



UNIVERSITY OF MACERATA

Department of Economics and Law

PhD Programme in

QUANTITATIVE METHODS FOR ECONOMIC POLICY

Curriculum

MULTISECTORAL AND COMPUTATIONAL METHODS OF ANALYSIS FOR

ECONOMIC POLICY

XXXIII Cycle

PhD Thesis

COVID-19: TRADE-OFF BETWEEN HEALTH AND ECONOMICS

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Academic Year: 2020 – 2021

I dedicate this space of my work to the people who have contributed, with their tireless support, to its realization.

First of all, a special thanks to my Supervisor, Prof. Claudio Socci, for his great support, his great patience, for his indispensable advice, and for the knowledge he passed on to me throughout my studies path.

Thanks also to all the research staff of Prof. Socci, and in particular to Prof. Rosita Pretaroli and Prof. Francesca Severini, for the technical and emotional support they gave me.

Finally, I would like to thank my colleague Silvia D'Andrea, with whom I shared the whole PhD path. It is also thanks to her that I have overcome the most difficult moments.

I dedicate this work to my wife and my children.

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Introduction

The 2020 can be considered a year of great importance for present and future generations marked by the global pandemic known as COVID-19. The impact of this phenomenon is far-reaching and can be traced back to two main aspects concerning health and economics. As for the first, the pandemic strongly affected the core of life and everything about it, leading, on the one hand, to the widespread diffusion of the contagion and the consequent increase in the mortality rate. On the other hand, it induced undesired psychological and physical consequences on people life. Indeed, factors such as social isolation, imprisonment at home, the weight of general uncertainty and the obsessive fear of being infected can severely affect the balance of each individual. The health aspect is undoubtedly the heart of the social system functioning and development and policy makers all over the world immediately introduced policy measures to combat the pandemic by prioritizing the health target.

However, closely linked to the health aspects, the economic consequences of the pandemic exacerbated the state of uncertainty of the economic systems as well as the economic and social conditions. The alteration of the production processes, investment capacity, consumption behaviour and labour market functioning forced the policy maker authorities to re-considerate the economic policy plans and change the priority set. Moreover, the rapid spread of the epidemic has also dramatically reduced international trade and led to a global economic crisis.

All countries are suffering severe economic losses, mainly because of the falling production due to the measures of COVID-19 infections containment, but some were harmed more than others. This difference depends on various factors such as the temporal and spatial dimension of the lock down. This isolation is generally established by the policy maker on the number of deaths per million of inhabitants and the rate of virus

infection, which serve as parameters for measuring the severity of the phenomenon. But it also depends on the structure of the economy, which is increasingly intertwined between production activities and between institutional sectors. In this context, a further element added to the components exacerbating the economic impact of the pandemic and it is represented by the weight of tourism in the economy (Sapir 2020). For most countries, a relevant component of final demand is linked to tourism flows in very specific time periods, and whether these people and income flows are interrupted, it will be necessary to wait for the following years before a recovery can be observed.

In this pandemic scenario, governments' ability to avoid the collapse of the economic activities through expansionary policies plays a key role. Indeed, the spread of the virus has triggered important changes in the policies implemented by governments and central banks. Economists agree that governments in Europe and in the United States — the current epicentre of the pandemic — will need to take extraordinary measures to address the disruptive economic consequences of the COVID-19 crisis. Heavy pressure on health systems and the forced cessation of economic activities require massive and urgent emergency action to address the immediate consequences of the crisis. In the aftermath of the emergency phase, governments will need to take further action to prevent the recession from turning into a prolonged depression. Therefore, understanding what is the economic functioning of a Country and understanding how the productive activities and institutional sectors interact each other represents the crucial point in designing the optimal policy measure intervention.

In this perspective, the aim of this work is developing a set of instruments able to describe the national and regional characteristics of the economic system and analyse the impact in a general equilibrium framework of the policy measures. In particular, the selection of the analysis approach is related to the features of the observed Country and

the target of the policy examined. Since the multisectoral aspects are relevant when analysing policy measures that are selective and differentiated by production processes and institutional sectors, the present study develops an Inoperability Extended Multisectoral Model for Italy, a Static CGE Model for Sardinia Region and a Dynamic CGE Model for USA to evaluate the Covid-19 pandemic in these economic systems.

More precisely, the first chapter analyses the impact of the lockdown in Italy as stated by the Prime Ministerial Decree of 22 March 2020, through an Inoperability Extended Multisectoral Model (IEMM) based on the Social Accountability Matrix (SAM). Italy was the first European country to experience an outbreak of Covid-19, but it was also the first to activate the lockdown policy on the entire national population, with the aim of limiting the contagions. On the basis of the Italian experience, other European and non-European countries have implemented containment policy more or less rapidly, leading Italy to be considered as a model to follow and to the point of being praised by the New York Times in the article “How Italy turned around its Coronavirus calamity¹”. The aim of the study is therefore to analyse the effects of the lockdown on the Italian economic system, and in particular the trade-off effect between health and economy. To this aim, the IEMM was developed since it is considered one of the proper models able to capture the effects of a calamity or a disaster that interrupt drastically the production processes. The IEMM is a linear model, derived from Leontief’s model and corrected for the market shares of each productive sector. The block of production, in disaggregated terms, affects the economic system not only through to the productive structure but also according to the relationship in the market among the industries. Moreover, since the model is based on the SAM, it provides for the endogenization of the demand components, through the construction of a matrix of the coefficients of the primary and

¹ Source: <https://www.nytimes.com/2020/07/31/world/europe/italy-coronavirus-reopening.html>

secondary distribution of income. The model allows estimating the impact of the interruption of production processes on the main macroeconomic components. At the same time it provides a disaggregated impact analysis on value added components, final demand and distribution of income by Institutional Sector.

