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# Policy responses to COVID-19 pandemic waves: cross-region and cross-sector economic impact

Andrea Bonfiglio[1]*, Silvia Coderoni[2], Roberto Esposti[3]

[1] CREA - Research Centre for Agricultural Policies and Bioeconomy, Italy
[2] Department of Agricultural and Food Economics, Università Cattolica del Sacro Cuore, Italy
[3] Department of Economics and Social Sciences, Università Politecnica delle Marche, Ancona, Italy

*Corresponding author
Dr. Andrea Bonfiglio
Research Centre for Agricultural Policies and Bioeconomy
CREA – Council for Agricultural Research and Economics
Via dell'Industria 1, Osimo (AN), Italy, 60027
Email: andrea.bonfiglio@crea.gov.it



**Abstract**

This paper proposes a modelling approach to assess the cross-region and cross-sector economic impacts of the restrictions imposed by governments to contain the COVID-19 pandemic. The nationwide lockdown imposed in Italy during the first wave of the pandemic is used as a benchmark. However, the adopted approach allows an ex-ante assessment of alternative policy responses, in the event of successive pandemic waves, in order to rationalize the policy intervention and reach the best possible compromise between containing the risk of contagion and reducing economic losses. The used approach consists of a non-linear programming model based on a multiregional Input-Output (I-O) table, which guarantees greater flexibility than traditional I-O analysis. It is applied to estimate both direct and indirect losses of GDP and employment produced by alternative policy responses represented by general and differentiated lockdowns. The evidence deriving from the Italian experience shows a sort of learning process through successive waves based on the introduction of increasingly flexible and tailored policy responses to the pandemic.

**Keywords:** COVID-19 pandemic; ex-ante policy response assessment; multi-regional input–output tables; constrained non-linear programming

**JEL Classification**: C61, C67, I18, R58

## 1 Introduction: the policy dilemma

With many countries entering the fourth wave of the SARS-CoV-2 (or COVID-19) pandemic, the respective governments are still struggling to achieve the best possible compromise between two conflicting needs: introducing restrictions to contain the sanitary risk and minimizing the economic losses of these restrictions. The often-drastic initial policy response has been progressively adjusted and fine-tuned across the subsequent waves of the pandemic. In fact, this adjustment is still ongoing in order to take into account new developments, such as virus variants and vaccination, as well as the increasing amount of knowledge and expertise accumulated over the previous waves.

Although different models of rationalization of the policy response have been proposed and adopted, these models are mostly oriented towards the public-health side of the dilemma, that is, the modelling of the spread of the contagion. A detailed representation of economic losses, and of their intersectoral and geographical spread, remains largely disregarded. This paper aims to propose a modelling approach that fills this gap in order to provide decision makers with a suitable tool for taking more targeted decisions in subsequent pandemic waves.

The used approach consists of a constrained non-linear programming (CNLP) model based on a multiregional I–O (MRIO) table. The impacts of restriction measures are computed in terms of Gross Domestic Product (GDP) loss, employment loss and reduction of the risk of contagion in the workplace. By capturing the intersectoral and interregional linkages within the economy, this approach has two main advantages. The first concerns the measurement of direct and indirect effects of the containment measures. Disregarding the indirect effects can misrepresent the real impact of restrictions as well as their distribution. The measurement of these effects together with the direct ones reshapes the controversial trade-off between the reduction of the risk of infection and the minimization of economic losses, and leads to the second, and more important, merit of the proposed modelling approach. The model is conceived following a decision-making logic since it allows an ex-ante evaluation of the overall impacts of alternative restriction policies. The options analysed in this study consist both in a general lockdown, involving sectors considered as non-essential, and in differentiated and partial closures at sectoral and regional levels to take into consideration the different specificities. The comparison between the corresponding impacts provides information on the possibility of ensuring the same risk reduction by imposing differentiated restrictions that contain the economic loss.

This modelling approach uses the Italian Government's response to the first wave of spring 2020 as a benchmark. Italy was the first Western country to confront with this unexpected event and the first policy reaction was to introduce radical lockdown measures with consequent large economic costs. The adequacy of this political response has been (and still is) at the core of the political debate in Italy. This debate has led to a gradual change in the government’s strategy. With the second wave (October-November 2020), a more flexible approach was adopted by applying constraints more suited to specific sectoral and, above all, regional conditions. However, this policy response was not based on any dedicated modelling toolkit. Therefore, the proposed approach and its results can provide useful suggestions to any decision maker in terms of more tailored mitigation strategies. Although this study focuses on the Italian case, the modelling approach can be transferred to other countries through appropriate adjustments, which include the construction of the corresponding MRIO table.

The remaining of the paper is structured as follows. Section 2 examines the policy issue as well as recent literature on the subject. Section 3 details the adopted modelling approach, the way alternative policy responses are modelled, and the data used. Section 4 reports and compares the direct and indirect impacts at sectoral and regional level generated by these alternative policies. Section 5 discusses potential applications of the approach and validates the results. Section 6 provides some policy advice and implications and concludes indicating a few future research directions.

## 2 The issue: modelling the impact of policy responses to the pandemic

In response to the spread of the COVID-19 pandemic, nearly all countries have adopted various “shelter-in-place” policies (Berry, Fowler, Glazer, Handel-Meyer, & MacMillen, 2021). Policy reactions have differed greatly across space, i.e., between regions and countries. They have ranged from declaring a state of emergency and generalised lockdowns in some countries to fairly limited restrictions or no closure in others. This differentiation has also reverberated in the evolution of the response over time and especially in the subsequent waves of the pandemic. Countries that initially imposed strong lockdowns then adopted more differentiated restrictions between regions and sectors. Conversely, several countries with an initially mild response then applied stronger and more generalised restrictions. Table 1 presents the different response in selected EU countries and its evolution over time as measured by the “stringency” index (see the note to the table).

At the core of these diverse policy responses, there is a largely unanswered question: what is the best compromise, under certain conditions, between limiting the risk of contagion and minimizing the economic losses produced by policy restrictions? Over the past two years, this question has monopolized not only the political debate but also the attention and research activity of economists and other social scientists (Brodeur, Gray, Islam, & Bhuiyan, 2021; Coutiño & Zandi, 2021). The dilemma immediately appeared serious and challenging: “shutting down the economy to slow down the contagion prevents the collapse of the healthcare systems and massive deaths, but comes at the cost of a potentially devastating supply- and demand-sided crisis" (Perugini & Vladisavljević, 2021: 146).

Table 1 - Different policy responses to COVID-19 pandemic across selected European countries and their evolution over time

| Country | Spring 2020 | | | Stringency index[a] | | |
|---|---|---|---|---|---|---|
| | State of emergency | Non-essential activities | Lockdown | Spring 2020 | Fall 2020 | Summer 2021 |
| Czech Republic | Y | L | Y | 82.4 | 69.4 | 37.9 |
| France | Y | L | L | 88.0 | 75.0 | 45.8 |
| Germany | N | L | L | 76.9 | 67.6 | 67.6 |
| Greece | N | L | L | 84.3 | 80.6 | 41.7 |
| Italy | Y | L | L | 85.2 | 82.5 | 47.2 |
| Netherlands | N | O | N | 78.7 | 56.5 | 32.4 |
| Poland | N | L | L | 81.5 | 75.0 | 44.4 |
| Spain | Y | L | L | 85.3 | 71.3 | 48.6 |
| United Kingdom | N | L | L | 79.6 | 67.6 | 51.4 |

Legend: Y = Yes; N = No; O = Open; L = limited closures/restrictions.
[a] The stringency index is a composite measure based on nine response indicators including school closures, workplace closures, and travel bans, rescaled to a value from 0 to 100 (100 = strictest). The relevant values, calculated on 1st April 2020, 1st December 2020, and 1st July 2021, are shown.
Source: Frontex (https://frontex.europa.eu) and Our World in Data (https://ourworldindata.org).

The Italian experience is emblematic in this respect. First among Western countries and economies to be affected by the pandemic (De Natale et al., 2020), in March 2020 the Italian Government responded to the explosion of infections by identifying those sectors that have been defined as essential, i.e., which ensure the continuity of the economy and satisfy the basic needs of the population such as food, health, education and other basic products and services (Italian Prime Minister, 2020a). To contain the risk of contagion, the remaining sectors, i.e., non-essential sectors, have been shut down in all regions. Since November 2020, however, the Italian Government has decided to classify the regions at NUTS-2 level into different categories according to a set of indicators to monitor the spread of the pandemic. Based on the criticality levels, a broad differentiation has been thus implemented both between sectors, i.e., essential vs. non-essential sectors, and regions, i.e., "red" vs. "white" regions, where the colours identify, respectively, greater contagion and stronger restrictions, and low or null level of contagion and no restrictions (Italian Prime Minister, 2020b).

The first decisions of the Italian Government on the sectors to be closed were based on the concept of essentiality and did not consider the implications related to the structure of the economy (Giammetti, Papi, Teobaldelli, & Ticchi, 2020). Although limited to non-essential sectors, however, these shutdowns still spread the impact on the whole economy as sector closures affected other still open upstream and downstream sectors due to intersectoral linkages. At the same time, the total risk reduction in the workplace was not limited to workers in closed sectors, but also included workers in other sectors, who temporarily or permanently stop their activity due to the aforementioned intersectoral linkages (Caracciolo et al., 2020).

