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The optimality of age-based lockdown policies

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Abstract

This paper studies an age-based lockdown that keeps over-60 workers at home as policy response to COVID-19 pandemic in a sample of thirty countries of the European single market. Three main policy issues are addressed, and the results can be summarized as follows. First, age-based lockdown policies are associated with limited output losses and, therefore, are an efficient strategy to limit the spread of the virus in a pandemic, especially in presence of strong age-dependent fatality rates. Second, lockdown policies generate substantial spillover effects; hence, international policy coordination avoiding that too many countries are in lockdown contemporaneously or that such coordination takes place across the countries with the highest integration of over-60 workers along GVCs may be helpful in reducing disruptions. Third, non-targeted lockdowns are much more costly than age-based ones; therefore, other things equal, age-based policies should always be preferred to non-targeted ones. Our analysis also suggests that, in our sample, the over-60 workers are relatively more numerous in sectors where the value added and the integration in GVCs is lower; this feature should be kept in mind in the design of other policies as it might play an important role.

JEL classification: D57, F16, F62, F66.

Keywords: Global Value Chains; age-dependent policies; over-60 workers; production networks; input-output.

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1. Introduction

The COVID-19 pandemic has represented one of the major shocks to the global economy from the Second World War. To limit the transmission of the virus and the death toll most countries have adopted various forms of lockdown policies (Khairulbahri, 2021) that have generated large output losses and the disruption of (domestic and foreign) value chains with a large shrink of the world trade volumes.

One of the key features of COVID-19 disease is represented by the individual's vulnerability exponentially increasing with age: almost 90 percent of COVID-19 deaths are people older than 60 years (Glynn, 2020), and the mortality rate for people above 65 is about 60 times higher than those in the 20–49 years age group. Such large age-related differences in the impact of COVID-19, as well as the large losses generally associated to lockdown policies, have led many economists to study the costs and benefits of age-dependent policies finding that targeted lockdowns may represent a useful tool to reduce significantly both the death toll of the pandemic and the economic cost of the confinement (Acemoglu et al., 2021). While the availability of vaccines has allowed many governments to soften some lockdown measures, the variants of the virus and the shortage of vaccines in many less developed countries make such policies still very useful. At the same time, the understanding of such policies for the present and future pandemics remains of major importance.

A first worth emphasizing issue is that the contributions studying age-based lockdown policies have so far neglected the heterogeneous distribution of the workforce across sectors as well as the global nature of contemporary production processes characterized by intermediate inputs acquired from multiple countries and industries along global value chains (GVCs). The key role played by GVCs in production in turn implies that lockdown policies adopted by one country interact with those of other countries in determining the output losses generated by such policies. The heterogeneous distribution of the workforce across sectors, the characteristics of country's value chains, and the adoption of the same policies in other countries are therefore three elements of

major importance for correctly estimating the output costs associated to (age-based) lockdown policies and, ultimately, for their policy design.

Motivated by these premises, we here analyze an age-based lockdown policy consisting of leaving at home the over-60 workers implemented under different (international) scenarios trying to answer the following three policy questions: (1) How large are the economic losses of an age-based lockdown policy? (2) To what extent the losses from lockdown in one country are affected by other countries adopting the same policy? And, therefore, in presence of spillover effects, would the policy coordination across countries be beneficial in reducing the costs associated with such policies? (3) How do the losses from an aged-based lockdown compare to those ones where the same number of workers left at home is selected randomly among the workforces? In other words, for a given number of workers left at home, are age-based lockdowns more or less costly (and to what extent) than non-targeted ones?

To address these policy questions, we combine the data on GVCs collected from the World Input-Output Tables (WIOD) with workforce data from the EU Labour Force Survey Database for thirty countries of the European single market (ESM). We then employ the hypothetical extraction method and some of its extensions (Dietzenbacher and Lahr, 2013; Dietzenbacher et al., 2019) as this is a standard input-output tool widely used in the recent GVCs literature for studying how the value-added of a sector, a region, or a country, changes following the perturbation of the input requirements matrix (Los et al., 2017; Giammetti et al., 2022).

Our analysis is developed as follows. We first compute two measures of GVCs participation of over-60 workers by employing the decomposition method proposed by Timmer et al. (2013): (a) the *backward* over-60 participation, that is the share of foreign over-60 workers integrated in the domestic value chains on total employment of a country, and (b) the *forward* over-60 participation, namely the share of domestic over-60 workers' input embodied in intermediate exports in total employment of a country. Our sample displays large cross-country variations in the backward and forward involvement of foreign over-60 workers in countries value chains that range from 0.2 to 4.4

percent and from 0.4 to 3.3 percent, respectively. These results confirm the correctness of our approach since they provide evidence on the importance of taking production links between countries and industries into account when analyzing the effects of lockdowns on the economy.

We then develop our analysis by estimating for each country (using the partial hypothetical extraction method developed by Dietzenbacher & Lahr, 2013) the output losses from an *age-based lockdown policy* that leaves at home the over-60 workers when such policy is adopted by: (i) the home country only, (ii) all countries except the home country, and (iii) all countries simultaneously.

