Abruzzo	26	50%	18%	19	79%	8%
Molise	6	51%	13%	3	79%	12%
Campania	109	48%	14%	59	78%	10%
Apulia	84	40%	15%	64	72%	11%
Basilicata	12	38%	14%	7	72%	10%
Calabria	49	35%	14%	26	66%	7%
Sicily	100	42%	14%	69	72%	11%
Sardinia	30	53%	13%	31	80%	12%

from home in the food supply chain: more than one fifth of the employees at risk can work from home in the Center-North, but this percentage falls to only 14% in the South. The characteristics of the tasks demanded within the hotel and restaurant value chain are more homogeneous across regions; the shares of employees that can work from home range from the 10% in the South and 13% in the Center.

We also evaluate the regional exposure by different value chain groups (see Table 7) in order to obtain a wider picture of the distribution of contagion risk and of the potential for reducing it via remote working. The contagion risk is relatively high in the value chains activated by essential goods and services and in those characterized by the lowest level of necessity (cf. respectively columns one and three in Table 7). This is mainly due to key value chains belonging to these groups, notably health expenditures in group (1) and hotel and restaurant expenditures in group (3) (see also Table 8). Among the consumption value chains, workers employed in sectors related to education expenditures are also exposed to relatively high contagion risk.

As to the riskiest value chains – notably, health, restaurants and hotels and education – we also split contagion risk into its two dimensions, i.e., infection and proximity risk.[15] We find that the value chains activated by education and hotel and restaurant expenditures are more affected by the latter, whereas health targeted consumption mostly depends upon the former. That is, whereas workers in hospitals are at the forefront of the battle against COVID-19, employees in the other two value chains are more at risk once contagion is relatively widespread among the population.

Apart from contagion risk heterogeneity across different value chains, strong variability is also present across regions within each production network. For instance, in value chains linked to consumption of essential goods and services, the contagion risk ranges from 59% in Aosta Valley to 39% in Calabria. This of course reflects the different degrees of specialization of Italian regions in serving the underlying value chains. However, the heterogeneity is preserved even when we focus on more disaggregated production networks. For instance, in the case of health related expenditures, risk ranges from 76% in Aosta Valley to 64% in Lazio (Table 8). This suggests that the bundle of tasks demanded from each NUTS2 region within each value chain are different and entail different degrees of COVID-19 risk. In particular, among the consumption-based value chains, those aimed at serving communication-related and housing-related expenditures are the ones mobilizing the lowest shares of workers at risk. Finally, it is interesting to note that the investment- and export-related value chains are associated with a relatively lower involvement of workers at risk.

The mitigation potential due to remote working is also highly variable across different value chains and, within each production network, between different regions. On average, the share of workers at risk who have the possibility of working remotely is relatively high

[15] Again, see Section 2 for a formal definition of the two dimensions capturing contagion risk.

Table 7: Employment at risk and risk reduction potential from remote working activated by different value chain groups

	value chain group											
	(1)		(2)		(3)		(4)		(5)		(6)	
Region	at risk	but can telework	at risk	but can telework	at risk	but can telework	at risk	but can telework	at risk	but can telework	at risk	but can telework
Piedmont	54%	17%	48%	35%	55%	20%	43%	16%	42%	30%	46%	23%
Aosta Valley	59%	15%	53%	33%	68%	18%	48%	11%	45%	30%	59%	18%
Lombardy	51%	22%	44%	38%	51%	24%	42%	18%	41%	33%	43%	28%
Trentino Südtirol	54%	18%	50%	39%	65%	16%	43%	14%	44%	24%	46%	19%
Veneto	54%	18%	48%	41%	60%	20%	42%	16%	43%	26%	47%	18%
Friuli Venezia Giulia	57%	17%	46%	35%	53%	23%	41%	11%	42%	24%	49%	17%
Liguria	56%	15%	45%	31%	60%	19%	49%	13%	42%	25%	43%	19%
Emilia-Romagna	52%	20%	47%	35%	56%	21%	43%	19%	44%	27%	45%	23%
Tuscany	52%	21%	46%	40%	59%	22%	47%	12%	42%	30%	48%	18%
Umbria	51%	18%	44%	36%	55%	21%	46%	12%	41%	25%	45%	16%
Marche	54%	16%	47%	31%	58%	16%	47%	14%	43%	24%	49%	17%
Lazio	49%	22%	41%	39%	49%	25%	42%	19%	39%	34%	38%	33%
Abruzzo	54%	18%	51%	32%	58%	17%	53%	11%	47%	23%	49%	19%
Molise	55%	12%	57%	37%	59%	18%	50%	9%	51%	21%	54%	16%
Campania	50%	14%	47%	36%	57%	18%	54%	11%	43%	22%	44%	15%
Apulia	44%	15%	49%	30%	58%	17%	45%	11%	47%	22%	44%	16%
Basilicata	43%	14%	53%	33%	57%	18%	45%	11%	50%	19%	56%	11%
Calabria	39%	14%	48%	36%	53%	19%	50%	12%	42%	31%	37%	17%
Sicily	46%	15%	45%	33%	54%	18%	54%	10%	43%	23%	39%	17%
Sardinia	57%	13%	48%	37%	63%	20%	55%	11%	42%	26%	55%	10%