The acknowledgment of the complex and asymmetrical combination of direct and indirect effects of restriction policies on both risk reduction and economic losses has ultimately led the Italian Government, and many other countries, to rationalize the policy response to the pandemic. As a result, the production of studies on the spread and containment of the infection (Sà, 2021) as well as on how the overall effects of the pandemic are distributed among sectors, economies, territories and population groups has grown enormously. Some of these works have analysed the different risk exposure of workers both across space and sectors. See, for instance, ISTAT (2020b) and Barbieri, Basso, & Scicchitano (2020) for the Italian case. Others have investigated the spread of contagion and health risks in relation to the endogenous aspects of the "attack rate" that can be affected by the characteristics of an economy (for instance its integration with the rest of the country and the world, age structure of the population, etc.) and of the respective institutions, such as the organization and functioning of the health system (Ferrari et al., 2020; Khairulbahri, 2021; Kumar, Priya, & Srivastava, 2021; Rodríguez-Pose & Burlina, 2021). Still others have focused on the differential impact of the pandemic between territories, regions and countries (Arbolino & Caro, 2021; Carnazza & Liberati, 2021; OECD, 2020). Bailey et al. (2020) provide an overview of all the possible spatial asymmetries of the spread of the pandemic, and the impacts of the consequent policy responses. Within this context, there are also studies investigating how interregional or international production networks influence the effects of the COVID-19 pandemic. This issue has been explored for instance by Antonietti, De Masi, & Ricchiuti (2020) who consider both space (EU28 countries) and sectors and discuss the hypothesis that the topology of these networks makes some sectors and countries more exposed to contagion. A further important implication of these interconnections concerns the alleged unequal effects that the pandemic has produced on different socioeconomic groups such as, for instance, female employment (Arbolino & Caro, 2021; Goel, Saunoris, & Goel, 2021; Perugini & Vladisavljević, 2021; Salvatore, 2021; Santos, 2020).

While the literature on the differential effects of the pandemic and on the relevant policy response is large and still increasing, contributions on how to rationalize this response, taking into account the selective impacts, remain rather scarce. What seems to be missing is an adequate integration of the two sides of the problem (risk mitigation and economic loss minimization) and explicit modelling of the policy response within the modelling tool itself.

In this connection, a promising methodological approach is represented by CNLP-MRIO models. This approach has been firstly proposed by Oosterhaven & Bouwmeester (2016) to assess the direct and indirect impacts produced by disruptive events, which, similarly to restrictions applied to governments, shut down all or part of output in given sectors. The effects of several adverse events have been recently assessed using this kind of models (Bonfiglio, Coderoni, Esposti, & Baldoni, 2020; Bouwmeester & Oosterhaven, 2017; Oosterhaven & Többen, 2017). There are already some contributions that have adopted I-O based approaches to assess the economic losses generated by government restrictions on economic activity to cope with the COVID-19 pandemic (Barrot, Grassi, & Sauvagnat, 2020; Giammetti et al., 2020; Giannakis et al., 2020; Havrlant, Darandary, & Muhsen, 2021; Santos, 2020). However, none of these are explicitly multiregional and, therefore, capable of computing both intersectoral and interregional effects, with the consequence that the spatial implications of mitigation policies are neglected. This prevents from taking into account regional specificities, such as, for instance, differentiated closures or the spread of virus variants or vaccination rates (Aizenman, Cukierman, Jinjarak, & Xin, 2021). Furthermore, in the estimation of impacts, telecommuting (or remote working) is also neglected, thus causing an overestimation of the losses that occur whenever it is assumed that the output of closed sectors becomes zero while, in fact, this does not happen. Compared to traditional I-O models, CNLP-MRIO models ensure higher flexibility, which implies the possibility of modelling telecommuting in addition to several other aspects such as substitution effects, thus reducing the tendency to overestimate impacts. Moreover, these models allow the identification of the optimal shares of sectoral output to be shut down to achieve the policy target in terms of containing the risk of contagion. This makes this approach particularly suitable for modelling and comparing the cross-sectoral and cross-region impacts generated by alternative policy responses to the COVID-19 pandemic.

# 3 Materials and methods

## 3.1 The model

The CNLP-MRIO model minimizes, under given constraints, the information gain that occurs moving from pre-event to post-event market equilibrium, measured by a MRIO table. Following Oosterhaven & Bouwmeester (2016), as an information measure, a variant of the Improved Generalized RAS objective function is adopted (Huang, Kobayashi, & Tanji, 2008). This measure equals:

$$\sum_{ij} Z_{ij}\left[\ln\left(\frac{Z_{ij}}{Z_{ij}^{ex}}\right)-1\right]+Z_{ij}^{ex} \tag{1}$$

where super-script *ex* stands for ex-ante and indicates known values taken from the existing I-O table; $Z_{ij}$ denotes the transaction between actor *i* and *j*. $Z_{ij}^{ex}$ is added at the end of the equation to ensure that the minimum value of Eq. (1) is zero.

Let us assume an economy made up of *N* intermediate sectors; *R*+1 regions, where *R* are the regions of the country and the additional region represents the rest of the world; *F* final demand sectors; and *P* components of primary inputs. The objective function of the model takes the following form:

$$\begin{aligned}&\underset{z_{ij}^{rs}, f_{ik}^{r}, p_{mi}^{r}}{\text{Minimize}}\\ &\sum_{r=1}^{R+1}\sum_{s=1}^{R}\sum_{i=1}^{N}\sum_{j=1}^{N}\left\{z_{ij}^{rs}\left[\ln\left(\frac{z_{ij}^{rs}}{z_{ij}^{rs,ex}}\right)-1\right]+z_{ij}^{rs,ex}\right\}+\\ &+\sum_{r=1}^{R+1}\sum_{i=1}^{N}\sum_{k=1}^{F}\left\{f_{ik}^{r}\left[\ln\left(\frac{f_{ik}^{r}}{f_{ik}^{r,ex}}\right)-1\right]+f_{ik}^{r,ex}\right\}+\\ &+\sum_{m=1}^{P}\sum_{r=1}^{R}\sum_{i=1}^{N}\left\{p_{mi}^{r}\left[\ln\left(\frac{p_{mi}^{r}}{p_{mi}^{r,ex}}\right)-1\right]+p_{mi}^{r,ex}\right\}\end{aligned} \tag{2}$$

where $z_{ij}^{rs}$ are the purchases of sector *j* in region *s* from sector *i* of region *r* or, alternatively, the sales of sector *i* from region *r* to sector *j* of region *s*; $f_{ik}^{r}$ represents the purchases of final sector *k* related to products from sector *i* of region *r*; $p_{mi}^{r}$is component *m* of primary inputs of sector *i* in region *r*.

The objective function reported in Eq. (2) is minimized under the following constraints:

$$\sum_{s=1}^{R}\sum_{j=1}^{N} z_{ij}^{rs}+\sum_{k=1}^{F} f_{ik}^{r}=\sum_{s=1}^{R+1}\sum_{j=1}^{N} z_{ji}^{sr}+\sum_{m=1}^{P} p_{mi}^{r} \quad i=1,\dots,N;\ r=1,\dots,R \tag{3}$$

$$\sum_{r=1}^{R+1} z_{ij}^{rs}=\sum_{r=1}^{R+1} a_{ij}^{rs}x_{j}^{s} \quad i,j=1,\dots,N;\ s=1,\dots,R \tag{4}$$

$$\sum_{m=1}^{P} p_{mj}^{s}=v_{j}^{s}x_{j}^{s} \quad j=1,\dots,N;\ s=1,\dots,R \tag{5}$$

$$\sum_{r=1}^{R+1}\sum_{k=1}^{F} f_{ik}^{r} = \sum_{r=1}^{R+1} c_i^r \left(\sum_{r=1}^{R+1}\sum_{j=1}^{N}\sum_{k=1}^{F} f_{jk}^{r}\right) \quad i = 1, \dots, N \tag{6}$$

$$z_{ij}^{rs}, f_{ik}^{r}, p_{mi}^{r} \geq 0 \quad i, j = 1, \dots, N;\ k = 1, \dots, F;\ m = 1, \dots, P;\ r, s = 1, \dots, R \tag{7}$$

where $x_j^s$ is total input (output) of sector *j* in region *s* and is obtained as: $x_j^s = \sum_{r=1}^{R+1}\sum_{i=1}^{N} z_{ij}^{rs} + \sum_{m=1}^{P} p_{mj}^{s}$, for $j = 1, \dots, N$ and $s = 1, \dots, R$; $a_{ij}^{rs}$ is an input or trade coefficient expressing the quantity of inputs from sector *i* of region *r* purchased by sector *j* of region *s* per output unit; $\sum_{r=1}^{R+1} a_{ij}^{rs}$ is the technical coefficient of sector *j* in region *s*, which indicates the need for intermediate inputs from sector *i* of all regions, including the rest of the world; $v_j^s$ is a coefficient expressing the quantity of primary inputs used by sector *j* of region *s* per output unit; $c_i^r$ is a final demand coefficient, expressing the quantity of products of sector *i* from region *r* demanded by final sectors per unit of total consumption; $\sum_{r=1}^{R+1} c_i^r$ is the total final demand coefficient related to sector *i*. Coefficients $a_{ij}^{rs}$, $v_j^s$ and $c_i^r$ are derived using information from the pre-event I-O table.

The economic meaning of these constraints is the following. Eq. (3) imposes that demand equals supply for each sector and region, i.e.: the economy is in equilibrium. Eq. (4) and Eq. (5) introduce the hypothesis of cost minimization under a Walras-Leontief production function. In particular, by applying a constraint on technical coefficients, rather than on single input or trade coefficients, Eq. (4) introduces the possibility of substitution effects between local and imported inputs. It should be noted that $\sum_{r=1}^{R+1}\sum_{i=1}^{N} a_{ij}^{rs} + v_j^s = 1$, for $j = 1, \dots, N$ and $s = 1, \dots, R$. Eq. (6) models the composition of final demands, using the comparable approach of cost minimization under a Walras-Leontief utility function. In this case, this constraint allows final demand sectors to relocate their demands between regions. Finally, Eq. (7) imposes that all elements of ex-post I-O table are nonnegative. The model is thus composed of Eq. (2)-(7) and is solved by GAMS 23.1 using CONOPT4 solver.