We find that the mean share of over-60 workers on total workforce in our sample is 7.2 percent and the estimated average output losses in the three scenarios (i)–(iii) are 3, 0.64 and 4.51 percent, respectively.¹ The analysis allows us to provide an answer to the first two policy questions. First, we obtain that independently on whether all countries adopt an aged-based lockdown or not (i.e. both in scenarios (i) and (iii)), this policy has limited economic costs, beyond being an effective strategy from an epidemiological perspective. Second, the estimated losses highlight the amplification of output disruptions following the contemporaneous interruption of domestic and foreign value chains, i.e. the output losses of each country when all countries adopt the lockdown policy are substantially larger than the sum of the losses recorded in the scenarios where either the home country only or the foreign countries only implement such a policy.² This implies that the international coordination in the adoption of lockdown policies could be a useful strategy in reducing output losses. For example, if countries are hit by the virus at different intensity over time, then governments might find it optimal to coordinate in a way that only countries most hit by the pandemic adopt lockdown policies; in this way, the consequent reduction in the contemporaneous interruption of domestic and foreign value chains leads to lower losses. An interesting corollary of

¹ This means that the elasticity of output with respect to older labor force is well below unity for all countries in all scenarios considered, i.e. a one percent reduction in employment of over-60 workers generates an output loss lower than one percent.

² In line with the literature (Acemoglu et al., 2012; Barrot & Sauvagnat, 2016), our findings suggest that the presence of GVCs may have a role in the magnitude of losses and the propagation of shocks.

this result is that the evaluations of lockdown policies that do not consider the output losses generated by the interruption of GVCs are likely to have a downward bias.

Finally, to address our third policy issue about the cost of aged-based lockdowns policies relative to those where the same number of workers left at home is selected randomly among the workforces, we re-estimate the losses under each of the three scenarios in the hypothetical situation where the share of over-60 workers is the same in all sectors. As this latter scenario is equivalent to leaving at home a random share of workers, we refer to it as the *non-targeted lockdown policy*.

Our findings are quite striking as we obtain that a non-targeted lockdown policy leads to output losses that, on average, are more than three and a half times larger than those from the age-based policy. This result implies that age-based policies are not only more effective in reducing the death toll but also enormously less costly from an economic point of view. Therefore, other things equal, age-based lockdown policies should always be preferred to non-targeted ones. Our analysis also suggests that over-60 workers are relatively more numerous in sectors with lower value added and less integrated in the GVCs in the countries of our sample.

It is also worth remarking that while the analysis presented in this paper draws on the current COVID-19 pandemic, it has much broader policy implications.³ For example, it could guide the evaluation of policies regarding retraining older workers versus encouraging their exit from the labor market following the technological revolution related to automation and artificial intelligence that is likely to make obsolete the skills of a large number of workers.

This paper is closely related to the recent strand of the literature studying optimal targeted lockdowns policies. For example, Acemoglu et al. (2021) study targeted lockdowns in a multi-group SIR model and find that an age-based lockdown could limit economic losses to 7 percent of GDP, compared to 37 percent under a tight lockdown scenario. Closely related, Favero et al. (2020) find that policies of gradual return to work may save many lives with limited economic costs, as

³ See Heylen and Van de Kerckhove (2019) for an analysis about policies fostering the employment older individuals and Auboin et al. (2021) for government intervention in innovation activities with a specific focus on the effects of the digital economy.

long as they differentiate by age group. Fischer (2020), Gollier (2020), and Wilder et al. (2020) argue that a strong sheltering of the seniors and vulnerable persons together with a deconfinement of young and middle-aged people would reduce both the death toll of the pandemic and the economic cost of the confinement and help build herd immunity.⁴

Our study also relates to the literature studying the economic impact of lockdown policies following COVID-19 pandemic in an input-output and GVCs framework (Baqae & Farhi, 2020; Barrot et al., 2021; Bonadio et al., 2020; Guan et al., 2020; Mandel & Veetil, 2020; Pichler et al., 2021). Within this strand of the literature, some works have analyzed how social distancing measures and sectoral lockdown policies implemented around the world to limit the spread of the virus have generated serious disruptions to GVCs (Goel et al., 2021) and impacted the world economy and international trade (Salvatore et al., 2021; Stiglitz, 2021a,b) still struggling with the recovery from the 2009 recession (Salvatore, 2021).⁵ Even though the number of jobs indirectly involved in GVCs has grown dramatically in the last decades due to the increasing fragmentation of production (Timmer et al., 2013), all papers undertaking a lockdown scenario analysis in a production network framework have focused on the asymmetry of input-output connections neglecting the heterogeneous distribution of the workforce across sectors and GVCs.

Our work is also related to some recent papers that consider the distribution of the workforce across sectors and investigate the consequences of social distancing on employment and remote work (Dingel & Neiman, 2020), on wages (Palomino et al., 2020), and on the supply and demand of goods (del Rio-Chanona et al., 2020). Closer to our paper, Orsi & Santos (2010) and Santos et al. (2013) develop an input-output analysis to study the economic consequences on interdependent

⁴ See also Khairulbahri (2021) for the importance of different types of lockdowns policies for controlling the pandemic and Perugini and Vladislavljević (2021) for how income inequality contributes to shaping the trade-off between lockdown and contagion.

⁵ Other works have highlighted that supply chains interruptions, in turn, create bottlenecks with adverse implications for economic productivity and growth (Salvatore, 2020), which might explain why the COVID-19 pandemic has led to one of the most severe losses of production capacity in the last half-century (Coutiño & Zandi, 2021). Singh et al. (2021) emphasize the importance of global links to address the impact of COVID-19 pandemic.

sectors of workforce disruptions due to an influenza epidemic. The main differences between these papers and ours are that we use a multi-country approach, focus on workforce demographics, and, more importantly, our analysis compares the effects of targeted and non-targeted policies. This latter feature of our work is particularly important since it provides a useful tool to guide governments and institutions in implementing policies to mitigate the work-safety trade-off while keeping the economy going. In this sense, our paper enriches the debate on effective policy responses that could implement to combat the ongoing COVID-19 pandemic or other future diseases with similar characteristics (see, among others, Carnazza & Liberati, 2021; Kumar et al., 2021; Morelli & Seghezza, 2021; Taylor, 2021).