(1): Essential goods and services; (2) Goods and services of medium necessity; (3) Other goods and services; (4) Construction investment; (5) Other investment; (6) Exports

Table 8: Employment at risk in the 12 value chains activated by consumption expenditures

	Household consumption related value chains											
Region	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Piedmont	48%	48%	50%	37%	49%	72%	49%	39%	46%	84%	78%	41%
Aosta Valley	53%	52%	56%	44%	53%	76%	57%	42%	51%	87%	84%	45%
Lombardy	45%	45%	47%	35%	43%	69%	43%	36%	46%	80%	74%	39%
Trentino Südtirol	48%	48%	53%	35%	48%	74%	51%	42%	48%	84%	78%	43%
Veneto	48%	48%	49%	33%	49%	72%	48%	41%	48%	84%	81%	40%
Friuli Venezia Giulia	49%	49%	52%	34%	47%	73%	48%	37%	49%	81%	77%	36%
Liguria	52%	52%	52%	36%	48%	70%	46%	40%	46%	83%	82%	41%
Emilia-Romagna	47%	47%	49%	39%	49%	71%	47%	39%	50%	79%	75%	44%
Tuscany	46%	46%	51%	34%	48%	72%	47%	39%	48%	80%	78%	43%
Umbria	46%	46%	45%	34%	46%	71%	46%	37%	48%	78%	77%	42%
Marche	49%	49%	62%	36%	49%	71%	48%	31%	47%	84%	78%	46%
Lazio	45%	45%	47%	32%	40%	64%	43%	36%	43%	78%	72%	36%
Abruzzo	50%	50%	52%	41%	53%	75%	52%	44%	45%	87%	79%	47%
Molise	51%	50%	57%	45%	55%	75%	56%	54%	54%	85%	79%	50%
Campania	48%	47%	52%	35%	49%	66%	47%	40%	49%	84%	78%	42%
Apulia	40%	39%	55%	41%	53%	71%	52%	38%	48%	87%	72%	47%
Basilicata	38%	37%	51%	37%	52%	69%	55%	52%	53%	89%	72%	46%
Calabria	35%	35%	50%	39%	47%	67%	48%	40%	45%	90%	66%	47%
Sicily	42%	42%	51%	35%	44%	69%	46%	43%	47%	85%	72%	42%
Sardinia	53%	53%	55%	34%	51%	73%	52%	44%	51%	87%	80%	42%

(1): Food and non-alcoholic beverages; (2): Alcoholic beverages, tobacco and narcotics; (3): Clothing and footwear; (4): Housing, water, electricity, gas and other fuels; (5): Furnishings, household equipment and routine household maintenance; (6): Health; (7): Transport; (8): Communication; (9): Recreation and culture; (10): Education; (11): Restaurants and hotels; (12): Miscellaneous goods and services.

in consumption value chains activated by expenditures for goods and services, in those characterized by a medium level of necessity and in those activated by non-construction investment (see respectively columns 2 and 5 of Table 7). As to the medium level of necessity group, the values are particularly high for the housing and, especially, communication and education value chains (see the details in Table 9). Conversely, a completely different picture emerges if one looks at the value chains activated by hotel and restaurant expenditures which employ mostly workers with non-teleworkable tasks. Also the construction investment value chain, as expected, mostly triggers non-teleworkable activities, which are, however, intrinsically less risky than other value chains.