### 3.2 Modelling the general-lockdown-based policy response

By a generalized lockdown imposed by the Italian Government in March 2020, non-essential sectors in all Italian regions were shut down to reduce the risk of contagion while the essential ones remained opened to meet basic needs. This has implied that all output of non-essential sectors was lost except for that share produced remotely, which is assumed to remain. The general lockdown is modelled by adding the following constraint to Eq. (2)-(7):

$$x_j^r = w_j L_j^{r,ex} \pi_j^r \Rightarrow x_j^r = w_j x_j^{r,ex} \quad \forall j \notin \mathbb{E};\ r = 1, \dots, R \tag{8}$$

where $w_j$ is the share of persons employed in non-essential sector *j* who can work remotely, $L_j^r$ is the level of employment in sector *j* of region *r*, $\pi_j^r$ is labour productivity in sector *j* of region *r* (output per worker) and $\mathbb{E}$ is the set of essential sectors. Product $w_j L_j^{r,ex} \pi_j^r$ transforms employment that can work remotely ($w_j L_j^{r,ex}$) into the corresponding output of sector *j*. The direct effects in terms of output loss produced by the general lockdown in region *r* can be calculated as $\sum_j (w_j - 1)\, x_j^{r,ex}$, $\forall j \notin \mathbb{E}$, while the indirect effects equal to $\sum_j (x_j^r - x_j^{ex})$, $\forall j \in \mathbb{E}$. The general lockdown generates a total reduction of workers at risk of infection that can be expressed as follows:

$$\Delta TotalRisk = \sum_{r=1}^{R} \sum_{j=1}^{N} k_j \left[ (1 + w_j) x_j^{r,ex} - x_j^r \right] \frac{1}{\pi_j^r} \tag{9}$$

where $w_j = 0\ \forall j \in \mathbb{E}$, $0 \le k_j \le 1$ is a fixed share of workers in sector *j* who are at risk of infection; $1/\pi$ transforms the reduction of output into reduction of employment.

Eq. (9) represents a key relationship in the present analysis. It expresses the outcome of the general lockdown in terms of total reduction in the risk of contagion. This reduction includes both direct and indirect effects, whose magnitude depends on the level of integration of a given economy. In fact, the closure of a given sector firstly brings about a direct reduction in the risk of contagion in the same sector since workers, of whom a part can work remotely, are removed from the workplace, and obliged to stay at home. Then, through a decrease in the sector's input demand and product supply, it causes an indirect reduction in the interconnected sectors because of a reduction of output and, therefore, of workers. These effects are further transmitted to all other sectors and regions not directly connected with the ones hit by restrictions, thus amplifying total impacts.

Impacts are calculated in terms of output, GDP, and employment. GDP impacts can be straightforwardly derived by comparing ex-ante and ex-post MRIO tables while, to derive those related to employment, output impacts must be converted into employment impacts by multiplying outputs by employment coefficients (i.e., $1/\pi_j^r$). The impacts estimated refer to the short term, which indicatively correspond to one year. In other terms, they are the result of a lockdown lasting twelve months. Therefore, the effects induced by a one-month lockdown are supposed to be one twelfth of the total impacts estimated by the model.

### 3.3 Modelling the differentiated-lockdown-based policy response

This policy response is designed based on Eq. (9). It looks for differentiated sectoral and regional closures that achieve the policy outcome measured by Eq. (9). More specifically, it searches for the production share of non-essential sectors to be shut down in each region, ensuring risk equivalence with respect to the general lockdown, i.e., that the overall reduction in the contagion risk remains the same as that produced by the general lockdown in each region and, consequently, at national level. The main purpose of modelling this policy option is to assess whether and to what extent a more flexible policy, allowing for regional differentiation and partial closures of non-essential sectors, can reduce economic losses while achieving the same reduction in the risk of contagion.

This differentiated lockdown is modelled by the following constraints:

$$\sum_{j=1}^{N} k_j\left[\left(1+w_j\right)x_j^{r,ex} - x_j^r\right]\frac{1}{\pi_j^r} = \Delta TotalRisk_r \qquad r = 1, \dots, R \tag{10}$$

$$x_j^r = \left\{1 - \left[\alpha_j^r\left(1 - w_j\right)\right]\right\}x_j^{r,ex} \quad \forall j \notin \mathbb{E};\ r = 1, \dots, R \tag{11}$$

$$0 \le \alpha_j^r \le 1 \quad \forall j \notin \mathbb{E};\ r = 1, \dots, R \tag{12}$$

where $\alpha_j^r$ is an optimal share of output in sector $j$ of region $r$ to be estimated by the model and indicates how much output of non-essential sectors is shut down in each region. Eq. (10) ensures that, in each region, the total (direct and indirect) reduction in the risk of contagion associated with a decrease in employment and including the positive effects in terms of reduction in the risk of contagion that are obtained by working remotely equals the one deriving from the general lockdown. Eq. (11) expresses the output of sector $j$ in region $r$ as a result of the restrictions applied to ex-ante output based on the degree of closure (as expressed by $\alpha_j^r$). The remaining output includes that part produced by the share of workers that can work remotely ($w_j\alpha_j^r x_j^{r,ex}$). If $\alpha_j^r = 1$ (i.e., all output of sector $j$ in region $r$ is shut down), Eq.(11) boils down to Eq. (8) and the differentiated lockdown coincides with the national one. Output, GDP, and employment impacts are calculated as in the general lockdown.

In the search for the best policy response, it is assumed that $w_j$ and $k_j$ are the same in all regions and do not vary. However, both parameters can be updated and further differentiated (i.e., $w_j^r$ and $k_j^r$) in order to take into account the evolution of the different employment policy as well as the variations in the different levels of risk of contagion. This feature is particularly important since it allows the modelling of the policy response to the pandemic in the face of new developments represented, for example, by changes in the organization of home- or smart-working, but also by the spread of new virus variants, different vaccination rates, different levels of adoption of the COVID-19 green certificate and variations in the regional levels of criticality, which affect the risk of contagion.

### 3.4 The data

The MRIO table used is a 2015 44-sector-by-20-Italian-region I-O table. The regions considered are at NUTS-2 level. A further region (rest of the world) is also added in order to model the substitution of domestic inputs and final products with those imported from abroad. Final uses are represented by household, other institutions and government consumption, gross fixed capital formation, inventory changes and exports. Primary inputs include labour income, other taxes less subsidies on production, net operating surplus, depreciation, and net indirect taxes on products. The MRIO table is derived starting from the latest national supply, use and import tables by using a hybrid regionalization technique, described in detail in Bonfiglio et al. (2020) , which combines mechanical procedures, insertion of official data and balancing techniques. This regionalization technique allows the derivation of MRIO tables at high levels of regional disaggregation, which can be used for estimating impacts that are realistic and consistent with those obtained by other studies (Bonfiglio et al., 2020). In the absence of more recent national tables, it is assumed that the sectorial structure and the state of technology remains unchanged between 2015 and 2020. The choice of the sectoral detail depends on the availability of employment data at NUTS-2 level, which are necessary to apply the regionalization procedure, and on the objectives of this study. National tables have been aggregated into 29 sectors, corresponding to the available regional detail of employment data, and then disaggregated, where necessary, into non-essential and essential sectors. The list of the resulting sectors is presented in Table A.1. The sectoral disaggregation has been made by employment ratios calculated from the latest (2011) census data and by using, as a reference, a list of essential sectors contained in a ministerial decree dated from 25 March 2020 (Italian Ministry of Economic Development, 2020) (Table A.2). Both employment data and superior data at a regional level used for improving the reliability of the MRIO table are taken from the official Datawarehouse of the Italian institute of statistics.

Information for deriving the share of workers at risk of infection comes from Barbieri et al. (2020). This study calculates indices of physical proximity and of exposure to diseases and infections for sectors at one-digit level of NACE-Rev2 classification. They are derived by using data from a 2013 Italian Sample Survey on Professions carried out by the National Institute for Public Policies Analysis. The survey has involved about 16 thousand workers employed in around

800 occupations, according to a 5-digit ISCO-08 classification. Both indices are scores going from 0 to 100 and can be interpreted as the probability of getting in touch with other colleagues or with the public (index of physical proximity) and the probability of being exposed to diseases and infections (index of exposure to diseases and infections). The share of workers at risk of infection is derived as a product of the two indices (both divided by 100), which expresses the conditional probability of being infected when there is proximity with other colleagues or the public.

Data about sectoral shares of workers that can work remotely come from a survey carried out by the Italian Institute of Statistics in May 2019 about the situation and the prospects of Italian firms during the COVID-19 health emergency (ISTAT, 2020b). The survey has involved about 90 thousand firms with three or more persons employed in the sectors related to industry, trade, and services according to one-digit NACE-Rev2 classification and representing 90% of national value added and employment. It provides information about the percentage of personnel that worked remotely in three different bimesters. The period considered here is March-April 2020. Missing data about sectors such as agriculture, public administration and household activities are estimated from the indices concerning the feasibility of a remote working arrangement calculated by Barbieri et al. (2020). To ensure consistency between the two sources, we first calculate the ratios of indices of feasibility of remote working arrangement to the average of indices, excluding those related to the missing sectors. The ratios derived for missing sectors are then multiplied by the average percentage of personnel that worked remotely in March-April 2020, thus obtaining an estimation of the percentage of personnel that worked remotely.

Table A.3 reports the share of workers that can work remotely and the share of workers at risk of infection for all 44 sectors of the MRIO table.

# 4 Findings

## 4.1 The impacts of the general-lockdown-based policy response

Table 2 reports the percentages of output and employment directly involved by sectoral closures and the shares of workers at risk of infection per macro-region and macro-sector in the case of a policy response to the pandemic based on a generalized lockdown at a national level. Details for 44 sectors and at a regional level are reported in Table A.4 and Table A.5, respectively. The general lockdown directly involves a part of economy that represents 40% of total output and 32% of employment. In other terms, 32% of workers, who produce 40% of output, stayed at home because of the closure of non-essential sectors. The Southern regions are the least penalized ones. Here, the sectors involved represent 35% and 27% of total output and employment, respectively. The sector that is most hit by the lockdown is construction, followed by industry, services and, finally, agriculture. The reduction in the risk of contagion depends on employment dynamics and on the different risk of infection existing at a sectoral level. In the ex-ante situation, the risk of contagion is estimated to be 5.4%. Compared to ex-ante situation, the general lockdown decreases the total risk of infection among workers, considering both direct and indirect effects, by more than a half (down to 2.5%). The highest reduction occurs in the services sector with about 4%. From a geographical perspective, the Southern regions register a slightly higher risk reduction than the others (just over 3%).