The second chapter proposes the impact analysis of the lockdown on the territory of the Sardinia Region through a Static Computable General Equilibrium model (GGE). This analysis emerges from the exigency to analyse the economic impact of the pandemic at not only national level, but also focusing on the peculiarities of singular Regions that are characterised by different interconnections among production processes, value added generation and Institutional sectors. Moreover, the pandemic triggered interventions also by Regional Governments that are involved in the process of avoiding the economic collapses of the systems. In this perspective, it becomes crucial to estimate the impact that local and national policy measures will have on territorial economic systems, with the aim of assessing the regulatory mechanisms necessary for the restart of the economic system. The construction of a CGE model for the Sardinia economy allows to relax the linearity and the fixed prices hypotheses, typical of multisectoral analysis. Moreover, the purpose of the analysis is making a precise assessment of the effects of the production interruption on a particular Region, such as Sardinia, whose economic structure is mostly dependent on tourism activities and tourists' flows. Since the lockdown occurred at the beginning of the tourist season, a dedicated analysis of the economic impact becomes crucial, especially because of the massive cancellation of stays for tourism even after the conclusion of the lockdown. The CGE model is calibrated on the specially constructed SAM for Sardinia. It allows quantifying the direct, indirect and induced impact of the pandemic on the main macroeconomic components in aggregate and disaggregate terms and in real and nominal terms.

The third chapter proposes an analysis of the impact of the lockdown on the United States of America through a dynamic computable general economic equilibrium model (DCGE). This is because a further fundamental theme of the economic debate is related to the impact that lockdown can have on the major economic powers and the transmission effects that could be generated on other economies. These economies has the capacity to transfer the effect of the internal crisis on the entire world economic system, and the analysis of the impact in disaggregated terms helps to provide a useful framework to define targeted and not generalized intervention measures. An analysis was therefore carried out to quantify the effect of the production block in the USA, through the elaboration of a dynamic CGE based on the SAM built ad hoc for the USA for the year 2017. Unlike the static CGE model, dynamism makes it possible to capture the dragging effect of the economic shock in subsequent years. A period not exceeding 5 years is considered because this represents the time lags where the same dynamism is plausible and the accumulation of capital can be modelled using constant parameters as for the growth rate of the economic system and interest rate.

The joint analysis conducted demonstrated the relevance of using a multisectoral approach especially for the construction of the simulation scenarios that are characterised by the introduction of shocks for selected production processes. Moreover, the different approach used for each case study allowed evaluating the impact of the lockdown policy, both at national and regional level, considering the damages form the interruption of production processes, the fall in final demand, the reduction in disposable incomes and the possible recovery paths for different economic system dimensions.

Chapter 1

Covid-19 Pandemic and the supply side shock in Italy

1. Mega events, catastrophes and pandemics: the economic approach

In *wartime* a nation's economic performance is functional to the military strategy and policy makers must adequate their policy decisions in order to adapt to the emergency and recreate the conditions for the economic recovery. A pandemic or a natural disaster can be interpreted for certain aspects as a *wartime* for a nation. The economic analysis of pandemics indeed, could lead to the emergence of a trade-off between the containment of the infection (public health) and the support to economic growth. A strong pandemic for its intensity and duration, as COVID-19, generates effects both on the health-care system and on the economic system, on a par with the natural catastrophes: the quantification of these effects is a priority for all Nations stricken by the pandemic.

The magnitude of the economic damage must however be measured only in the moment in which pandemics is downgraded to epidemics. The economic performance of the countries affected by pandemics is conditioned by impositions that people have to undergo in terms of limits of personal freedoms and limits to the capacity of enduring the production processes. In the first case, a great contraction of final demand could take place, generating consequences on labour supply that might reduce because of the interruption of several working tasks. On the other hand, limiting the possibility to carry out production processes generates a predictable contraction in the supply of good and services. In addition, the negative economic effects could be non-negligible also for countries only marginally affected by the pandemic. The production activities that undergo a partial or total stop are part of the set of those that can be postponed.

The main target of Governments, and more generally of the political economy authorities, should be the public health protection. The short-term economic growth should be downgraded to a secondary goal, a topic that continues to be monitored but does not prejudice the attention devoted to the emergency health services. Therefore, fiscal and monetary policies that are usually directed to economic cycle stabilization should support the health target, during the event itself and the post pandemic. All types of constraints, included the budget constraints, should be at least alleviated if not disabled.