Again, regions show remarkable differences in the shares of workers that can mitigate contagion risk via remote working. For instance, in Lombardy, 33% of employees at risk involved in the non-construction investment value chain can work from home. In Basilicata, this share falls to 19%. In general, northern and central regions are more involved in tasks which can be performed remotely than southern regions. Regional differences partly reflect a heterogeneous sectoral participation to different value chains, which are more service based in the North, but are also related to the diverse bundles of tasks which are demanded in each region within the same sectors.

4.3 A Deeper Inspection of Economic and Contagion Risks

In the previous sections we showed that economic and contagion risk are substantially heterogeneous across regions and value chains. In this section we further proceed to investigate the extent to which these two risk correlate, that is, whether employees at risk of contagion tend to over-concentrate in value chains where regional production is relatively more specialized. The estimation of a positive association would imply that contagion risk increases where regional production concentrates. Contrarily, a negative relationship would suggest that employment at risk is high where regional production is low, which could alleviate concerns about the economic costs of lockdown-induced stops to production. Unveiling such correlation may therefore prove useful for the design of region-specific lockdown policies, that balance the epidemic spread and economic losses.

We formally investigate the association between economic and contagion risk by means of a battery of regressions based upon the following specification:

$$WaR_{ir} = \alpha + \beta Spec_{ir} + \gamma_e Spec_{ir} D_i^e + \gamma_m Spec_{ir} D_i^m + D_i^e + D_i^m + \lambda_r + \delta x_{i,r} + \epsilon_{ir},$$

where WaR_{ir} represents the share of "workers at risk" in region r and value chain i, $Spec$ quantifies the specialization as measured by the employees over the regional population within each region value chain pair, D^e and D^m are dummy indicators for essential and medium-necessity value chains, λ_r is a set of region-specific dummies, and $x_{i,r}$ is a set of controls composed by the shares of workers employed by each region and value chain in

Table 9: Share of employees at risk who can work from home in the 12 value chains activated by consumption expenditures

	Household consumption related value chains											
Region	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Piedmont	19%	19%	20%	27%	17%	13%	23%	46%	51%	78%	9%	28%
Aosta Valley	15%	15%	17%	25%	19%	17%	22%	37%	40%	79%	12%	35%
Lombardy	24%	24%	23%	30%	24%	17%	27%	46%	48%	79%	12%	35%
Trentino Südtirol	19%	19%	16%	34%	18%	16%	21%	35%	54%	77%	9%	34%
Veneto	20%	20%	21%	32%	22%	14%	25%	41%	43%	80%	12%	34%
Friuli Venezia Giulia	18%	18%	18%	28%	22%	16%	24%	26%	45%	78%	9%	40%
Liguria	15%	15%	17%	25%	20%	13%	23%	40%	43%	82%	11%	35%
Emilia-Romagna	21%	21%	20%	28%	18%	16%	23%	35%	46%	77%	13%	29%
Tuscany	22%	22%	21%	35%	24%	17%	28%	45%	47%	80%	13%	39%
Umbria	20%	20%	19%	33%	20%	14%	24%	34%	47%	79%	13%	33%
Marche	16%	16%	11%	22%	16%	16%	20%	29%	43%	77%	8%	25%
Lazio	23%	23%	24%	32%	22%	20%	29%	50%	51%	82%	14%	36%
Abruzzo	18%	19%	14%	28%	19%	15%	21%	32%	39%	79%	8%	28%
Molise	13%	13%	15%	25%	15%	12%	19%	37%	38%	86%	12%	25%
Campania	14%	14%	12%	26%	17%	16%	21%	40%	37%	85%	10%	33%
Apulia	15%	15%	14%	27%	14%	14%	19%	32%	41%	82%	11%	27%
Basilicata	14%	14%	16%	29%	15%	15%	17%	59%	48%	78%	10%	28%
Calabria	14%	14%	18%	37%	16%	13%	22%	49%	44%	77%	7%	35%
Sicily	14%	14%	16%	29%	16%	16%	21%	40%	41%	82%	11%	29%
Sardinia	13%	13%	18%	34%	21%	14%	24%	34%	50%	78%	12%	32%