Table 3 and Table 4 report both direct and indirect impacts in terms of percentage variations of GDP caused by the closure of non-essential sectors by macro-region and macro-sector, respectively. The total GDP impact produced by a one-month general lockdown is estimated to be about -6% of ex-ante GDP. The direct impact due to the closure of non-essential sectors amounts to -7%. This negative variation takes account of the possibility of a part of workers to work remotely and is therefore lower than the one which would occur if all output were shut down. The indirect impact is the one generated indirectly in essential sectors owing to the closure of those non-essential and is equivalent to a negative variation of about 5%. This loss is lower than the direct one, but it is significant, thus highlighting how disregarding the indirect effects of closures may induce misleading conclusion on their actual impact. The importance of linkages is also demonstrated by the fact that indirect effects represent about 85% of total impacts. Most impacts are localised in the regions of Northern Italy, which capture about 45% of total impacts, followed by the regions of Central Italy (32%) and, finally, those of Southern Italy. GDP variations among macro-regions are similar although larger negative effects can be noticed in the case of Northern Italy. The incidence of indirect effects on total impacts is however higher in the regions of Southern Italy. Looking at the sectoral detail, it turns out that most impact (85%) concentrates in the services sector. However, the most affected sectors compared to ex-ante situation are construction and industry, undergoing negative variations of about 7%. Agriculture is the sector where indirect effects contribute to a larger extent, reaching a percentage of 90% under the general lockdown. This is explained by the occurrence that most agricultural activities have been regarded as essential, so they have been affected only indirectly.

Figure 1(a) shows the distribution of GDP impacts over Italian NUTS-2 regions. As can be noted, the general lockdown mostly hit the regions of Northern Italy, particularly, Emilia-Romagna, Veneto, and Lombardy, which undergo GDP losses of about 6%. However, the most penalized region is one of Southern Italy, i.e., Sardinia, with a negative variation of 6.2%. Among the first ten most hit regions, there are some of Central Italy, such as Tuscany and Umbria, and others of Southern Italy, i.e., Basilicata and Campania.

Total impacts on employment are very similar (Table 5 and Table 6). The slight differences are caused by different labour productivity across sectors and regions. The total employment impact produced by the one-month general lockdown amounts to about -6%. The direct impact produced in non-essential sectors is -8%, while the indirect effects are about -5%. Indirect effects represent 94% of total impacts. Most impacts are localised in the regions of Northern Italy, which capture about 42% of total impacts, followed by the regions of Central Italy (31%) and, finally, those of Southern Italy. Employment variations among macro-regions are similar even if the regions of Northern Italy are those registering greater negative effects. The contribution of indirect effects on total impacts is larger in Southern Italy (95%). At a sectoral level, results show that the services sector is the one where impacts tend to concentrate (85%), but construction and industry are the most affected with variations of around -7%. Looking at the importance of indirect impacts, it turns out that agriculture is the sector where indirect effects contribute to total impacts to a larger extent.

Figure 2(a) shows the distribution of impacts on employment across Italian regions. The general lockdown mainly affects the regions of Northern Italy, in particular Emilia-Romagna and Lombardy, which record employment losses that are higher than 6%. Sardinia is however the most penalized region with a 6.6% reduction.

### 4.2 The impacts of the differentiated-lockdown-based policy response

A policy response to the pandemic based on a differentiated lockdown at regional and sectoral level directly affects less than 8% of output and 6% of employment (Table 2). In terms of output, the most penalized sectors are services, followed by agriculture, construction, and industry. Looking at employment, it is agriculture the sector suffering from higher losses. Services, industry, and construction follow. By construction, total reduction in the risk of contagion is the same as that produced by the general lockdown. However, compared to a generalized closure, the risk that remains after a differentiated lockdown is different between sectors both at a regional and national level. Moreover, in all macro-regions, it is lower in the services sector and higher in others.

The negative impact on GDP is less than 2%, three times lower than the one produced by the general lockdown (Table 3). In contrast with the general lockdown, the indirect effects related to essential sectors are higher than the direct ones. They amount to -2% while direct effects are -1%. Moreover, the distribution of impacts between essential and non-essential sectors, i.e., between indirect and direct effects, is more uniform, the indirect impacts being about 60% of total impacts. Compared to the general lockdown, effects are analogously more concentrated in Northern Italy, even if with a slightly higher share (47%), but the regions of Southern Italy are more penalized, undergoing higher negative variations in terms of direct, indirect, and total impacts. This greater penalization in the South can also be observed graphically (Figure 1(b)). Sardinia and Calabria are the regions which are particularly affected, with negative variations of more than 2%.

Different from the general lockdown, services are the most penalized sectors, relatively to the others, with a negative variation of around 2% (Table 4). The ranking of sectors in relation to the importance of indirect effects is however similar. Agriculture is the sector where indirect effects contribute to a larger extent. The main difference lies in the different incidence of indirect impacts. Under the general lockdown, the importance of indirect effects is quite homogenous, while under the differentiated lockdown there is less uniformity. Here, indirect effects evidently weigh to a lesser extent in sectors such as industry and, above all, construction, exhibiting percentages that are about 30% and 40%, respectively, against over 70% of agriculture.

Again, results related to employment are consistent with those associated with GDP, with differences justified by different levels of labour productivity (Table 5 and Table 6). The negative impact on employment is little more than 2%, i.e., 30% of the impact generated by the general lockdown. Unlike the general lockdown, the essential sectors are more penalized than the non-essential ones. In fact, indirect impacts amount to -2.5%, against direct impacts that are about -1%. Moreover, the share of indirect effects is 63%, therefore showing a more uniform distribution of impacts between essential and non-essential sectors. Although Northern Italy absorbs a larger share of total impacts (43%) as in the general lockdown, the regions of Southern Italy appear to be more penalized than the others, registering higher negative variations in relation to any type of impact. From Figure 2(b), it turns out that the most affected regions in Southern Italy are Sardinia, Calabria, Sicily, and Campania, showing negative variations that are more than 2%. However, Lombardy (North) as well as Lazio and Toscana (Centre) are also among the most penalized regions, with negative changes over 2%.

At a sectoral level, results show that the services sector is the one where impacts tend to concentrate as in the general lockdown, but they are relatively more penalized than the others, suffering from a higher negative variation (-3%). Looking at the importance of indirect impacts, agriculture is confirmed as the sector in which indirect effects contribute most to total impacts. What changes compared to the general lockdown is the distribution of indirect impacts among sectors, which is more heterogenous under the differentiated lockdown. Indirect effects of industry and construction capture about 30% of total impacts, while both agriculture and services absorb over 70%.

Table 2 – Output and employment directly involved and workers at risk of contagion by macro-region, macro-sector and type of policy response, Italy (in %)

| | Ex-ante | General lockdown | | | Differentiated lockdown | | |
|---|---|---|---|---|---|---|---|
| | Risk | Output | Emp. | Risk | Output | Emp. | Risk |
| North | | | | | | | |
| Agriculture | 1.5 | 25.5 | 25.2 | 0.4 | 6.4 | 6.4 | 1.3 |
| Industry | 0.8 | 55.3 | 68.0 | 0.1 | 4.2 | 5.3 | 0.7 |
| Construction | 0.5 | 66.6 | 66.4 | 0.1 | 5.8 | 5.6 | 0.5 |
| Services | 6.9 | 29.5 | 23.6 | 3.0 | 10.5 | 6.9 | 2.8 |
| Total | 5.1 | 41.9 | 35.6 | 2.2 | 7.7 | 6.5 | 2.2 |
| Centre | | | | | | | |
| Agriculture | 1.5 | 27.5 | 28.6 | 0.5 | 7.2 | 7.5 | 1.3 |
| Industry | 0.9 | 54.1 | 65.7 | 0.2 | 4.0 | 5.0 | 0.8 |
| Construction | 0.5 | 66.8 | 66.7 | 0.1 | 4.3 | 4.3 | 0.5 |
| Services | 6.8 | 29.1 | 22.2 | 3.4 | 10.0 | 6.0 | 3.2 |
| Total | 5.3 | 40.5 | 32.2 | 2.6 | 7.4 | 5.7 | 2.6 |
| South | | | | | | | |
| Agriculture | 1.5 | 28.8 | 28.0 | 0.6 | 7.8 | 7.7 | 1.2 |
| Industry | 1.2 | 43.8 | 52.7 | 0.3 | 4.4 | 5.4 | 1.1 |
| Construction | 0.5 | 68.3 | 68.5 | 0.0 | 4.7 | 4.8 | 0.5 |
| Services | 7.4 | 27.0 | 19.5 | 3.6 | 9.4 | 5.5 | 3.4 |
| Total | 5.8 | 34.9 | 27.2 | 2.7 | 7.5 | 5.6 | 2.7 |
| Italy | | | | | | | |
| Agriculture | 1.5 | 27.4 | 27.5 | 0.5 | 7.2 | 7.3 | 1.3 |
| Industry | 0.9 | 52.9 | 64.5 | 0.2 | 4.2 | 5.2 | 0.8 |
| Construction | 0.5 | 67.1 | 67.1 | 0.1 | 5.1 | 5.0 | 0.5 |
| Services | 7.0 | 28.8 | 22.0 | 3.3 | 10.1 | 6.2 | 3.1 |
| Total | 5.4 | 40.0 | 32.3 | 2.5 | 7.6 | 6.0 | 2.5 |

Table 3 – GDP impacts by macro-region and type of policy response, Italy

| | Direct | | Indirect (I) | | Total (T) | | I/T (%) |
|---|---|---|---|---|---|---|---|
| | % | Var. % | % | Var. % | % | Var. % | |
| General lockdown | | | | | | | |
| North | 47.5 | -7.3 | 43.9 | -4.8 | 44.5 | -5.8 | 83.8 |
| Centre | 31.1 | -7.3 | 31.6 | -4.6 | 31.5 | -5.6 | 85.0 |
| South | 21.5 | -7.2 | 24.5 | -4.7 | 24.0 | -5.5 | 86.5 |
| Total | 100.0 | -7.3 | 100.0 | -4.7 | 100.0 | -5.7 | 84.8 |
| Differentiated lockdown | | | | | | | |
| North | 49.7 | -1.1 | 45.1 | -2.0 | 47.0 | -1.6 | 56.0 |
| Centre | 30.7 | -1.1 | 31.1 | -1.9 | 30.9 | -1.6 | 58.6 |
| South | 19.6 | -1.2 | 23.8 | -2.1 | 22.1 | -1.8 | 63.0 |
| Total | 100.0 | -1.1 | 100.0 | -2.0 | 100.0 | -1.7 | 58.3 |