The present COVID-19 pandemic imposes a health emergency derived from the relevance of the pathology but also from the high degree of mortality that it implies. The present health situation puts under stress the provision of health services to patients with relevant consequences also with respect to the ordinary and planned activities. The pressure on the National Health Service SSN, with its relevant regional peculiarities, spread its negative effects on all pathologies, even the non-pandemic ones, widening the probability to have further loss of human lives classified as “induced”.

The global macroeconomic framework that is taking shape, leads with great probability towards the worsening of the forecasted scenario of growth trend with a downgrading of the performances of the principal developed countries.

Given the global character of the pandemic, the global economy will most probably suffer a new technical recession, associated with the actual one, in the current year if, realistically, an extension of the health emergency will become unavoidable. The COVID-19 pandemic, from a strictly economic viewpoint, shows the fundamental characters of a natural catastrophe. The fight against the virus diffusion through the reduction of contagions, outside a pharmacological strategy, demands the total block of individual transfers. This compromises the availability of the work force for all those

processes in which a substitution of work in presence with more flexible forms of labour cannot be realized.

Then, the non-agile production processes undergo an inevitable and sudden output break due to scarce labour mobility, either voluntary or forced, of individuals. In other words, all activities, deferrable or non-agile, will be forced to an immediate closure, with undesired and relevant extra costs. At the end of the health emergency the reopening phase not always will occur with the same dynamics and intensity it had in the pre-pandemic phase. Moreover, those activities not directly involved in the shutdown, because involved in the production of non-stock-able commodities and services, as essential goods, after a light acceleration in the initial phase, due prevalently to a panic effect, might experiment a trend inversion towards a significant slowdown.

The output production and the resulting sales revenues create asynchronies in the cash flows and firms are not always able to face the considerable demand fluctuations using the conventional tools as financial loans.

At the end of the health emergency, whose time-duration remains highly uncertain, the economic impact evaluation will be centred on GDP in its sectoral disaggregation, both in the production and final demand contexts. Many activities will classify the economic loss as deadweight loss, evaluating the possibility of moving towards an innovation of process, aiming to augment the economic resilience of the single production process and of the whole production system. Other producing activities, among which those that do not operate at full capacity and those that produce for the warehouse, will have the occasion of recovering in the short term a relevant share of the loss incurred.

In the aim of attempting a tentative evaluation of the economic consequences of pandemic, with the uncertainty on the duration of the health emergency, it is necessary to

design potential simulation scenarios where time and intensity of the shutdown of activities are combined together.

The shutdown of the single process can be conveniently represented with reference to a multisectoral approach preferably in the general equilibrium framework. However not all activities can shut the entire line of production so that it is necessary to design shocks with substantial sectoral differences both on the demand and the supply side. Simulations are concentrated on the single activities in partial or complete shut down and on those for which a decline of domestic demand is reported. Moreover, given the global relevance of pandemic, the drop of foreign demand will reinforce most likely the fall of domestic demand.

Potential shocks in deferrable production due to voluntary or forced blocks with different intensity and duration can be easily treated in multisectoral models, either short or extended. Inoperability of production processes is not tied to cyclical factors or to structural breaks. The resulting innovation process represents a consequence of pandemic rather than a result of a conventional economic policy plan in peacetime.

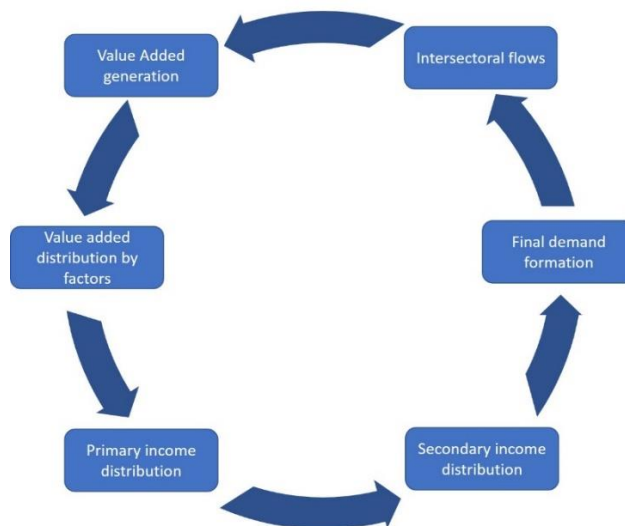
COVID-19 pandemic requires immediately an estimation of the magnitude of the economic damages, excluding in this preliminary phase the human capital loss. The interruption of selected commodities' supply with the associated reduction of final demand, will induce in the private sector a sharp decline in output. This contraction will be reflected on value added (labour and property incomes) generation and on the allocation of incomes. The resulting drop of disposable income can be reduced probably by partial measures acting through the traditional channels, such as social safety nets supported by continuous intervention operated by government.

The extension of the set of workers and firm categories that can access the traditional assistance programs is only a form of partial claw-back. Moreover, the

temporary suspension of the fiscal obligations and the programs of liquidity injection on the behalf of ECB are aimed to limit the possible liquidity criticalities that could affect the economy. The limited relevance of the refinancing and of the extension of the assistance programs aimed to the containment of GDP decline in various Institutional Sectors is strictly linked to the duration of the health emergency.