(1): Food and non-alcoholic beverages; (2): Alcoholic beverages, tobacco and narcotics; (3): Clothing and footwear; (4): Housing, water, electricity, gas and other fuels; (5): Furnishings, household equipment and routine household maintenance; (6): Health; (7): Transport; (8): Communication; (9): Recreation and culture; (10): Education; (11): Restaurants and hotels; (12): Miscellaneous goods and services.

positions different from production activities (i.e., personal services, firm services, logistic) with δ the vector of associated parameters.

We estimate the model through OLS and we consider – as dependent variable – the share of workers at risk either gross or net of occupations which can be performed remotely (see Table 10 as well as the graphical insight in Figure 6). Our results point to significant yet heterogeneous associations between economic and contagion risk across different value chain groups. Indeed, we find evidence of a marked positive correlation between workers at risk and production specialization within *non-essential* value chains. At the opposite, a negative or barely significant association is found for *essential* and *medium necessity* goods and services, either considering the remote working potential of occupations or not.[16] These results further confirm that the same lockdown policy may affect regions asymmetrically and that closure of essential and non-essential activities brings about different trade-offs. Regions with relatively high share of workers at risk in essential and medium necessity workers bear relatively lower economic risk: hence, even strong lockdown policies may be less of a concern for these regions than for others. Differently, for non essential value chains, higher activation of regional production increases with workers at risk, which implies that mild lockdowns (e.g. affecting just non-essential activities) are more effective in reducing contagion risk in those regions where they also induce larger economic impacts.

Table 10: Baseline Region: Piedmont; Baseline value chain: Non essential value chains. Baseline Share of workers: Agriculture and industry

	(1) Workers at risk	(2) Workers at risk (non remote)
Constant	0,305***	0,253***
D^m	0,143***	-0,0746**
D^e	0,0739***	0,225***
Spec	0,0532***	0,142***
$D^m \times Spec$	-0,106***	-0,149***
$D^e \times Spec$	-0,0635***	-0,191***
Regional FE	Yes	Yes
Controls	Yes	Yes
N	240	240

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

We also consider two alternative robustness specifications by unpacking the results by necessity group and accounting for each specific value chain. We find some interesting patterns concerning the relations between economic specialization and health risk across value chains (see Table 11). Let us begin from the value chains within the *essential* group. Food and Beverages display a negative association between economic specialization

[16] For goods and services of medium necessity, when accounting for non remote workers at risk only, there is a downward shift in the constant term – basically due to the high remote working potential in Education value chain with the coefficient compensating the effect of the baseline group.