Table 4 – GDP impacts by macro-sector and type of policy response, Italy

| | Direct | | Indirect (I) | | Total (T) | | I/T (%) |
|---|---|---|---|---|---|---|---|
| | % | Var. % | % | Var. % | % | Var. % | |
| General lockdown | | | | | | | |
| Agriculture | 1.8 | -7.2 | 2.8 | -4.4 | 2.7 | -5.2 | 89.9 |
| Industry | 10.8 | -7.9 | 10.6 | -5.3 | 10.6 | -6.8 | 84.5 |
| Construction | 2.7 | -8.0 | 1.9 | -5.6 | 2.0 | -7.2 | 79.8 |
| Services | 84.7 | -6.9 | 84.7 | -4.6 | 84.7 | -5.3 | 84.8 |
| Total | 100.0 | -7.3 | 100.0 | -4.7 | 100.0 | -5.7 | 84.8 |
| Differentiated lockdown | | | | | | | |
| Agriculture | 1.6 | -1.0 | 3.1 | -0.9 | 2.5 | -1.0 | 72.8 |
| Industry | 31.4 | -0.2 | 15.2 | -0.8 | 22.0 | -0.5 | 40.4 |
| Construction | 9.2 | -0.3 | 3.3 | -0.2 | 5.8 | -0.2 | 33.2 |
| Services | 57.7 | -1.6 | 78.4 | -2.3 | 69.8 | -2.1 | 65.5 |
| Total | 100.0 | -1.1 | 100.0 | -2.0 | 100.0 | -1.7 | 58.3 |

Table 5 – Employment impacts by macro-region and type of policy response, Italy

| | Direct | | Indirect (I) | | Total (T) | | I/T (%) |
|---|---|---|---|---|---|---|---|
| | % | Var. % | % | Var. % | % | Var. % | |
| General lockdown | | | | | | | |
| North | 47.7 | -7.9 | 41.5 | -4.6 | 41.8 | -5.8 | 93.4 |
| Centre | 29.4 | -7.9 | 31.1 | -4.5 | 31.0 | -5.6 | 94.5 |
| South | 22.9 | -7.9 | 27.4 | -4.9 | 27.2 | -5.7 | 95.1 |
| Total | 100.0 | -7.9 | 100.0 | -4.7 | 100.0 | -5.7 | 94.2 |
| Differentiated lockdown | | | | | | | |
| North | 47.3 | -1.0 | 40.5 | -2.5 | 43.0 | -2.0 | 59.0 |
| Centre | 30.1 | -1.0 | 29.9 | -2.5 | 29.9 | -2.0 | 62.6 |
| South | 22.6 | -1.3 | 29.6 | -2.5 | 27.0 | -2.2 | 68.8 |
| Total | 100.0 | -1.1 | 100.0 | -2.5 | 100.0 | -2.1 | 62.7 |

Table 6 – Employment impacts by macro-sector and type of policy response, Italy

| | Direct | | Indirect (I) | | Total (T) | | I/T (%) |
|---|---|---|---|---|---|---|---|
| | % | Var. % | % | Var. % | % | Var. % | |
| General lockdown | | | | | | | |
| Agriculture | 7.8 | -7.2 | 4.5 | -4.2 | 4.7 | -5.0 | 90.4 |
| Industry | 29.0 | -7.9 | 6.9 | -5.5 | 8.2 | -7.1 | 79.5 |
| Construction | 9.4 | -8.0 | 2.3 | -5.7 | 2.7 | -7.2 | 79.6 |
| Services | 53.8 | -7.8 | 86.4 | -4.6 | 84.5 | -5.3 | 96.3 |
| Total | 100.0 | -7.9 | 100.0 | -4.7 | 100.0 | -5.7 | 94.2 |
| Differentiated lockdown | | | | | | | |
| Agriculture | 3.2 | -1.0 | 5.0 | -1.0 | 4.3 | -1.0 | 72.7 |
| Industry | 37.7 | -0.3 | 11.7 | -0.7 | 21.4 | -0.4 | 34.2 |
| Construction | 14.6 | -0.3 | 4.3 | -0.2 | 8.2 | -0.2 | 33.2 |
| Services | 44.5 | -1.9 | 79.0 | -2.9 | 66.1 | -2.6 | 74.9 |
| Total | 100.0 | -1.1 | 100.0 | -2.5 | 100.0 | -2.1 | 62.7 |

Figure 1 – Distribution of GDP impacts by region at NUTS-2 level and type of policy response, Italy (% variation)

(a) General lockdown (b) Differentiated lockdown

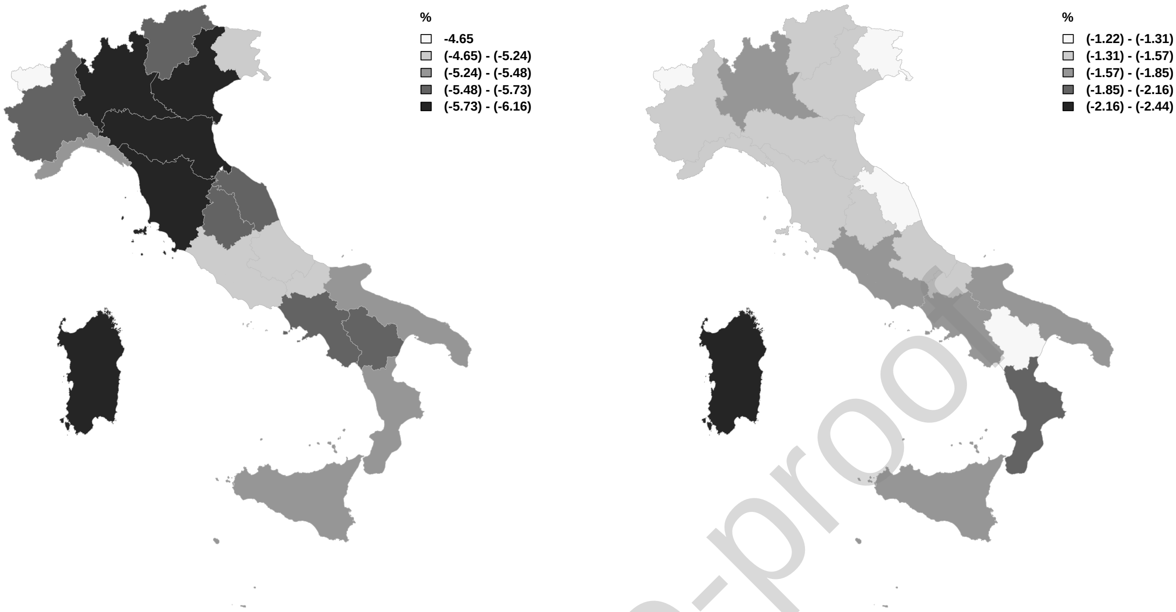
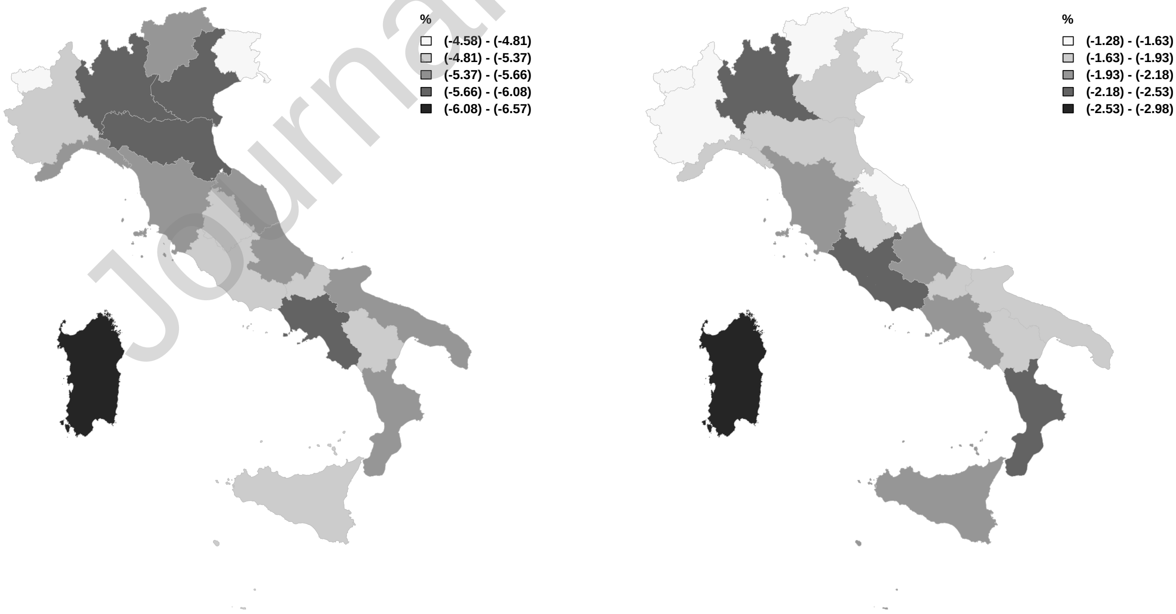



Figure 2 – Distribution of employment impacts by region at NUTS-2 level and type of policy response, Italy (% variation)

(a) General lockdown (b) Differentiated lockdown



## 5 Policy application and validation

The modelling approach proposed here allows an ex-ante assessment of the impacts produced by alternative restriction policies to contain the COVID-19 pandemic. The results described in the previous section derive from the application of this approach to measure the effects generated by the Italian lockdown of spring 2020 and by an alternative policy response based on differentiated closures across regions and sectors. Nevertheless, an interesting feature of the model is its flexibility which allows it to be adapted to various other situations both hypothetical and real. For instance, in the second wave of the pandemic, Italy and several other countries defined specific criteria to differentiate regions in terms of spread of contagion (from “white” to “red” regions). As explained in section 3.3, the model parameters can be revised to take this differentiation into account. Furthermore, the flexibility of the model makes it suitable for analysing further eventualities in the design of restriction policies. For example, different levels of spread of virus variants could be included in the analysis. Similarly, different vaccination rates as well as the different levels of adoption of the COVID-19 green certificate could be considered.