The paper is organized as follows. Section 2 explains the methodology. Section 3 describes the data and the policy scenarios. Section 4 presents the results of our analysis and discusses the policy implications. Section 5 concludes.

2. Methodology

In this section, the methods to decompose the contribution of over-60 workers in GVCs and to estimate the output losses from age-based and non-targeted lockdown policies are outlined from first principles. We first describe the input-output framework common to the two techniques employed. This is followed by an introduction of the ‘GVC jobs’ measure proposed by Timmer et al. (2013) and by a description of the measure used for estimating the number of over-60 workers involved in GVCs. In Section 4, these measures are used to explain the output losses computed employing the partial hypothetical extraction method (Dietzenbacher and Lahr, 2013) that is explained at the end of this section.

Following the main literature (Miller and Blair, 2009), we assume that there are S sectors, P production factors and N countries. Each country-sector produces one good such that there are SN products. The SN country-sectors produce output by using domestic production factors and intermediate inputs, which may be sourced domestically or abroad. Output may be used to satisfy

domestic and foreign final demand or intermediate production. Final demand consists of consumption and investment by domestic and foreign households and governments.

Let \mathbf{Z} be the $S \times S$ transaction matrix denoting the interindustry flows by the S industries, \mathbf{F} the matrix of industry final demands, and \mathbf{x} the vector of industry gross output. The accounting equations are given as $\mathbf{x} = \mathbf{Z}\mathbf{i} + \mathbf{F}\mathbf{i}$, where \mathbf{i} is the summation vector, i.e., a vector of all ones. Now define the direct input coefficients as the ratio of input supplied by i and bought by j over the gross output of sector j as $a_{ij} = z_{ij}/x_j$, which is the typical element of the economy's direct requirements matrix \mathbf{A} , also known as the technical coefficients matrix. We know that $\mathbf{A} = \mathbf{Z}\hat{\mathbf{x}}^{-1}$, where the circumflex or hat denotes a diagonal matrix, and the values on the diagonal of \mathbf{A} are elements of the vector \mathbf{x} . Thus, we can substitute $\mathbf{A}\mathbf{x} = \mathbf{Z}\mathbf{i}$ in the accounting equations to get $\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{F}\mathbf{i}$. Solving for \mathbf{x} yields:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{F}\mathbf{i} = \mathbf{L}\mathbf{F}\mathbf{i}, \quad (1)$$

where \mathbf{I} is the identity matrix and $\mathbf{L} \equiv (\mathbf{I} - \mathbf{A})^{-1}$ is the Leontief inverse or multiplier matrix, which makes it clear the direct and indirect dependence of each of gross outputs on the values of each final demand.

Following the literature on production fragmentation (Timmer et al., 2014), and specifically referring to the ‘GVC jobs’ measure proposed by Timmer et al. (2013), we estimate the number of over-60 workers involved in GVCs by decomposing the contribution by over-60 workers to value added. In particular, we pre-multiply the Leontief inverse by the direct over-60 workers input per unit of gross output $d_{i,s}^w$ produced in sector s in country i , i.e.

$$\mathbf{OW} = \hat{\mathbf{d}}_{i,s}^w(\mathbf{I} - \mathbf{A})^{-1}\hat{\mathbf{f}}. \quad (2)$$

The resulting \mathbf{OW} matrix decomposes the direct and indirect contribution of over-60 workers to sectors and countries' production. It should be noted that in order to isolate the participation of foreign over-60 workers in GVCs we set to zero all the elements in \mathbf{f} corresponding to domestic demands vector such that the elements on the main-diagonal blocks of the matrix \mathbf{OW} , corresponding to the contribution of domestic over-60 to domestic production are all zeros. As a

result, the row sum of the \mathbf{OW} matrix gives the total number of foreign over-60 workers backward activated in sector s country i value chain, whereas the column sum of the \mathbf{OW} matrix provides the number of domestic over-60 workers forward integrated in foreign countries' production.

To estimate the output losses from age-based and non-targeted lockdown policies in a GVCs framework, we refer to the partial hypothetical extraction method developed by Dietzenbacher and Lahr (2013).⁶ Technically, this method consists of reducing by a percentage α the technical coefficient matrix \mathbf{A} and the vector of final demands \mathbf{f} of the standard Leontief equation, and then comparing the new output with the pre-perturbation output. In our analysis, we extract the contribution of the over-60 workers as factors of production. Following the sector inoperability index employed by Orsi and Santos (2010), our country-sector α is equal to the share of unavailable workforce weighted for the labor input share:

$$\alpha_{i,s} = \frac{Over_60_Workers_{i,s}}{Size_of_Workforce_{i,s}} \times \frac{Labor_Input_{i,s}}{Gross_output_{i,s}}. \quad (3)$$