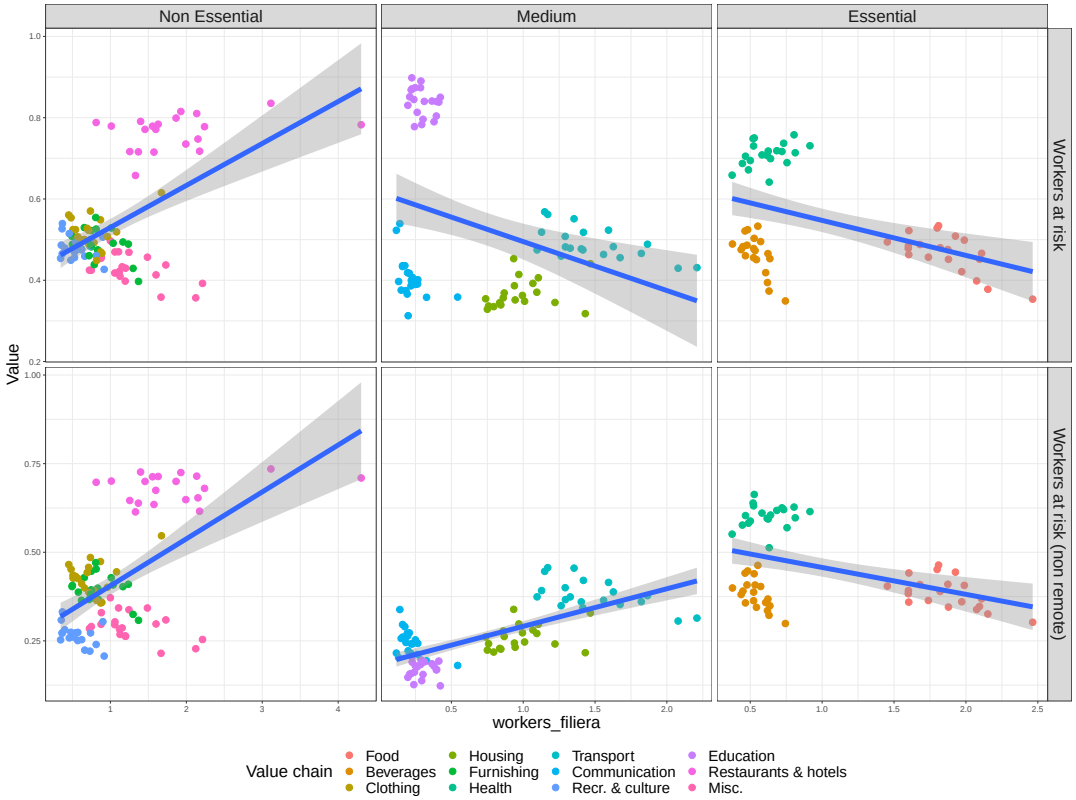


Figure 6: Workers at risk and economic specialization across groups of value chains ranked by necessity. We stress that the slope of the best fitting line for Medium necessity value chansons and Workers at risk (non remote), namely the bottom center panel, is not significant from zero. The change of slope with respect to the top center panel is arguably due to the role of Education.

and health risk, whereas the opposite holds for Health, unveiling a potential trade-off between health risk and the economy for the latter. With respect to the basic needs, value chains activated by expenditures in goods and services characterized by a medium level of necessity (housing, transport, communication and education) display a lower baseline intrinsic risk with the exception of education, as observable from the estimates of the value chain specific dummies. Among them, however, only housing is also characterized by a positive correlation between specialization and health risk, suggesting the existence of a potential trade-off. A similar kind of relation is expressed by clothing among non-essential value chains.[17]

Finally, we notice that the share of workers at risk in each value chain positively associates with the percentage of employees devoted to the personal-service segments of the value chains, indicating that the type of activity with which regions contribute to the whole value chain is also a driver of the overall contagion risk. As a further confirmation, once we remove those who can work remotely from the population of workers at risk,

[17]The detection of these trade-off can also be used as an indication for the value chains which deserve more focus in future policies: an increase in the remote-work potential for these value chains might allow to contain the contagion risk during future pandemics events.

Table 11: Baseline Region: Piedmont; Baseline value chain: Food/Beverages. Baseline Share of workers: Agriculture and industry

	(1) Workers at risk	(2) Workers at risk (non remote)
Constant	0,551***	0,480***
Beverages	-0,0360	-0,0254
Clothing	-0,235***	-0,166***
Housing	-0,295***	-0,249***
Furnishing	-0,133*	-0,0873
Health	-0,0554	0,0107
Transport	-0,121*	-0,0707
Communication	-0,222***	-0,180***
Recreation & Culture	-0,191***	-0,232***
Education	0,163**	-0,429***
Restaurants & Hotels	0,0408	0,0986*
Misc.	-0,213***	-0,158**
Spec.	-0,0954**	-0,0678**
Beverages x *Spec.*	-0,169*	-0,121
Clothing x *Spec.*	0,209***	0,158***
Housing x *Spec.*	0,132**	0,0950**
Furnishing x *Spec.*	0,0439	0,0119
Health x *Spec.*	0,185***	0,103*
Transport x *Spec.*	0,0560	0,0213
Communication x *Spec.*	0,00646	0,0712
Recreation & Culture x *Spec.*	0,0912*	0,0644
Education x *Spec.*	-0,0816	0,0730
Restaurants & Hotels x *Spec.*	0,107***	0,0765**
Misc. x *Spec.*	0,0794*	0,0584*
Business services	0,0817	-0,164*
Personal services	0,174***	0,124***
Logistcs	0,0740	-0,0142
Other activities	0,0194	0,0630
Regional FE	Yes	Yes
N	240	240

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

contagion risk negatively correlates with the percentage of employees occupied in business-service segments of the value chain, which is where tasks can more easily be performed at home.