However, for this approach to be extended to other possible applications, the results presented here should first be validated to assess the robustness and usefulness of the model. Following Kumar et al. (2021), validation can be given a twofold interpretation. The first is whether the model complies with the “common sense of the actors within the system” (structural validation). In this study, structural validation is provided by the consistency of the results of the two policy responses with general expectations. In this respect, both responses make sense in terms of direction, extent, and distribution of the corresponding impacts. As widely expected, partial closures are less impactful than generalized lockdowns and impacts tend to be concentrated where the levels of GDP and employment are already high. Furthermore, the existence of both direct and indirect effects and the different risk of contagion in the workplace, which varies according to the sector and the region, justify the possibility of keeping the two objectives together, namely, to reduce economic losses and contain the risk of contagion.

The second, and more critical, challenge to validation consists in assessing how accurately the proposed model can reproduce real systems (behavioural validation). The empirical application carried out here allows this kind of validation as it reflects the concrete experience of Italy. While this application may seem a little out of date with respect to the current evolution of the pandemic (the fourth wave) and the consequent response, the relevant results can still be compared with the real figures now available on the impact of the restrictions.

Behavioural validation can be firstly carried out by evaluating whether the estimated impacts generated by the lockdown imposed by Italian Government in March 2020 are consistent with official statistics. According to ISTAT (2020b), the contribution of the activities considered non-essential and suspended was around 40% of total revenues (corresponding to total output in an I-O table), basically the same percentage as that provided by the model. In the first quarter of 2020, GDP contracted by 5.3%, which is very close to the decrease in GDP estimated here (5.7%). The Bank of Italy confirmed this decline (Bank of Italy, 2020). As regards employment, ISTAT calculated a decrease of 1.2% in April 2020. In this case, the differences with model results are more marked. However, at least initially, official employment statistics are less indicative of the actual impact since temporary and emergency funds, such as the Ordinary Redundancy Fund ("CIG – Cassa integrazione guadagni") and the Wage Integration Fund ("FIS – Fondo d'integrazione salariale"), have been activated to attenuate the effects on unemployment induced by pandemic mitigation measures. Therefore, the decrease in employment estimated by the model includes a share of dismissed workers, measured by official statistics, and a residual share of workers temporarily removed from their jobs but protected by social safety nets.

In addition, behavioural validation can be given a more general scope by verifying whether the model appropriately captures the actual relationship between growth performance and policy restrictions observed across countries and over time. Table 7 reports, for some selected European countries, the quarterly GDP growth rates, and the level of "stringency" of policy responses. From the table, it is clear that the wide restrictions introduced in spring 2020 led to a sharp decline in the growth rates with an average of around -15%. During the second wave, the response was evidently rationalized as demonstrated by the drop in the stringency index in all countries, with an average of around -11 points. The decline in GDP growth compared to the same period of the previous year was also significantly lower than in the first wave, with no country falling more than -10% and an average of -5%. This finding seems fully consistent with the results of this study, which show that, moving from a generalized lockdown to differentiated restrictions, the economic losses more than halve.

Table 7 – Relationship between stringency index and growth performance in selected European countries across the pandemic waves

| Country | Stringency index[a] variation (April 2020 - December 2020) | GDP growth rate[b] | |
|---|---|---|---|
| | | Q2/2020 (Spring 2020) | Q4/2020 (Fall 2020) |
| Czech Republic | -13.0 | -10.9 | -5.3 |
| France | -13.0 | -18.6 | -4.3 |
| Germany | -9.3 | -11.3 | -2.9 |
| Greece | -3.7 | -15.7 | -7.3 |
| Italy | -2.7 | -18.1 | -6.6 |
| Netherlands | -22.2 | -9.1 | -3.1 |
| Poland | -6.5 | -7.8 | -2.5 |
| Spain | -13.9 | -21.5 | -8.8 |
| United Kingdom | -12.0 | -21.4 | -7.1 |

[a] The stringency index is a composite measure based on nine response indicators including school closures, workplace closures, and travel bans, rescaled to a value from 0 to 100 (100 = strictest). The variation between the relevant values calculated on 1st April 2020 and 1st December 2020 is shown.
[b] Quarterly GDP growth rate with respect to the previous year.
Source: Author's elaboration on data from Our Word in Data (https://ourworldindata.org) and OECD

## 6 Policy advisory and conclusions

The spread of the COVID-19 pandemic has confronted public decision makers with a somewhat unprecedented dilemma, i.e., the trade-off between, on the one hand, the imposition of strict social distancing rules and sectoral closures to maximize the reduction of the risk of contagion and, on the other hand, the adoption of less rigid mitigation measures to minimize the consequent economic losses (Perugini & Vladisavljević, 2021). As other authors have already noted (Stiglitz, 2021; Taylor, 2021), although these crises do not happen often, still they are recurrent. The experience of most European countries, including Italy, shows a sort of learning process through successive waves with the introduction of increasingly flexible and tailored policy responses to the pandemic. At the same time, however, the COVID-19 pandemic has highlighted the lack of an appropriate modelling toolkit to assist a more rational and efficient policy response.

In principle, the optimal policy response should seek the best compromise between the containment of the risk of contagion and the reduction of economic losses or, in other words, the minimum economic loss given a target level of reduction of the risk of contagion. Such an assessment, however, requires that decision makers own full information on the values at stake, that is, on all the effects, both direct and indirect and both sectoral and regional, induced by the policy response itself. Neglecting these effects essentially means disregarding the complex interdependences that exist within an economy. The knowledge of these interconnections become increasingly critical with the refinement of the policy response towards more differentiated restrictions. A progressive adaptation has actually occurred during the successive waves of the pandemic and is likely to continue in the coming months, due to new facts to be considered in the implementation of restrictions such as, for example, the spread of new variants or vaccination rates.

The model proposed here aims to contribute to this refinement of policy. The relevant results highlight two critical issues. Firstly, it turns out that limiting the assessment to the direct impacts of closures may severely underestimate GDP and employment losses as well as the reduction of the risk of contagion induced by the restriction measures adopted. This underestimation may lead to wrong policy decisions. Secondly, a correct identification of the distributional implications of the restrictions is possible only by analysing how the economic burden of such measures is eventually distributed over the individual sectors and regions. In this regard, as other studies in this field show, the results provided here suggest that regional governments are called upon to play a key role in defining the policy response to the pandemic, but within a centrally coordinated policy framework aimed at achievement of the general objective in terms of reducing the risk of contagion (Crescenzi, Giua, & Sonzogno, 2021; Perugini & Vladisavljević, 2021).

An important feature of the proposed approach is its decision-making logic. Its structure gives the model a great deal of flexibility in providing an ex-ante assessment of policy options that involve a certain degree of differentiation between sectors and regions. This flexibility mimics the ability of an economy to rationalize closures to minimize losses, leveraging intersectoral and interregional linkages, and substitution effects. In this regard, the results of the model show that, at least in the Italian experience of spring 2020, a differentiated policy in terms of sectoral and regional restrictions can allow the achievement of the same reduction in the risk of contagion induced by a general lockdown but with a significant reduction in the total loss of production.

Another policy implication of this study is that the government's response to the pandemic lead to asymmetrical consequences. This information is of great political importance as it guides the type and extent of mitigation or compensation measures for short-term losses. In addition, the knowledge of the asymmetrical impacts of the pandemic can orient long-term recovery policies. As well as between countries, recovery interventions should also differentiate between sectors and regions focusing on those that have suffered the greatest loss (Carnazza & Liberati, 2021). In this respect, a future interesting application of the proposed approach could be the ex-ante assessment of some of the actions envisaged by the EU recovery and resilience fund (or "Next Generation EU" – Regulation EU 2021/241). The model, in fact, can help to identify the target sectors but also to estimate the intersectoral and interregional impacts of funding once those sectors have been identified.

However, some further improvements are needed before the potential of the proposed approach can be fully exploited. Three directions, in particular, seem more relevant and promising. Firstly, the model is essentially static, that it, it does not take the different timing of direct and indirect effects into consideration. Unlike direct effects, indirect effects may take longer to manifest, and this can affect the search for the optimal policy solution. Therefore, a dynamic version of the model that considers the different temporal distribution of effects can be an interesting research direction. Secondly, although the proposed model takes full account of the presence of home-workers, it remains true that the regulation and organization of home- or smart-working has evolved during the pandemic, and it is likely that some of these new forms will remain even when restrictions are eventually lifted. A more sophisticated formulation of this kind of work within the adopted modelling framework could therefore significantly improve the reliability of the results. Finally, the MRIO table adopted here is based on a given regional and sectoral level of detail. Finer sectoral articulation and more flexible spatial aggregation (i.e., a combination of the NUTS-2 and NUTS-3 levels) can represent a major computational challenge but could also make this model a more powerful policy modelling tool.