The interest in a country's economic problems and the need to solve questions about the effects of policies on the economic system are the basis for the development of research on Input-Output models. From this point of view, multisectoral models, disaggregated in terms of production typology and Institutional Sectors, represent a tool for economic policy analysis, as they are able to capture the disaggregated effect of the policies themselves and to simulate the effects of targeted interventions at sector level. In their extended form, the models are calibrated on the social accounting matrix (SAM), and are therefore able to capture the circularity of income, from its formation, to its primary allocation and secondary distribution, up to its use as final demand, as shown in the Figure 1

Figure 1. Income Circular flow



Under particular assumptions, which will be presented during the discussion of this chapter, the extended multisectoral model can be restructured in the form of "inoperability", which allows a specific analysis of anomalous functioning production economic system, expressed as a percentage of its planned production capacity (Santos and Haimés, 2004).

2. Framework of the Italian economy

The application of the extended multisectoral models is referred to a benchmark given by the quantitative representation of the complete circular flow at a given time. The introduction of the policy measures for the containment of the contagion will determine deviations from the benchmark, providing results of the impacts on the macroeconomic variables. The Social Accounting Matrix, SAM, provides a most flexible accounting scheme especially suitable for representing the social and economic situation in its complexities. All the economic flows, among the various types of operators, are allocated according to their several origins and destinations, quantitatively corroborating the major logical links within the economy. Then, the SAM records the flows acting among operators in the various stages of the circular flow of income: production, value added generation, primary allocation of incomes, secondary distribution of incomes, income uses and accumulation, putting in evidence the multisectoral flow circularity. Its specific characteristics emphasise the general quantitative picture of the stages through which economic values originate and close to restart: production, among industries, value added according industries and value added components, income distribution, according value added components and institutions, income redistribution among institutions, and final demand by institutions and commodities. The scheme of the SAM for the year 2016 is shown in Figure 2.

Figure 2. Social Accounting Matrix and interactions among Institutional Sectors

	Commodities $i = 1, \dots, 63$	Activities $j = 1, \dots, 63$	Primary Factors $f = 1, 2$	Taxes on output $w = 1, \dots, 14$	Taxes on activities $k = 1, \dots, 13$	Private Inst. Sectors $r = 1, \dots, 4$	Government $g = 1, \dots, 6$	Income Taxes $t = 1, \dots, 20$	Investments	Rest of the world
Commodities $i = 1, \dots, 63$		Intermediate Consumption				Private Final Consumptions	Government Final Consumption		Investments	Exports
Activities $j = 1, \dots, 63$	Output									
Primary Factors $f = 1, 2$		Value added at factors costs								Primary Incomes
Taxes on Output $w = 1, \dots, 14$	Indirect Taxes on Output									
Taxes on Activity $k = 1, \dots, 13$		Indirect Taxes on activities								
Private Inst. Sectors $r = 1, \dots, 4$			Primary Incomes			Transfers among Private Institutions	Transfers public to private institutions.			Transfers from Abroad
Government $g = 1, \dots, 6$			Primary Incomes	Net Indirect Taxes on output	Net Indirect Taxes on activities	Transfers private to public institutions	Transfers Among Public Institutions	Income Tax revenues		Transfers from Abroad
Income Taxes $t = 1, \dots, 20$						Income Tax				
Savings (z)						Private savings	Public savings			(+/-) Savings
Rest of the world	Imports		Primary Incomes			Transfers abroad	Transfers to abroad			

The SAM for 2016 is characterized by 63 industries and 63 commodities ((complete list is available in Appendix 1); 2 primary factors, Labour and Capital; 4 private Institutional Sectors (Non-financial corporations, Financial corporations, Households, Non-profit institutions). Public administration is divided into 6 institutions (Central Government, Social Security Administration, Regional, Provincial and Communal governments, Other central administrations). The Rest of the World completes the set of Institutional Sectors.

SAM includes 20 different income taxes, 14 taxes on production and 13 taxes on activities included VAT, IRAP and Social Benefits.

The construction of the SAM started from the structure of the Input-Output table for the year 2016 produced by the National Institute of Statistics (ISTAT)², and the ISTAT data for what concerns the primary distribution of income³.

² <https://www.istat.it/it/archivio/238228>

³ <http://dati.istat.it/>

For taxes on commodities and industries, data published by ISTAT with details of taxes by item and by type of administration (central or peripheral) were used. The total was then distributed on the basis of the tax type, where a particular activity is identified, or on the basis of Value Added shares, where there is no specific and univocal reference. To strengthen the imputation methodology, data on tax returns have also been downloaded from the Department of Finance's website⁴, providing details by macro-sector of economic activity. Data on total taxes were also checked for those obtained from the RGS-ISTAT SIOPE database on public administrations' home flows, which provides details on the type and location of PA. With regard to income taxes, the detail produced by ISTAT was used. The transfers were estimated on the basis of the SIOPE data previously called up and checked for the RGS Statistical Yearbook data Table 2.2.5: Final allocations and results of State budget management by title and economic category. Finally, ISTAT's 2016 Institutional Accounts were used to check the consistency of the overall framework, especially with reference to gross savings.