5 A Policy Experiment

In this section, we exploit the empirical results of the previous sections in order to perform a policy experiment. More precisely, we assume that mandatory social-distancing measures are imposed for four weeks only on non-essential goods and services value chains (cf. Table 1) and only in the riskiest regions in terms of contagion speed – classified by the Italian government as "red areas" in November 2020, that is Lombardy, Piedmont, Aosta

Valley, Trentino Südtirol, Tuscany, Calabria and Campania.[18] The analysis is carried out assuming that all the other inter-regional and international value chains, apart from the non-essential consumption ones in the red zones, are kept open. We also assume that remote working is always implemented whenever it is possible. The impact of the policy experiment is measured both in terms of production and value-added losses, as well as in terms of number of employees preserved from the risk of contagion. The latter dimension is evaluated by disentangling the contribution of value chain closures in red areas from the contribution of remote working activities implemented over the whole national territory.

Table 12: Value added loss and employment involvement of closing down non-essential consumption value chains in Piedmont, Aosta Valley, Lombardy, Trentino Südtirol, Tuscany, Campania and Calabria for 4 weeks

Region	Value added loss (%)	Employment (thousands)
Piedmont	1,2%	202
Aosta Valley	1,3%	7
Lombardy	1,3%	547
Trentino Südtirol	1,6%	73
Veneto	0,2%	30
Liguria	0,2%	7
Friuli Venezia Giulia	0,3%	13
Emilia-Romagna	0,2%	49
Tuscany	1,3%	173
Umbria	0,2%	6
Marche	0,2%	19
Lazio	0,3%	81
Abruzzo	0,1%	12
Molise	0,1%	2
Campania	1,2%	159
Apulia	0,1%	29
Basilicata	0,2%	4
Calabria	1,2%	62
Sicily	0,1%	28
Sardinia	0,1%	4

In Table 12, we show the impact in terms of value added (%) and employment (thousands) of the light lockdown. The value chains providing non-essential goods and services account for more than 13% of total value added in red-zone regions on an annual basis, reaching the highest level in Trentino Südtirol (19.2%). Scaling the impact on a monthly basis, we observe potential losses between 1.2% and 1.6% in the red regions, and between 10 and 30 basis points in the other Italian regions, which receive the shock only indirectly,

[18]Lombardy, Piedmont, Aosta Valley and Calabria have been classified red areas since 6 November. Tuscany and Campania since 15 November. Differently from other regions classified as red areas, Trentino Südtirol (more precisely only the Bozen NUTS3 province) autonomously classified itself as red area since 11 November.

trough their embeddedness in these value chains. At the national scale, the loss would amount to a 0.7% of GDP.

The idea to impose a lockdown on regions experiencing a more significant pandemic crisis rests on the possibility to decrease the number of workers at risk of contracting the virus in their every day commuting, thus spreading the diffusion of the virus among the population. The impacts of these restrictions are displayed in Figure 7. In Lombardy, 49% of its roughly 3.5 millions employees are highly exposed to a COVID-19 infection. However, one third of them can potentially work remotely. Furthermore, about one sixth of the remaining employees can be preserved from contagion by implementing the full closure of non-essential value chains. To sum up, the two measures (lockdown and remote working) are able to protect 44% of the labor force at risk of contagion. Results in Piedmont and Campania are similar: the share of workers at risk over total employment is higher, especially in Campania (54% of its 1,3 millions of employees), and the decrease in the number of employees at risk who cannot rely on remote working is lower. Trentino Südtirol is the region with the highest gain, in terms of risk, from the joint implementation of the two measures. Almost 50% of its employees at high risk would be protected by the closure of non-essential value chains and by the extensive reliance upon remote working in the other value chains.

Figure 7: Share of total employment at risk of contracting the COVID-19 and risk reduction due to remote working and value chain closures.