Partially extracting industry s requires that the intermediate and final deliveries sold by this industry decrease by a certain amount. Specifically, the s^{th} row and column of the \mathbf{A} matrix and the final demand vector \mathbf{f}_s decrease by a factor α . We define the perturbed requirement matrix and final demand vector as \mathbf{A}^* and \mathbf{f}^* , respectively. Thus, the estimated new vector of sector gross outputs will be:

$$\mathbf{x}^* = (\mathbf{I} - \mathbf{A}^*)^{-1} \mathbf{f}^*. \quad (4)$$

In order to relate equation (1) to the value added and GDP of each sector and country, we pre-multiply equation (1) by the value-added coefficients matrix $\widehat{\mathbf{V}}$, i.e. a diagonal matrix, of which the typical element on the main diagonal, v_j^s/x_j^s , is the value-added coefficient of industry j in country s . This leads to:

$$\mathbf{v}^* = \widehat{\mathbf{V}}(\mathbf{I} - \mathbf{A}^*)^{-1} \mathbf{f}^*. \quad (5)$$

⁶ In a recent contribution, Giammetti et al. (2020) used the same technique to study the role played by the domestic value chains in transmitting the economic impact of Covid-19 lockdown measures in Italy.

The absolute change in value-added due to age-based and non-targeted lockdown policies is then derived by the difference $\mathbf{s}' = (\mathbf{v} - \mathbf{v}^*)$, or in relative terms by the ratio $(\mathbf{v} - \mathbf{v}^*)/\mathbf{v}$.⁷

3. Data and empirical strategy

To measure GVCs participation of over-60 workers and the output losses from age-based and non-targeted lockdown policies we need to track for each country gross output, value added and labor input by industry, the global input-output matrix, final goods shipments, and over-60 workforce participation. This type of data is available from the World Input-Output Database (WIOD), (Timmer et al., 2015). The WIOD contains time-series of global input-output tables (WIOTs) and supplementary labor accounts from 2000 to 2014. We use the data of 2014, the most recent year available. The dataset covers 56 industries classified by the International Standard Industrial Classification revision 4 (ISIC Rev. 4), in 43 countries in the world plus a region called ‘Rest of the World’. The tables provided by the WIOD are accompanied by Socio Economic Accounts which contain country-sector panel data on employment (number of workers, compensation, and share of labor), capital stocks, gross output, and value added at current and constant prices.

Despite the richness of data covered, WIOD does not provide data on the number of workers by age. We thus collected data on over-60 workforce participation at the industry level from the EU Labour Force Survey Database (EU LFS). The EU LFS is a large household survey providing data on labor participation of people aged 15 and over. The data collection is available for 90 industries classified according to NACE Rev. 2 system. We used the correspondence table between NACE Rev. 2 and ISIC Rev. 4 to map the EU LFS data into the WIOD classification system. Due to limitations on labor participation data at the 2-digit sector level for non-European countries, our analysis focuses on thirty members of the European single market (ESM) included in the WIOD.

⁷ We should emphasize that both the decomposition methodology and the partial hypothetical extraction method outlined above are basically accounting frameworks, rather than fully specified economic models. They start from exogenously given final demand and trace the value added (and related jobs) generated at the various stages of production in an international input-output model, without explicitly modelling the interaction of prices and quantities like in Computable General Equilibrium models.

Notably, our sample includes all ESM countries except Iceland and Lichtenstein due to the lack of data in the WIOD. It also includes the U.K. because this country was still part of the ESM in 2014, the year considered in our analysis.

To address the policy issues presented in the Introduction, we consider three scenarios tested under two hypothetical lockdown measures. Specifically, we first estimate the output losses of each country i from an age-based lockdown policy that leaves at home the over-60 workers when such a policy is adopted by: (i) the country i only, (ii) all countries except country i , and (iii) all countries simultaneously. The results obtained in scenarios (i) and (iii) will allow us to answer our policy question (1) on the economic costs of age-based lockdown policies, while from the comparison of output losses in these three scenarios we will be able to evaluate the potential gains from the international coordination of such policies, that is policy issue (2).

We then move to address policy question (3) about the relative cost of age-based and non-targeted lockdowns. This analysis is developed by re-estimating the losses in each of the three scenarios (i)–(iii) using the same share of excluded workers for all sectors, and with such a share equal to the country share of over-60 workers. We refer to this lockdown policy as non-targeted because we are here estimating the cost of leaving at home the same share of workers across all age groups. In other words, the two policies considered, age-based versus non-targeted, leave at home the same share (or number) of workers but while the distribution of over-60 workers across sectors is gathered from the data in the age-based policy, the share of workers excluded in the non-targeted scenario is the same for all sectors and equal to the country share of over-60 workers. By comparing the losses under the two types of lockdown policies (age-based versus non-targeted) we will be able to infer whether the cost of leaving at home workers over a certain age is different from that of imposing the lockdown on all workers as well as to highlight the degree of productivity and integration in GVCs of over-60 workers.

4. Results and policy implications

- *The role of over-60 workers in the GVCs*

Before discussing the results of our scenario analysis, we present some preliminary evidence about the role of over-60 workers in the production links between countries and industries that will help us to better understand the policy implications of our study.