3. Disaggregated income circular flow approach

Economic analysis of pandemics, in particular on the forecasted effects of policies aimed at its containment, find space in the literature, especially on the topics of the method of estimation proposed. The availability of contributions on evaluation tools has significantly expanded in recent years. The models used for impact analysis rely on sophisticated techniques of parametrization and validation; some of them incorporate elements that refer to the behaviour of individuals. In a recent work performed through a meta-analysis of the contributions in this field (Carrasco et al., 2013), emerge how the most commonly used models are the Agent-Based, the CGE and Network models. Further

⁴ <https://www.finanze.gov.it/opencms/it>

contribution have been provided by the utilization of cost-benefit analysis where, given a predetermined project all costs and benefits directly or indirectly attributable to the project are taken into consideration.

In this work, an extended multisectoral model of inoperability is developed with the aim of providing an evaluation of the macroeconomic components' impact of COVID-19 pandemic, living aside, for the moment, the policy activated for its containment.

Multi-sectoral models represent a valid tool for the analysis of direct and indirect effects on the economic system of policy measures, or spontaneous variations of a selective nature, i.e. phenomena that do not affect demand or supply as a whole. This type of policy includes the containment of contagions implemented by the Italian Government through the lockdown in which only the activities considered non-essential suffered the interruption of production, while the production of necessities remained unchanged. However, through sectoral interdependencies, among productive activities and among Institutional Sectors, the policy impacts on the entire economic system, affecting in the case of lockdown also the sectors not targeted by the policy.

This chapter aims to assess the effects of the lockdown policy through the application of an Extended Multisectoral model, highlighting the importance of the impact multipliers and Linkages, with the aim of identifying the productive activities with the greatest transfer effect to the economic system and the most important Institutional Sectors.

The Extended Multisectoral models represent an expansion of the Miyazawa model (Miyazawa, 1970), since final demand is completely endogenized⁵. Rather than concentrating only on consumption expenditures, also income transfers are taken into explicit consideration. This operation is performed through an extension of the model that

⁵ Only exports are considered as a component of exogenous demand.

comprehends the behaviours of the institutions that determine primary and secondary distribution of incomes. All the relations between income generation, primary income allocation, secondary income distribution and the related formation of final demand are modelled through a linear system. This type of model also considers fixed prices, which implies that policy simulations do not allow evaluating the inflationary effect. These assumptions will be relaxed in the following chapters.

The accounting identity that shows, for each “i” commodity⁶, the available output and its destinations is written as:

$$\mathbf{m} + \mathbf{q} \equiv \mathbf{r} + \mathbf{f} \quad (1)$$

where $\mathbf{m}(i \times I)$ is the imports vector, $\mathbf{q}(i \times I)$ the domestic total output vector, $\mathbf{r}(i \times I)$ the vector of domestic absorption of intermediate materials and $\mathbf{f}(i \times I)$ the final demand vector. Final demand is given by the sum of its domestic components i.e. final consumptions, public expenditures, investments and exports. According their role in the model, however, final demand components are either endogenous \mathbf{f}_E or exogenous \mathbf{f}_X

$$\mathbf{f} = \mathbf{f}_E + \mathbf{f}_X \quad (2)$$

Substituting eq. (2) into eq. (1) we get:

$$\mathbf{m} + \mathbf{q} \equiv \mathbf{r} + \mathbf{f}_E + \mathbf{f}_X \quad (3)$$

Total final output then results as the sum of intermediate endogenous and exogenous demands, which in the usual case consists of exports, minus imports:

$$\mathbf{q} = \mathbf{r} + \mathbf{f}_E + \mathbf{f}_X - \mathbf{m} \quad (4)$$

Considering an open economy characterized by “i” types of commodities and by “j” activities producing them vector \mathbf{r} of intermediate commodity consumptions can be written as:

$$\mathbf{r} = \mathbf{A} \mathbf{q} \quad (5)$$

⁶ The approach is the same also considering the economic system on the side of industries “j”.

Matrix of technical coefficients $\mathbf{A}(i \times i)$ is built as the product of matrix $\mathbf{B} = \mathbf{U} \hat{\mathbf{x}}^{-1}$, sometimes called the Use matrix, that provides the amount of use of the i^{th} commodity exhibited by the j^{th} industry with the Make, or supply, matrix $\mathbf{D} = \mathbf{V} \hat{\mathbf{q}}^{-1}$, that gives the shares of fabrication of commodity “ i ” provided by industry “ j ”.