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## Appendix

Table A.1 – List of 44 sectors of Italian MRIO table

| ID | Macro-sector | Sector |
|---|---|---|
| S1 | Agriculture | Crop and animal production, hunting and related service activities, forestry and logging (E) |
| S2 | Agriculture | Crop and animal production, hunting and related service activities, forestry and logging |
| S3 | Agriculture | Fishing and aquaculture (E) |
| S4 | Industry | Mining and quarrying (E) |
| S5 | Industry | Mining and quarrying |
| S6 | Industry | Food products, beverages and tobacco products (E) |
| S7 | Industry | Food products, beverages and tobacco products |
| S8 | Industry | Textiles, wearing apparel, leather and related products (E) |
| S9 | Industry | Textiles, wearing apparel, leather and related products |
| S10 | Industry | Wood, paper and paper products, printing and reproduction of recorded media (E) |
| S11 | Industry | Wood, paper and paper products, printing and reproduction of recorded media |
| S12 | Industry | Coke and refined petroleum products, chemicals and chemical products, basic pharmaceutical products and pharmaceutical preparations (E) |
| S13 | Industry | Rubber and plastic products, other non-metallic mineral products (E) |
| S14 | Industry | Rubber and plastic products, other non-metallic mineral products |
| S15 | Industry | Basic metals, fabricated metal products, except machinery and equipment (E) |
| S16 | Industry | Basic metals, fabricated metal products, except machinery and equipment |
| S17 | Industry | Computer, electronic and optical products, electrical equipment, machinery and equipment n.e.c. (E) |
| S18 | Industry | Computer, electronic and optical products, electrical equipment, machinery and equipment n.e.c. |
| S19 | Industry | Motor vehicles, trailers and semi-trailers, other transport equipment |
| S20 | Industry | Furniture, other manufacturing, repair and installation of machinery and equipment (E) |
| S21 | Industry | Furniture, other manufacturing, repair and installation of machinery and equipment |
| S22 | Industry | Electricity, gas, steam and air conditioning supply (E) |
| S23 | Industry | Water supply, sewerage, waste management and remediation activities (E) |
| S24 | Construction | Construction (E) |
| S25 | Construction | Construction |
| S26 | Services | Wholesale and retail trade, repair of motor vehicles and motorcycles (E) |
| S27 | Services | Wholesale and retail trade, repair of motor vehicles and motorcycles |
| S28 | Services | Transportation and storage (E) |
| S29 | Services | Accommodation and food service activities (NCE |
| S30 | Services | Accommodation and food service activities |
| S31 | Services | Information and communication (E) |
| S32 | Services | Financial and insurance activities (E) |
| S33 | Services | Real estate activities |
| S34 | Services | Professional, scientific and technical activities (E) |
| S35 | Services | Professional, scientific and technical activities |
| S36 | Services | Administrative and support service activities (E) |
| S37 | Services | Administrative and support service activities |
| S38 | Services | Public administration and defence; compulsory social security (E) |
| S39 | Services | Education (E) |
| S40 | Services | Human health and social work activities (E) |
| S41 | Services | Arts, entertainment and recreation |
| S42 | Services | Other service activities (E) |
| S43 | Services | Other service activities |
| S44 | Services | Activities of households as employers, undifferentiated goods-and services-producing activities of households for own use (E) |

Note: (E) indicates sectors or aggregation of sectors that are defined essential by the ministerial decree 25 March 2020. Sectors named identically are the result of disaggregation into essential and non-essential sub-sectors.

Table A.2 – List of essential sectors and correspondence with the sectors of Italian MRIO table

| ATECO Code | Sector | Sector ID |
|---|---|---|
| 1 | Crop and animal production, hunting and related service activities | S1 |
| 3 | Fishing and aquaculture | S3 |
| 5 | Mining of coal and lignite | S4 |
| 6 | Extraction of crude petroleum and natural gas | S4 |
| 09.1 | Support activities for petroleum and natural gas extraction | S4 |
| 10 | Manufacture of food products | S6 |
| 11 | Manufacture of beverages | S6 |
| 13.96.20 | Manufacture of other technical and industrial textiles | S8 |
| 13.95 | Manufacture of non-wovens and articles made from non-wovens, except apparel | S8 |
| 14.12.00 | Manufacture of workwear | S8 |
| 16.24 | Manufacture of wooden containers | S10 |
| 17 | Manufacture of paper and paper products | S10 |
| 18 | Printing and reproduction of recorded media | S10 |
| 19 | Manufacture of coke and refined petroleum products | S12 |
| 20 | Manufacture of chemicals and chemical products | S12 |
| 21 | Manufacture of basic pharmaceutical products and pharmaceutical preparations | S12 |
| 22.2 | Manufacture of plastics products | S13 |
| 23.13 | Manufacture of hollow glass | S13 |
| 23.19.10 | Manufacture of laboratory, hygienic or pharmaceutical glassware | S13 |
| 25.21 | Manufacture of central heating radiators and boilers | S15 |
| 25.92 | Manufacture of light metal packaging | S15 |
| 26.6 | Manufacture of irradiation, electromedical and electrotherapeutic equipment | S17 |
| 27.1 | Manufacture of electric motors, generators, transformers and electricity distribution and control apparatus | S17 |
| 27.2 | Manufacture of batteries and accumulators | S17 |
| 28.29.30 | Manufacture of weighing machinery | S17 |
| 28.95.00 | Manufacture of machinery for paper and paperboard production | S17 |
| 28.96 | Manufacture of plastic and rubber machinery | S17 |
| 32.50 | Manufacture of medical and dental instruments and supplies | S20 |
| 32.99.1 | Manufacture of protective safety equipment | S20 |
| 32.99.4 | Manufacture of funeral boxes | S20 |
| 33 | Repair and installation of machinery and equipment | S20 |
| 35 | Electricity, gas, steam and air conditioning supply | S22 |
| 36 | Water collection, treatment and supply | S23 |
| 37 | Sewerage | S23 |
| 38 | Waste collection, treatment and disposal activities; materials recovery | S23 |
| 39 | Remediation activities and other waste management services | S23 |
| 42 | Civil engineering | S24 |
| 43.2 | Electrical, plumbing and other construction installation activities | S24 |
| 45.2 | Maintenance and repair of motor vehicles | S26 |
| 45.3 | Sale of motor vehicle parts and accessories | S26 |
| 45.4 | Sale, maintenance and repair of motorcycles and related parts and accessories | S26 |
| 46.2 | Wholesale of agricultural raw materials and live animals | S26 |
| 46.3 | Wholesale of food, beverages and tobacco | S26 |
| 46.46 | Wholesale of pharmaceutical goods | S26 |
| 46.49.2 | Wholesale of books, magazines and newspapers | S26 |
| 46.61 | Wholesale of agricultural machinery, equipment and supplies | S26 |
| 46.69.91 | Wholesale of instruments and equipment for scientific use | S26 |
| 46.69.94 | Wholesale of fire and accident prevention articles | S26 |
| 46.71 | Wholesale of solid, liquid and gaseous fuels and related products | S26 |
| 49 | Land transport and transport via pipelines | S28 |
| 50 | Water transport | S28 |
| 51 | Air transport | S28 |

Source: Authors' elaborations on data from Italian Ministry of Economic Development (2020)

Table A.2 – List of essential sectors and correspondence with the sectors of Italian MRIO table (continued)

| ATECO Code | Sector | Sector ID |
|---|---|---|
| 52 | Warehousing and support activities for transportation | S28 |
| 53 | Postal and courier activities | S28 |
| 55.1 | Hotels and similar accommodation | S29 |
| J | Information and communication | S31 |
| K | Financial and insurance activities | S32 |
| 69 | Legal and accounting activities | S34 |
| 70 | Activities of head offices; management consultancy activities | S34 |
| 71 | Architectural and engineering activities; technical testing and analysis | S34 |
| 72 | Scientific research and development | S34 |
| 74 | Other professional, scientific and technical activities | S34 |
| 75 | Veterinary activities | S34 |
| 78.2 | Temporary employment agency activities | S36 |
| 80.1 | Private security activities | S36 |
| 80.2 | Security systems service activities | S36 |
| 81.2 | Cleaning activities | S36 |
| 82.20 | Activities of call centres | S36 |
| 82.92 | Packaging activities | S36 |
| 82.99.2 | Distribution agencies for books, newspapers and magazines | S36 |
| 82.99.99 | other support activities typically provided to businesses not elsewhere classified | S36 |
| 84 | Public administration and defence; compulsory social security | S38 |
| 85 | Education | S39 |
| 86 | Human health activities | S40 |
| 87 | Residential care activities | S40 |
| 88 | Social work activities without accommodation | S40 |
| 94 | Activities of membership organisations | S42 |
| 95.11.00 | Repair of computers and peripheral equipment | S42 |
| 95.12.01 | Repair and maintenance of landline, cordless and mobile phones | S42 |
| 95.12.09 | Repair and maintenance of communications transmission equipment | S42 |
| 95.22.01 | repair and servicing of household appliances | S42 |
| 97 | Activities of households as employers of domestic personnel | S44 |

Source: Authors' elaborations on data from Italian Ministry of Economic Development (2020)

Table A.3 – Workers that can work remotely (WWR) and workers at risk of infection (WRI) by sector (in %)