To this purpose, we have computed the share of foreign over-60 workers backward and forward involved in country i value chains over the total of over-60 workforce employed in country i , respectively.⁸ These measures, displayed in Figures 1 and 2, show the existence of a substantial degree of variation across countries in both indexes; the same is true for the share of over-60 workers on total workforce whose mean value is 7.2 percent in a range between 3.61 and 12.53 percent (see column 1 of Table 1 for details). Our measure of backward involvement in countries value chains has a mean of 0.86 percent (the range is 0.24–4.43 percent), while forward integration takes a mean value of 1.32 percent (the range is 0.44–3.26 percent). We can notice that there are countries significantly relying on the foreign over-60 workforce, such as Luxembourg, Ireland, Malta, Belgium, Denmark, Austria, Norway, and others in which domestic over-60 workers are highly forward integrated into foreign GVCs as in the case of the Netherlands, and Northern and East-Central European countries.⁹ These measures tell us that age-based lockdown policies adopted by the latter set of countries are likely to generate significant losses in other countries, such as the former ones. As we will discuss next, these are important features to be considered when analyzing the coordination of policies across countries.

⁸ As already mentioned in Section 2, the backward and forward participation measures reflect the contribution of foreign over-60 to countries' domestic production and the contribution of domestic over-60 to foreign countries' production, respectively. In particular, the backward participation refers to the concept of vertically integrated labor and it is measured as the share of foreign over-60 workers into total employment of a country, while the forward participation gives the number of domestic over-60 workforce integrated in foreign countries' production.

⁹ For example, the production of Luxembourg final demand requires more foreign over-60 workers than domestic. France, Austria, Hungary, Slovenia, and Slovakia employ a small fraction of domestic over-60, while the backward integration of foreign over-60 in their value chains is significant.

The results of our scenario analysis are contained in Table 1. Columns 2–4 of the table report the estimated output losses under the age-based lockdown policy for the three scenarios considered (i)–(iii); columns 6–8 show the results for the non-targeted lockdowns.

- **Policy question (1): the economic costs of age-based lockdown policies**

To answer our policy question (1) about the costs of age-based lockdown policies we need to consider the estimated output losses in scenarios (i) and (iii) that are reported in columns (2) and (4), respectively. From column 2 that displays the losses when a lockdown policy is implemented by the home country only (i.e., in scenario (i)) we observe an average output loss of 3 percent and that there is a wide heterogeneity on how countries are affected by such policy (the range of variation is between 0.92 and 5.1 percent). This leads us to two considerations. First, our estimates suggest that the losses are relatively limited once compared with the share of over-60 workers on total workforce: the elasticity of output with respect to older labor force is well below unity for all countries (see Figure 3), i.e. a one percent reduction in employment of over-60 workers generates an output loss lower than one percent (it ranges between 0.17 and 0.53 with an average of 0.42). Second, the countries that are most vulnerable in this scenario are those employing a larger share of over-60s workers in domestic production: the correlation between output losses and share of over-60 workers is 0.85.¹⁰

It is also important to highlight the mechanisms at work. The lockdown of workers generates two effects: a direct loss related to their productivity, and an indirect effect that comes from the disruptions of domestic value chains. Hence, the higher the productivity of the (over-60) workers and their contribution in the domestic value chains, the higher will be the output losses.

The limited costs from the age-based lockdowns are confirmed also by the estimates of scenario (iii) where all countries adopt such policy even though output losses are significantly higher. The estimates reported in column 4 show that the average loss is 4.51 percent (in a range

¹⁰ Indeed, the countries that would be mostly hit by this policy are the Northern European ones, such as Sweden, Norway, Denmark, the United Kingdom, Finland, Germany, and Estonia, while Luxembourg, Slovakia, Hungary, Romania, Slovenia, and Malta record the lowest losses due to a relatively limited share of over-60 workers.

between 2.62 to 7.17 percent), i.e. fifty percent higher than in the case where the home country only adopts the lockdown.¹¹ The elasticity of output with respect to older labor is still lower than one for all countries and the mean is 0.64 (see Figure 3).

- **Policy question (2): the benefits from international policy coordination**

We have seen above that the losses when the age-based lockdown is implemented by all countries are about fifty percent higher than those where the home country only adopts this policy. This result suggests that lockdowns generate important spillover effects across countries and, therefore, that there can be potential gains from the coordination of these policies.

Defining an effective policy coordination require both understanding the size of such spillovers and the mechanisms originating them. To this purpose, we first estimated the output losses when the age-based lockdown policy is adopted by all countries except the home one (scenario (ii)), and then compared them with the increase of losses when we move from the lockdown policy at home (i) to a global one (iii). Such a comparison will allow us to understand the size of the output losses due to the *joint* interruption of domestic and foreign value chains and, therefore, the potential gains from policy coordination.

The estimates generated by a lockdown of foreign countries (scenario (ii)) are reported in column 3: the average loss is 0.64 percent, and the range of variation is 0.17–1.27 percent. It is immediate that such losses are not correlated with the share of domestic over-60 workers because the home country is not in lockdown in this scenario but are instead mainly indirect and driven by the integration of foreign over-60 workers into domestic value chains. The more a country's production depends on over-60 foreign workers' activity, the higher is the indirect loss due to

¹¹ The distribution of output losses across countries in scenario (iii) is quite similar to that one from scenario (i) as the losses from the lockdown of domestic over-60 workers are significantly larger than those from foreign workers (scenario (ii)).

spillover effects; as a matter of fact, the correlation between output losses in column 3 and the index of backward integration in Figure 1 is 0.57 (the statistical significance is at 1%).¹²

If we compare the output losses in the home country from the foreign lockdown with the increase of losses when we move from the lockdown policy at home (i) to a global one (iii) (that is, the increase of losses due the lockdown of foreign countries when the home country is *already* in lockdown), we observe that the latter are much larger: the average increase of losses is 1.51 percent vs. 0.64 percent under scenario (ii). Column 5 reports the ratio between the increase in losses from scenario (i) to (iii) and the losses under the foreign policy (ii) showing that, on average, the former are about two and a half times larger. Such difference in the magnitude of losses can be explained by the fact that the interruption of GVCs is only partial when the over-60 lockdown is implemented in a country or in foreign countries; therefore, indirect losses and second-round effects are mitigated. When instead the supply chain disruptions affect all the economies of the sample, the shocks propagate and amplify through the GVCs.