Putting

$$\mathbf{f}_D = \mathbf{f}_E - \mathbf{m} \quad (6)$$

which gives net endogenous demand and substituting eq. (5) and (6) in eq. (4), we get:

$$\mathbf{q} = \mathbf{A} \mathbf{q} + \mathbf{f}_D + \mathbf{f}_X \quad (7)$$

In an economy characterized by s Institutional Sectors final demand represents the utilization of income and is tied to total output \mathbf{q} through disposable income \mathbf{y} of the same Institutional Sectors. Consequently, we need to design the entire process of distribution and redistribution of incomes. Starting from the vector of value added generated by each commodity \mathbf{v}_i we can write:

$$\mathbf{v}_i = \mathbf{L} \mathbf{q} \quad (8)$$

where $\mathbf{L}(i \times i)$ is a diagonal matrix whose diagonal element is determined as column sum of matrix $(\mathbf{I} - \mathbf{A})$. This allows for the determination of the vector of value added by commodity, $\mathbf{v}_i (i \times I)$. The vector of value added according the industry origin can be transformed into the vector of value added by destination, $\mathbf{v}_c (c \times I)$, i.e. by VA components, \mathbf{c} , through the use of matrix $\mathbf{W}(c \times i)$ from the IO table. We get:

$$\mathbf{v}_c = \mathbf{W} \mathbf{v}_i \quad (9)$$

where matrix $\mathbf{W}(c \times i)$ gives the share of value added generated in each commodity that has been attributed to each VA component. The generation and primary distribution of income concludes with the attribution of the VA categories to the Institutional Sectors, i.e those sectors that are entitled to decide on the destination of income. Value added components are then attributed the institutions owner. Compensation of employees,

capital incomes, taxes on activities and indirect taxation contribute to the formation of the vector of primary balances:

$$\mathbf{v}_s = \mathbf{P} \mathbf{v}_c \quad (10)$$

where matrix $\mathbf{P}(s \times c)$ is the matrix of the primary distributive shares of Value Added by Institutional Sector and $\mathbf{v}_c(s \times I)$.

The secondary distribution of incomes leads to the determination of the disposable incomes by institutions, $\mathbf{y}_s(s \times I)$, through the analysis of all interrelation among Institutional Sectors and refers to unilateral income transfers both voluntary or required.

$$\mathbf{y}_s = (\mathbf{I} + \mathbf{T}) \mathbf{v}_s \quad (11)$$

where $\mathbf{I}(s \times s)$ is a unit matrix and $\mathbf{T}(s \times s)$ the transfer income shares among Institutional Sectors by each institution. Substituting eq. (8) (9) and (10) in eq. (11) we get the disposable income vector of Institutional Sectors, $\mathbf{y}_s(s \times I)$ expressed as a function of the total output vector:

$$\mathbf{y}_s = [(\mathbf{I} + \mathbf{T}) \mathbf{P} \mathbf{W} \mathbf{L}] \mathbf{q} \quad (12)$$

Matrix $\mathbf{C}(s \times s)$ is a diagonal matrix of the average consumption propensity of each Institutional Sector, so that matrix $(\mathbf{I} - \mathbf{C})$ represents the savings propensity of the Institutional Sectors. Matrix $\mathbf{S}(s \times s)$ represents the active saving, the ratio between savings of Institutional Sectors, with exclusion of the rest of the world, and investment expenditures of Institutional Sectors as they emerge from the Social Accounting Matrix. Matrix $\mathbf{M}(s \times s)$ is a diagonal matrix of the average import propensity, equal for each Institutional Sector; it is obtained through the ratio between total imports and the total disposable income of Institutional Sectors.

We define matrix $\mathbf{G}(i \times s)$ as the product of matrices \mathbf{F} and \mathbf{C} plus the matrix obtained as $\mathbf{K} \mathbf{S}(\mathbf{I} - \mathbf{C})$ less matrix \mathbf{ZM} . The matrix $\mathbf{F}(i \times s)$ gives the shares of final consumption by commodity with respect to the total consumption expenditure of Institutional Sectors;

matrix $\mathbf{K}(i \times s)$ transforms investment by Institutional Sectors into investment by commodity; finally, matrix $\mathbf{Z}(i \times s)$ represents the shares of imports by commodity

$$\mathbf{G} = \mathbf{F} \mathbf{C} + \mathbf{K} \mathbf{S} (\mathbf{I} - \mathbf{C}) - \mathbf{Z} \mathbf{M} \quad (13)$$

Endogenous final demand can be then determined as:

$$\mathbf{f}_D = \mathbf{G} [(\mathbf{I} + \mathbf{T}) \mathbf{P} \mathbf{W} \mathbf{L}] \mathbf{q} \quad (14)$$

Substituting eq. 14 in eq. 7 we get:

$$\mathbf{q} = \mathbf{A} \mathbf{q} + \mathbf{G} [(\mathbf{I} + \mathbf{T}) \mathbf{P} \mathbf{W} \mathbf{L}] \mathbf{q} + \mathbf{f}_X \quad (15)$$

Putting $\mathbf{E} = \mathbf{G} [(\mathbf{I} + \mathbf{T}) \mathbf{P} \mathbf{W} \mathbf{L}] \mathbf{q}$ gives:

$$\mathbf{q} = \mathbf{A} \mathbf{q} + \mathbf{E} \mathbf{q} + \mathbf{f}_X \quad (16)$$