| ID | Sector | WWR | WRI |
|---|---|---|---|
| S1 | Crop and animal production, hunting and related service activities, forestry and logging (E) | 13.9 | 1.5 |
| S2 | Crop and animal production, hunting and related service activities, forestry and logging | 13.9 | 1.5 |
| S3 | Fishing and aquaculture (E) | 13.9 | 1.5 |
| S4 | Mining and quarrying (E) | 4.8 | 0.6 |
| S5 | Mining and quarrying | 4.8 | 0.6 |
| S6 | Food products, beverages and tobacco products (E) | 4.8 | 0.6 |
| S7 | Food products, beverages and tobacco products | 4.8 | 0.6 |
| S8 | Textiles, wearing apparel, leather and related products (E) | 4.8 | 0.6 |
| S9 | Textiles, wearing apparel, leather and related products | 4.8 | 0.6 |
| S10 | Wood, paper and paper products, printing and reproduction of recorded media (E) | 4.8 | 0.6 |
| S11 | Wood, paper and paper products, printing and reproduction of recorded media | 4.8 | 0.6 |
| S12 | Coke and refined petroleum products, chemicals and chemical products, basic pharmaceutical products and pharmaceutical preparations (E) | 4.8 | 0.6 |
| S13 | Rubber and plastic products, other non-metallic mineral products (E) | 4.8 | 0.6 |
| S14 | Rubber and plastic products, other non-metallic mineral products | 4.8 | 0.6 |
| S15 | Basic metals, fabricated metal products, except machinery and equipment (E) | 4.8 | 0.6 |
| S16 | Basic metals, fabricated metal products, except machinery and equipment | 4.8 | 0.6 |
| S17 | Computer, electronic and optical products, electrical equipment, machinery and equipment n.e.c. (E) | 4.8 | 0.6 |
| S18 | Computer, electronic and optical products, electrical equipment, machinery and equipment n.e.c. | 4.8 | 0.6 |
| S19 | Motor vehicles, trailers and semi-trailers, other transport equipment | 4.8 | 0.6 |
| S20 | Furniture, other manufacturing, repair and installation of machinery and equipment (E) | 4.8 | 0.6 |
| S21 | Furniture, other manufacturing, repair and installation of machinery and equipment | 4.8 | 0.6 |
| S22 | Electricity, gas, steam and air conditioning supply (E) | 29.6 | 0.7 |
| S23 | Water supply, sewerage, waste management and remediation activities (E) | 6.6 | 6.1 |
| S24 | Construction (E) | 4.1 | 0.5 |
| S25 | Construction | 4.1 | 0.5 |
| S26 | Wholesale and retail trade, repair of motor vehicles and motorcycles (E) | 5.5 | 1.9 |
| S27 | Wholesale and retail trade, repair of motor vehicles and motorcycles | 5.5 | 1.9 |
| S28 | Transportation and storage (E) | 7.9 | 2.0 |
| S29 | Accommodation and food service activities (E) | 0.8 | 1.9 |
| S30 | Accommodation and food service activities | 0.8 | 1.9 |
| S31 | Information and communication (E) | 48.8 | 0.2 |
| S32 | Financial and insurance activities (E) | 26.1 | 0.5 |
| S33 | Real estate activities | 25.7 | 0.1 |
| S34 | Professional, scientific and technical activities (E) | 36.7 | 1.0 |
| S35 | Professional, scientific and technical activities | 36.7 | 1.0 |
| S36 | Administrative and support service activities (E) | 14.5 | 3.3 |
| S37 | Administrative and support service activities | 14.5 | 3.3 |
| S38 | Public administration and defence; compulsory social security (E) | 16.6 | 5.8 |
| S39 | Education (E) | 33.0 | 10.7 |
| S40 | Human health and social work activities (E) | 2.5 | 36.2 |
| S41 | Arts, entertainment and recreation | 5.9 | 2.1 |
| S42 | Other service activities (E) | 2.7 | 7.9 |
| S43 | Other service activities | 2.7 | 7.9 |
| S44 | Activities of households as employers, undifferentiated goods-and services-producing activities of households for own use (E) | 16.0 | 5.1 |

Note: (E) indicates sectors or aggregation of sectors that are defined essential by the ministerial decree 25 March 2020. Sectors named identically are the result of disaggregation into essential and non-essential sub-sectors.

Source: Authors' elaborations on data from ISTAT (2020) and Barbieri *et al.* (2020).

Table A.4 – Output and employment directly involved and workers at risk of infection by sector and type of policy response, Italy (in %)

| ID | Macro-sector | Ex-ante Risk | General lockdown | | | Differentiated lockdown* | | |
|---|---|---|---|---|---|---|---|---|
| | | | Output | Emp. | Risk | Output | Emp. | Risk |
| S1 | Agriculture | 1.5 | 0.0 | 0.0 | 0.7 | 0.0 | 0.0 | 1.3 |
| S2 | Agriculture | 1.5 | 100.0 | 100.0 | 0.0 | 26.3 | 26.6 | 1.1 |
| S3 | Agriculture | 1.5 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 1.3 |
| S4 | Industry | 0.6 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.6 |
| S5 | Industry | 0.6 | 100.0 | 100.0 | 0.0 | 9.9 | 9.9 | 0.6 |
| S6 | Industry | 0.6 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.6 |
| S7 | Industry | 0.6 | 100.0 | 100.0 | 0.0 | 17.0 | 17.1 | 0.5 |
| S8 | Industry | 0.6 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.6 |
| S9 | Industry | 0.6 | 100.0 | 100.0 | 0.0 | 9.4 | 9.4 | 0.6 |
| S10 | Industry | 0.6 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.6 |
| S11 | Industry | 0.6 | 100.0 | 100.0 | 0.0 | 13.3 | 13.6 | 0.5 |
| S12 | Industry | 0.6 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.6 |
| S13 | Industry | 0.6 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.6 |
| S14 | Industry | 0.6 | 100.0 | 100.0 | 0.0 | 8.9 | 8.8 | 0.6 |
| S15 | Industry | 0.6 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.6 |
| S16 | Industry | 0.6 | 100.0 | 100.0 | 0.0 | 7.2 | 7.2 | 0.6 |
| S17 | Industry | 0.6 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.6 |
| S18 | Industry | 0.6 | 100.0 | 100.0 | 0.0 | 5.7 | 5.8 | 0.6 |
| S19 | Industry | 0.6 | 100.0 | 100.0 | 0.0 | 8.7 | 8.8 | 0.6 |
| S20 | Industry | 0.6 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.6 |
| S21 | Industry | 0.6 | 100.0 | 100.0 | 0.0 | 9.0 | 8.9 | 0.6 |
| S22 | Industry | 0.7 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.6 |
| S23 | Industry | 6.1 | 0.0 | 0.0 | 2.5 | 0.0 | 0.0 | 4.9 |
| S24 | Construction | 0.5 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.5 |
| S25 | Construction | 0.5 | 100.0 | 100.0 | 0.0 | 7.6 | 7.5 | 0.5 |
| S26 | Services | 1.9 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 1.5 |
| S27 | Services | 1.9 | 100.0 | 100.0 | 0.0 | 23.3 | 23.5 | 1.5 |
| S28 | Services | 2.0 | 0.0 | 0.0 | 0.9 | 0.0 | 0.0 | 1.7 |
| S29 | Services | 1.9 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 1.5 |
| S30 | Services | 1.9 | 100.0 | 100.0 | 0.0 | 22.4 | 22.2 | 1.4 |
| S31 | Services | 0.2 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 |
| S32 | Services | 0.5 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.4 |
| S33 | Services | 0.1 | 100.0 | 100.0 | 0.0 | 46.0 | 46.1 | 0.1 |
| S34 | Services | 1.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.9 |
| S35 | Services | 1.0 | 100.0 | 100.0 | 0.0 | 63.4 | 63.4 | 0.4 |
| S36 | Services | 3.3 | 0.0 | 0.0 | 1.2 | 0.0 | 0.0 | 2.7 |
| S37 | Services | 3.3 | 100.0 | 100.0 | 0.0 | 32.5 | 32.4 | 2.3 |
| S38 | Services | 5.8 | 0.0 | 0.0 | 3.1 | 0.0 | 0.0 | 4.2 |
| S39 | Services | 10.7 | 0.0 | 0.0 | 5.7 | 0.0 | 0.0 | 6.9 |
| S40 | Services | 36.2 | 0.0 | 0.0 | 19.8 | 0.0 | 0.0 | 9.6 |
| S41 | Services | 2.2 | 100.0 | 100.0 | 0.0 | 24.8 | 24.7 | 1.6 |
| S42 | Services | 7.9 | 0.0 | 0.0 | 4.2 | 0.0 | 0.0 | 5.8 |
| S43 | Services | 7.9 | 100.0 | 100.0 | 0.0 | 37.2 | 37.4 | 4.9 |
| S44 | Services | 5.1 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 1.2 |
| Total | | 5.4 | 40.0 | 32.3 | 2.5 | 7.6 | 6.0 | 2.5 |

* The percentages of output and employment directly involved by the lockdown for each sector vary regionally.

Table A.5 – Output and employment directly involved and workers at risk of infection by NUTS-2-level region and type of policy response, Italy (in %)

| Region | Macro-region | Ex-ante | General lockdown | | | Differentiated lockdown | | |
|---|---|---|---|---|---|---|---|---|
| | | Risk | Output | Emp. | Risk | Output | Emp. | Risk |
| Abruzzo | South | 5.2 | 43.5 | 34.5 | 2.3 | 6.9 | 5.1 | 2.3 |
| Basilicata | South | 5.5 | 45.8 | 30.2 | 2.7 | 6.4 | 4.4 | 2.7 |
| Calabria | South | 5.9 | 28.6 | 21.8 | 2.5 | 6.2 | 4.5 | 2.5 |
| Campania | South | 5.5 | 36.6 | 28.7 | 2.7 | 7.7 | 6.0 | 2.7 |
| Emilia-Romagna | Centre | 5.1 | 43.8 | 35.7 | 2.4 | 7.0 | 5.9 | 2.4 |
| Friuli-VG | North | 5.6 | 45.8 | 34.4 | 3.3 | 6.4 | 4.0 | 3.3 |
| Lazio | Centre | 5.6 | 29.7 | 24.3 | 2.7 | 7.6 | 5.1 | 2.7 |
| Liguria | North | 5.7 | 36.0 | 29.7 | 3.1 | 6.9 | 4.8 | 3.1 |
| Lombardy | North | 5.0 | 40.3 | 35.8 | 1.5 | 8.3 | 7.5 | 1.5 |
| Marche | Centre | 5.0 | 50.8 | 40.8 | 2.6 | 7.4 | 5.3 | 2.6 |
| Molise | South | 6.0 | 35.9 | 29.2 | 3.1 | 5.6 | 4.4 | 3.1 |
| Piemonte | North | 5.3 | 44.3 | 35.3 | 2.8 | 7.4 | 5.6 | 2.8 |
| Puglia | South | 5.5 | 38.0 | 29.4 | 2.7 | 7.5 | 5.8 | 2.7 |
| Sardinia | South | 6.3 | 31.1 | 29.4 | 2.3 | 9.9 | 8.2 | 2.3 |
| Sicilia | South | 6.5 | 30.0 | 21.9 | 3.3 | 7.5 | 4.9 | 3.3 |
| Tuscany | Centre | 5.1 | 44.1 | 36.8 | 2.6 | 8.0 | 6.8 | 2.6 |
| Trentino | North | 5.8 | 36.6 | 30.9 | 3.2 | 6.3 | 5.1 | 3.2 |
| Umbria | Centre | 5.3 | 42.2 | 33.9 | 3.0 | 6.6 | 5.0 | 3.0 |
| Valle d'Aosta | North | 5.5 | 37.2 | 32.4 | 3.0 | 7.6 | 5.2 | 3.0 |
| Veneto | North | 4.8 | 45.4 | 38.6 | 2.2 | 7.4 | 6.7 | 2.2 |
| Italy | | 5.4 | 40.0 | 32.3 | 2.5 | 7.6 | 6.0 | 2.5 |