This analysis brings us to the conclusion that governments can limit output disruptions by coordinating the lockdown policies. Specifically, this requires: (a) avoiding that too many countries are in lockdown contemporaneously, and (b) that countries displaying more integration of over-60 workers (backward or forward) coordinate more closely.

- ***Policy question (3): the differential cost between age-based and non-targeted lockdowns***

Our analysis has focused on age-based lockdown policies because COVID-19 fatality rates are extraordinarily higher among older individuals. However, cost-benefit analysis requires also assessing whether keeping at home over-60 workers is costlier than locking down younger ones.

The estimated losses of a non-targeted lockdown policy for the three scenarios considered (i)–(iii) are reported in columns 6–8 of Table 1. They are generally distributed similarly to the losses of the age-based policies while being strikingly higher: the average output losses in the home (i),

¹² The countries with the highest losses under this policy scenario are small countries such as Luxembourg, Estonia, the Netherlands, Czech Republic, Malta, and Hungary, while Greece, Spain, the United Kingdom, Italy, Portugal, France, and Germany display the smallest losses.

foreign (ii) and simultaneous (iii) scenarios are 10.68 (vs. 3), 2.54 (vs. 0.64) and 15.95 (vs. 4.51) percent, respectively.¹³ In other words, the losses from the non-targeted lockdowns are, on average, more than three and a half times larger than the correspondent losses from the age-based policies.

Such results allow us to answer our policy issue (3) by stating that age-based lockdown policies should always be preferred to non-targeted ones because they generate substantially lower output disruptions. This in turn suggests that over-60 workers are much more numerous in sectors characterized by a low productivity and less developed integration in domestic and foreign value chains. As this feature might be important also for other policy issues (e.g., the decision to retrain large categories of older-age workers whose jobs are displaced by technological progress) we investigated it further.

To this purpose, we computed the ratio between the output losses from the non-targeted lockdown policy and those from the age-based one for each scenario. Column 10 that refers to scenario (i) where the policy is implemented by the home country only shows an average ratio of 3.81 in the range [2.83, 9.18]. The larger this ratio, the larger the losses of leaving at home the same share of workers in all sectors (non-target policy) relative to locking down the over-60 workers (targeted policy), i.e. which the age-based policy is “cheaper” than the non-target one. In other words, older workers are likely to be over-represented in sectors with a lower degree of productivity and integration in domestic value chains and leaving them at home leads to limited disruptions relative to a random lockdown involving the same number of workers. Column 11 reports the same ratio for the foreign scenario (ii): the average is around 4 and the range of variation is limited, from 3.61 to 4.63. A larger value of this ratio means that the country imports goods and services from sectors of other countries that employ relatively few over-60 workers, i.e. the backward integration

¹³ See also column 9 that is the equivalent of column 5.

of over-60 workers is low. Therefore, leaving such workers at home leads to a limited interruption of foreign value chains and, consequently, of output disruptions.¹⁴

5. Conclusions

This article has been motivated by the COVID-19 pandemic that has forced many countries to implement various forms of lockdowns and by the strong age-dependency of Covid fatality rates. We here focused on age-based lockdowns addressing three policy questions through an input-analysis of various scenarios. Our results can be summarized as follows.

First, age-based lockdown policies give rise to relatively low economic losses. Therefore, they are a very efficient strategy to limit the spread of the virus in a pandemic characterized by strong age-dependent fatality rates. Second, the adoption of lockdown policies generates substantial spillover effects on other countries through the amplification of output disruptions following the contemporaneous interruption of domestic and foreign value chains. This implies that international policy coordination is a useful strategy in reducing the deadweight losses from such policies. In particular, we emphasized that a reduction of disruptions could be pursued by avoiding that too many countries are in lockdown contemporaneously, and that countries with a higher integration of over-60 workers (backward or forward) coordinate more closely. Third, we have shown that age-based lockdown policies should always be preferred to non-targeted ones because they generate substantially lower output losses.

¹⁴ Column 12 shows the ratios for policy scenario (iii) confirming the same results. The countries with the smallest ratios (around 3) between the losses from the non-targeted and the aged-based policies are Denmark, the United Kingdom, Switzerland, Germany, Croatia, and France, while Romania, Slovenia, Greece, Luxemburg, Slovakia, and the Czech Republic are the countries with the highest ratios (close to 4 except Romania). The distribution of the ratios of losses is relatively limited in all three scenarios (i)–(iii); Romania is an exception as the ratio of losses in scenario (i) for this country is above 9, which in turn leads to a ratio of 7.6 in scenario (iii); this result suggests that Romanian over-60 workers are distributed in sectors with much lower productivity relatively to the distribution of such workers in other countries.

We also highlighted that the limited losses from age-based policies (relative to non-target ones) are likely to be due to the fact that over-60 workers are much more numerous in sectors characterized by a low productivity and less integrated in GVCs. This feature might be important also for other policy issues. For example, as the future evolution of automation and artificial intelligence is likely to generate the need of retraining of many categories of workers, our analysis could be of guidance in evaluating the opportunity of favoring the exit of older-age workers from the labor market rather than retraining them.