The resulting reduced form of the extended I-O, which includes the income distribution process and final demand formation will be given by:

$$\mathbf{q} = [\mathbf{I} - \mathbf{A} - \mathbf{E}]^{-1} \mathbf{f}_X \quad (17)$$

or alternatively

$$\mathbf{q} = \mathbf{R} \mathbf{f}_X$$

where total-output vector \mathbf{q} represents the expected results to be attained. Of course, results for all the other variables can be determined using the convenient set of matrices. In the case of expected results on value-added we can easily substitute eq. (17) in eq. (8) and get:

$$\mathbf{R}_{VA} = \mathbf{L} \mathbf{q} = \mathbf{L} \mathbf{R} \mathbf{f}_X \quad (18)$$

Through the \mathbf{R} matrix it is therefore possible to calculate the impact multipliers considering the column or row sum; the \mathbf{R} matrix is a square matrix commodity by commodity with size $(i \times i)$, and therefore a transformation of the second subscript is necessary in order to differentiate row totals from column totals; for this reason it is assumed that:

$$\mathbf{R}(i \times i) = \mathbf{R}(i \times k) \quad \text{with} \quad k = i$$

The impact multipliers are therefore obtained as follows:

$$O_k = \sum_{i=1}^n r_{ik} \quad (19)$$

where, for example, the multipliers O_1 corresponds to the effect on total production as a result of a unitary increase in exogenous final demand of the production activity 1; on the contrary:

$$O_i = \sum_{k=1}^n r_{ik} \quad (20)$$

detects the increase in output of product 1 necessary to meet an increase in exogenous final demand for all products. Through a standardisation process on the average of impact multipliers it is also possible to construct two types of indexes, Backward and Forward, which respectively highlight the products that register a greater increase in output and input, with respect to the others⁷, following a unitary increase in demand for a product.

Indicating with:

$$\mu_k = \frac{\sum_{i=1}^n r_{ik}}{n}$$

$$\mu_i = \frac{\sum_{k=1}^n r_{ik}}{n}$$

$$\mu = \frac{\sum_{i=1}^n \sum_{k=1}^n r_{ik}}{N}$$

Backward and Forward linkages are calculated as:

$$\text{Back}_k = \frac{\mu_k}{\mu} \quad (21)$$

⁷ When an Backward or Forward linkage for commodity “i” assumes a value greater than 1, it means that the increase in output of the “i” commodity is greater than all the others, and vice versa when it assumes a value less than 1.

$$\text{For}_i = \frac{\mu_i}{\mu} \quad (22)$$

Since these indices are based on the average, it is necessary to calculate a dispersion index that allows to analyse the distribution of multipliers within the vector of each commodity. In this way, low variability corresponds to a homogeneous distribution of the multiplicative effect between all products, and vice versa. The index used is the coefficient of variation because, since it is a non-dimensional index, it allows comparing measurements of different sizes. The coefficient of variation for backwards and forward linkages are calculated as follows

$$\sigma_k = \frac{\sqrt{\frac{\sum_{i=1}^n (r_{ij} - \mu_k)^2}{n-1}}}{\mu_k} \quad (23)$$

$$\sigma_i = \frac{\sqrt{\frac{\sum_{k=1}^n (r_{ij} - \mu_i)^2}{n-1}}}{\mu_k} \quad (24)$$

4. Supply shock and the Extended Multisectoral Inoperability Model

The *Inoperability Input Output Model* (IIM) is used for evaluating the impacts that events of great magnitude, as pandemic, can create in the economic system, as in (Santos and Haimés, 2004; Leugh et al., 2007) where the authors evaluate the economic impact of a terrorist attack. IIM is based on the results of Input-Output Leontief model, as the *expected results* of the physiological performance of the interindustry interactions and the *actual results* of unexpected locks in the delivery-flows of intermediate interactions. As seen above, when analysing highly interconnected components in an input-output (I-O) framework, an important concept is that of the key sector describing the influence of a product or an industry on the expansion of the whole economic system

(Lahr and Dietzenbacher, 2001). Clearly this assumption becomes more relevant in a SAM context, where the concept of the key production sector is extended also to the Institutional Sectors. From this point of view, production interruptions in key sectors deriving from a large-scale exogenous event, such as natural disasters and pandemics, can generate amplified effects that the extended multisectoral model in its classical formulation is unable to capture. Consequently, through the application of the concept of inoperability to extended multisectoral models (EIIM) (Ciaschini et al, 2018) it is possible to carry out an analysis of the effects that a major exogenous event can have both on the production system and on the formation, distribution and redistribution of income. Under physiological conditions, the economy attains the expected results. In this case, where no interruptions in the deliveries are observed we can determine a matrix of the corresponding market shares well-matched with the given set of technical coefficients. The structure of intermediate deliveries of the output of each industry j^{th} to the i^{th} industry is represented by set of ratios $\left(\frac{q_j}{q_i}\right)$ for $i=1\dots,n$ and $j=1\dots,n$. Multiplying these ratios by the corresponding constant technical coefficient, a_{ij} , we obtain the market share, a_{ij}^* , of all industry-outputs with respect to the industry that produces commodity i , i.e.:

$$a_{ij}^* = a_{ij} \left(\frac{q_j}{q_i}\right)$$

The matrix of the market shares will be then given by:

$$A^* = \begin{bmatrix} a_{11} \left(\frac{q_1}{q_1}\right) & a_{12} \left(\frac{q_2}{q_1}\right) & \dots & a_{1n} \left(\frac{q_n}{q_1}\right) \\ \vdots & \vdots & \dots & \vdots \\ a_{n1} \left(\frac{q_1}{q_n}\right) & a_{n2} \left(\frac{q_2}{q_n}\right) & \dots & a_{nn} \left(\frac{q_n}{q_n}\right) \end{bmatrix} \quad (25)$$