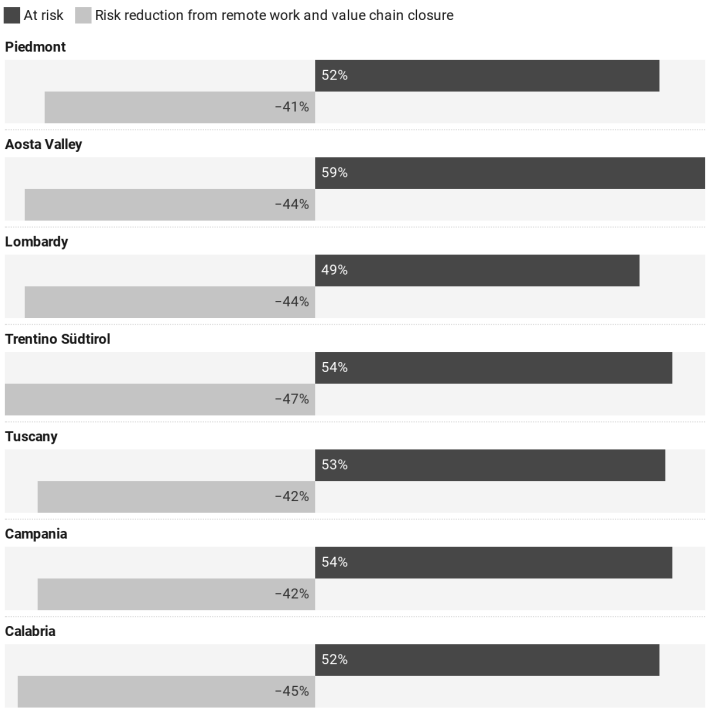


Table 13 breaks down the total effect on risk reduction into specific contributions of the two measures. In Lombardy, 31% of workers at risk could work from home (i.e.,

about 543 thousand employees out of over 1.7 million). On the other hand, the closure of non-essential consumption value chains would protect 300 thousand workers from the risk of contagion. Overall, the combination of the two measures would protect nearly 800 thousand workers from the risk of contracting the COVID-19 virus in the workplace. The closure of non-essential supply chains, therefore, would add another 233 thousands (13,3% of workers at risk) workers to the group of employees protected from contagion through remote working. The additional impact of the closure of non-essential consumption supply chains reaches its peak in Trentino Südtirol (19,2% of workers at risk), whose dependence on supply chains linked to tourism consumption, which activates jobs more at risk of contagion and characterized by lower levels of remote working, is particularly pronounced.

Table 13: Contributions of remote working and value chain closures to COVID-19 risk reduction

Region	*Employees*	*Preserved employees*		
	at risk	by remote working	by value chain closures	by both
Piedmont	719	204	115	297
Aosta Valley	26	7	5	11
Lombardy	1.745	543	300	776
Trentino Südtirol	217	59	49	101
Tuscany	632	179	108	265
Campania	724	225	95	303
Calabria	232	76	36	105

To conclude, the examined policy allows a relatively high protection of workers at risk in regions characterized by an intense spread of COVID-19, while containing the economic cost.

Notice that our policy experiment is performed against a benchmark which considers an economy operating in a pre-pandemic world. As recently stressed also by IMF (2020), independently of mandatory measures, the spread of the pandemic itself would have decreased economic activity via voluntary choices undertaken by individuals, thus reducing the economic costs associated to lockdown policies (see also Goolsbee & Syverson, 2020).

6 Conclusions

In this work, we have evaluated the degree of embeddedness of Italian regions in different value chains to infer their exposure to economic and the contagion risks related to the spread of COVID-19. This approach is useful to stress the limits of a purely horizontal approach to lockdown interventions, which would abstract from the strong inter-sectoral links at the inter-regional level. Given the heterogeneous involvement of Italian regions in different value chains and the diverse susceptibility of the latter to contagion risk, the

impact of the COVID-19 pandemic and the ensuing lockdown policies has been heterogeneous. In particular, we found that southern regions, whose degree of specialization in essential consumption value chains is higher than northern ones, may have suffered relatively less losses from the lockdown closures during the first wave of contagion in Spring 2020. Moreover, northern regions, whose production systems are more embedded in investment- and export-related supply chains, have been highly exposed to mandatory social distancing measures and the related costs. At the same time, remote working potential, relatively higher in northern regions, may have acted as a mitigating factor. Our work has also shown that contagion risk and remote working potential in different value chains are heterogeneous and do not follow the distinction between essential vs. non-essential value chains. More precisely, we have found relatively riskier (and less teleworkable) activities both in essential (e.g., health expenditures) and in non-essential (e.g., hotels and restaurants expenditures) value chains, and vice-versa. These findings suggest that even the production of essential goods and services always involves a certain degree of contagion risk.