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Table 1. Shares of over-60 workers and estimated output losses under age-based and non-targeted policies.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Age-based lockdown losses				Non-targeted lockdown losses				Ratio of losses			
	(ABL)				(NTL)				(NTL/ABL)			
	Over-60	Home	Foreign	All	Ratio of	Home	Foreign	All	Ratio of	Home	Foreign	All
Country	shares	country	countries	countries	losses	country	countries	countries	losses	country	countries	countries
		only	only	(iii)	[(iii)-	only	only	(iii)	[(iii)-	only	only	(iii)
		(i)	(ii)	(iii)	(i)]/(ii)	(i)	(ii)	(iii)	(i)]/(ii)	(6)/(2)	(7)/(3)	(8)/(4)
Austria	4.48	2.00	0.68	3.33	1.97	6.71	2.73	11.56	1.78	3.36	4.01	3.47
Belgium	4.20	2.02	0.84	3.53	1.79	6.20	3.21	11.47	1.64	3.07	3.82	3.25
Bulgaria	8.39	3.93	0.58	5.68	3.02	13.06	2.32	18.86	2.50	3.32	4.00	3.32
Croatia	5.80	2.87	0.48	4.20	2.77	8.53	1.92	12.86	2.26	2.97	4.00	3.06
Cyprus	6.15	2.41	0.50	3.51	2.20	8.53	2.18	12.89	2.00	3.54	4.36	3.67
Czech Republic	6.34	2.36	0.87	4.11	2.01	10.27	3.61	17.00	1.86	4.35	4.15	4.14
Denmark	9.22	4.63	0.56	6.40	3.16	13.09	2.16	18.29	2.41	2.83	3.86	2.86
Estonia	12.53	4.40	1.06	6.75	2.22	18.07	4.08	25.81	1.90	4.11	3.85	3.82
Finland	9.37	4.53	0.53	6.35	3.43	14.28	2.03	19.72	2.68	3.15	3.83	3.11
France	4.79	2.46	0.33	3.45	3.00	7.40	1.26	10.70	2.62	3.01	3.82	3.10
Germany	8.84	4.49	0.44	6.16	3.80	13.58	1.82	18.63	2.77	3.02	4.14	3.02
Greece	6.00	1.92	0.17	2.66	4.35	8.65	0.66	11.55	4.39	4.51	3.88	4.34
Hungary	3.90	1.49	0.85	2.93	1.69	5.49	3.51	11.14	1.61	3.68	4.13	3.80
Ireland	7.39	2.34	0.75	3.71	1.83	9.34	2.71	13.90	1.68	3.99	3.61	3.75
Italy	6.90	3.46	0.29	4.70	4.31	11.28	1.18	15.50	3.58	3.26	4.07	3.30
Latvia	8.47	3.46	0.81	5.25	2.21	13.55	3.09	19.76	2.01	3.92	3.81	3.76
Lithuania	7.58	2.77	0.71	4.18	1.97	10.17	2.80	15.18	1.79	3.67	3.94	3.63
Luxembourg	3.61	0.92	1.27	2.73	1.42	4.98	4.65	11.70	1.45	5.41	3.66	4.29
Malta	5.59	1.83	0.85	3.28	1.71	7.54	3.27	12.93	1.65	4.12	3.85	3.94
Netherlands	8.29	3.92	0.97	5.90	2.04	11.89	4.29	19.18	1.70	3.03	4.42	3.25
Norway	10.46	4.66	0.80	6.61	2.44	14.71	3.70	21.61	1.86	3.16	4.63	3.27
Poland	5.90	2.25	0.68	3.70	2.13	9.44	2.78	15.18	2.06	4.20	4.09	4.10
Portugal	9.74	3.75	0.31	4.93	3.84	14.24	1.23	18.26	3.27	3.80	3.97	3.70
Romania	8.89	1.52	0.54	2.62	2.04	13.95	2.12	19.92	2.82	9.18	3.93	7.60
Slovakia	3.96	1.37	0.81	2.74	1.69	6.11	3.36	11.63	1.64	4.46	4.15	4.24
Slovenia	4.83	1.54	0.79	2.93	1.76	7.22	3.23	12.79	1.72	4.69	4.09	4.37
Spain	5.44	2.66	0.25	3.62	3.84	8.57	0.99	11.84	3.30	3.22	3.96	3.27
Sweden	11.53	5.10	0.64	7.17	3.23	16.81	2.41	22.92	2.54	3.30	3.77	3.20
Switzerland	8.68	4.38	0.48	6.00	3.38	13.29	1.79	18.03	2.65	3.03	3.73	3.01
United Kingdom	8.74	4.61	0.28	6.09	5.29	13.45	1.14	17.68	3.72	2.92	4.07	2.90
<i>Min</i>	3.61	0.92	0.17	2.62	1.42	4.98	0.66	10.70	1.45	2.83	3.61	2.86
<i>Max</i>	12.53	5.10	1.27	7.17	5.29	18.07	4.65	25.81	4.39	9.18	4.63	7.60
<i>Mean</i>	7.20	3.00	0.64	4.51	2.68	10.68	2.54	15.95	2.33	3.81	3.99	3.69

Figure 1. Over-60 workers backward integrated in countries' GVCs on total countries' employment.

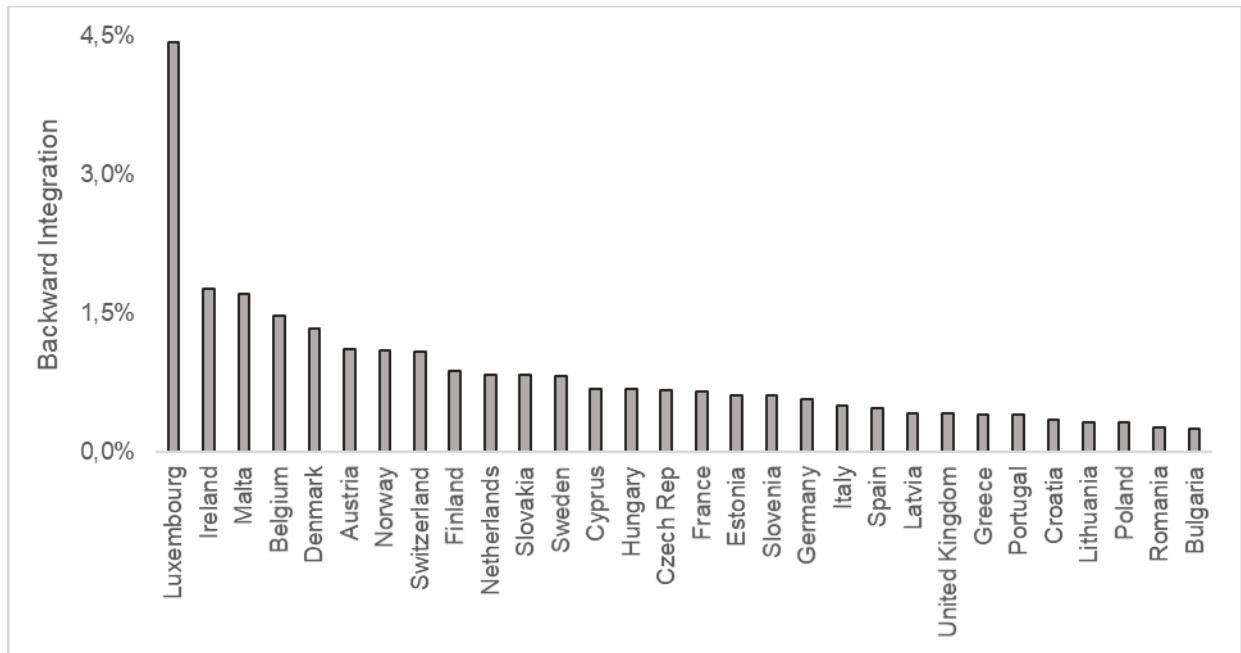


Figure 2. Over-60 workers forward integrated in countries' GVCs on total countries' employment.

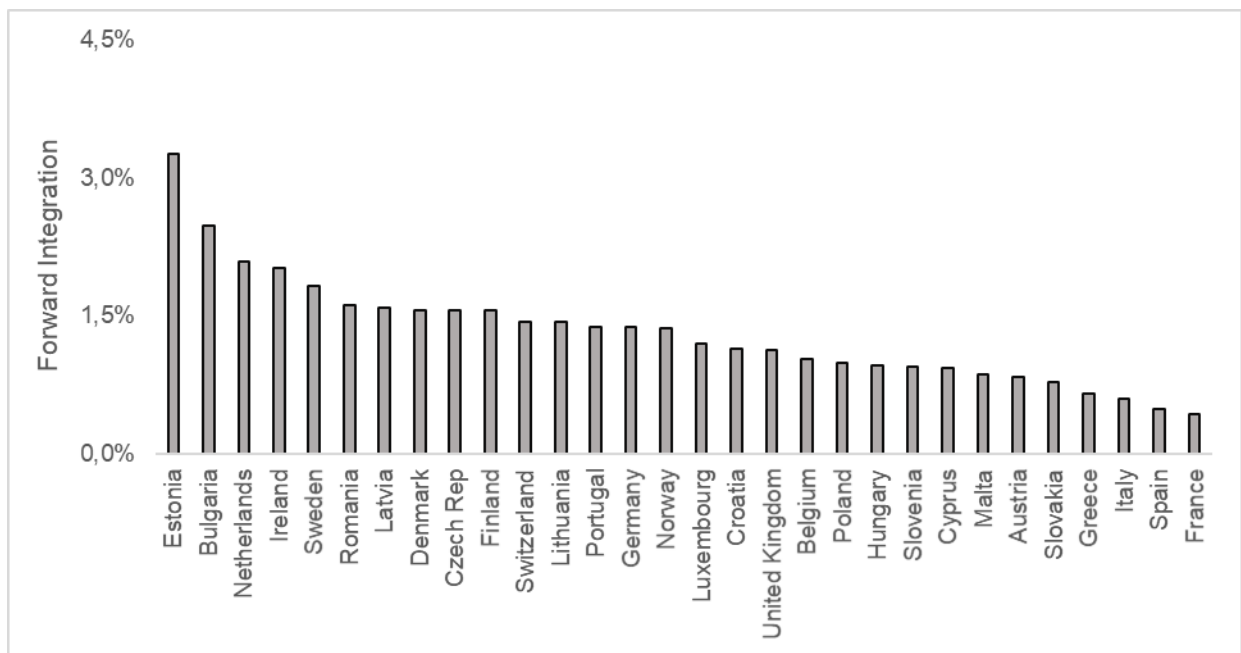


Figure 3. Elasticity of output with respect to over-60 workers under age-based (ABL) and non-targeted (NTL)

lockdown policies in scenarios (i) and (iii).