Our empirical analysis uncovers specific patterns in the relation between economic specialization and health exposure to COVID-19 in different value chains. Increasing regional specialization has a positive or a negative impact on the contagion risk according to the value chain on which production concentrate. This stems from regional specific patterns in terms of the different segments of the value chains they contribute most (e.g., production activities, business services, personal services), as well as from the specific bundle of tasks workers are requested to perform. Moreover, we document a robust negative correlation between economic and contagion risk in essential and medium necessity value chains (while a positive one is found for non essential good and services), indicating that regions with relatively higher shares of workers at risk in such value chains face a significantly softer trade off from strict lockdown policies.

On the policy side, our findings suggest that the joint implementation of geographically based measures, coupled with restrictions on consumption and leisure activities, and with interventions fostering remote working could prevent almost 3.5 million employees (2 million of which in red areas) from being exposed to a higher than average contagion risk, with a relatively low cost for the whole economy.

Our research can be further expanded along several dimensions. First, a distinction between substitutable and non-substitutable inputs would help in identifying the most relevant bottlenecks within the inter-regional value chains. Second, a deeper assessment of contagion risk would require accounting for the interactions between workers and customers, as well as public transport commuting. One could even perform a more finely-grained analysis at the level of mobility areas (e.g., Monte, 2020), where local interactions between workers and customers and pressures on public transport and hospitals typically occur. In this respect, the analysis applied at regional level for Italy could be extended at

the local labor market area scale, generalizing the results in Ferraresi et al. (2020a) which have been carried out for a single region. Finally, on the policy side, our work would benefit from the inclusion of both a time dimension and an epidemiological module, in order to better evaluate when (and for how long) to introduce social distancing interventions in order to minimize both the health and economic costs of the pandemic.

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Appendix

Table A.1: IO Sectors

Code	Description
1	Agriculture, forestry and fishing
2	Mining And Quarrying
3	Manufacture Of Food, Beverages And Tobacco
4	Manufacture Of Textiles, Wearing Apparel And Leather
5	Manufacture Of Wood And Of Products Of Wood And Cork, Except Furniture
6	Manufacture Of Paper And Paper Products, Printing And Reproduction Of Recorded Media
7	Manufacture Of Coke And Refined Petroleum Products
8	Manufacture Of Chemicals And Pharmaceutical Products
9	Manufacture Of Rubber And Plastic Products
10	Manufacture Of Other Non-Metallic Mineral Products
11	Manufacture Of Basic Metals, Fabricated Metal Products, Except Machinery And Equipment
12	Manufacture Of Computer, Electronic And Optical Products
13	Manufacture Of Electrical Equipment
14	Manufacture Of Machinery And Equipment N.E.C.
15	Manufacture Of Transport Equipment
16	Furniture, Manufacturing N.E.C, Repair And Installation Of Machinery And Equipment
17	Electricity, gas, water supply, sewerage, waste and remediation services
18	Construction
19	Wholesale And Retail Trade; Repair Of Motor Vehicles And Motorcycles
20	Transportation And Storage
21	Accommodation And Food Service Activities
22	Publishing, Motion Picture, Video, Sound And Broadcasting Activities
23	Telecommunications Activities
24	Computer Programming, Consultancy And Related Activities; Information Activities
25	Financial And Insurance Activities
26	Real Estate Activities
27	Legal And Accounting Consulting, Architectural And Engineering Activities; Technical Testing And Analysis Services
28	Public Administration And Defence; Compulsory Social Security
29	Education
30	Human Health And Social Work Activities
31	Arts, Entertainment And Recreation and others services
32	Others services

Figure A.1: Regional production activation by Italy's internal consumption of clothing and hotels and restaurants and exports to Germany and United States in per capita terms.