In fact, since the technical coefficient is defined as the intermediate flow M_{ij} divided by the output of industry of destination:

$$a_{ij} = \frac{M_{ij}}{q_j}$$

It is possible to obtain:

$$\mathbf{A}^* = \begin{bmatrix} M_{11} \left(\frac{1}{q_1} \right) & M_{12} \left(\frac{1}{q_1} \right) & \dots & M_{1n} \left(\frac{1}{q_1} \right) \\ \vdots & \vdots & & \vdots \\ M_{n1} \left(\frac{1}{q_n} \right) & M_{n2} \left(\frac{1}{q_n} \right) & \dots & M_{nn} \left(\frac{1}{q_n} \right) \end{bmatrix} \quad (26)$$

where each element is the intermediate flow, M_{ij} , weighted according the output level of the industry of origin, which is indeed the definition of intermediate market share of commodity i .

Under exceptional events some industries or all the industries in the economy undergoes a loss in output that will prevent the expected deliveries to industries take place. Then, it is possible to write \mathbf{A}^* matrix (25) as a transformation of the technical coefficient matrix \mathbf{A} . Operator ‘ $\hat{\cdot}$ ’ (e.g. \hat{q}) gives an $(n \times n)$ diagonal matrix where the elements of vector q appear on the main diagonal and zeros are elsewhere. The logical link between matrix \mathbf{A}^* of the market shares and the Leontief coefficients matrix, \mathbf{A} , then, is as follows:

$$\mathbf{A}^* = \hat{q}^{-1} \mathbf{A} \hat{q} \quad (27)$$

Let’s denote with \tilde{q}_i the actual total output deliveries of industry i , after the lockdown, in a context where the capability of commodity i to comply with the demands of the industries is weakened. The difference between the expected value and the actual value will determine the inoperability of the i^{th} industry:

$$z_i = \frac{q_i - \tilde{q}_i}{q_i} \quad (28)$$

In matrix form:

$$\mathbf{z} = \hat{q}^{-1} [\mathbf{q} - \tilde{\mathbf{q}}] \quad (29)$$

On the other hand, the obstruction of final demand can be expressed by vector \mathbf{f}^* , whose elements are a function of the difference between the levels of expected demand and the levels actually attained by final demand in the inoperability situation. The economy can experience an unexpected reduction in demand following an interruption for various reasons as the result of diminished supply and or because of the persistent consumer concern on future events as well as safety apprehensions.

The normalized losses of exogenous final demand for each commodity are represented by scalars f_i^* , determined as the ratio between the expected final demand net of actual demand and expected total output. The contraction due to the catastrophic event, and the potential total output:

$$f_i^* = \frac{f_i - \tilde{f}_i}{q_i} \quad i = 1, \dots, n \quad (30)$$

or in matrix form:

$$\mathbf{f}^* = \hat{\mathbf{q}}^{-1}(\mathbf{f} - \tilde{\mathbf{f}}) \quad (31)$$

The inoperability model can be written as:

$$\mathbf{z} = \mathbf{A}^* \mathbf{z} + \mathbf{f}^* \quad (32)$$

The Inoperability Extended Multisectoral Model, IEMM, is designed on the basis of the demand-oriented IIM, integrating in the inoperability process endogenous demand and income transfers among institutions (Ciaschini et al., 2018). We design an \mathbf{E}^* matrix of the loop income distribution/final demand formation, similar to matrix E. This matrix however is obtained substituting diagonal matrix L, that determines the Value Added vector given total output, with matrix L^* whose diagonal elements are taken as column-sums of matrix \mathbf{A}^* of the market shares. Then, putting $\mathbf{E}^* = \mathbf{G} [(\mathbf{I} + \mathbf{T})\mathbf{P} \mathbf{W} L^*]$ and:

$$\mathbf{f}_X^* = \hat{\mathbf{q}}^{-1}(\mathbf{f}_X - \tilde{\mathbf{f}}_X) \quad (33)$$

the extended inoperability model becomes:

$$\mathbf{z} = \mathbf{A}^* \mathbf{z} + \mathbf{E}^* \mathbf{z} + \mathbf{f}_X^* \quad (34)$$

or in the reduced form:

$$\mathbf{z} = [\mathbf{I} - \mathbf{A}^* - \mathbf{E}^*]^{-1} \mathbf{f}_X^* \quad (35)$$

The effects on value added are determined through matrix \mathbf{L}^* :

$$\mathbf{v}_i^* = \mathbf{L}^* \mathbf{z} = \mathbf{L}^* [\mathbf{I} - \mathbf{A} - \mathbf{E}^*]^{-1} \mathbf{f}_X^* \quad (36)$$

where v_i^* is the value added inoperability as share of total output.

5. Key industries in EMM

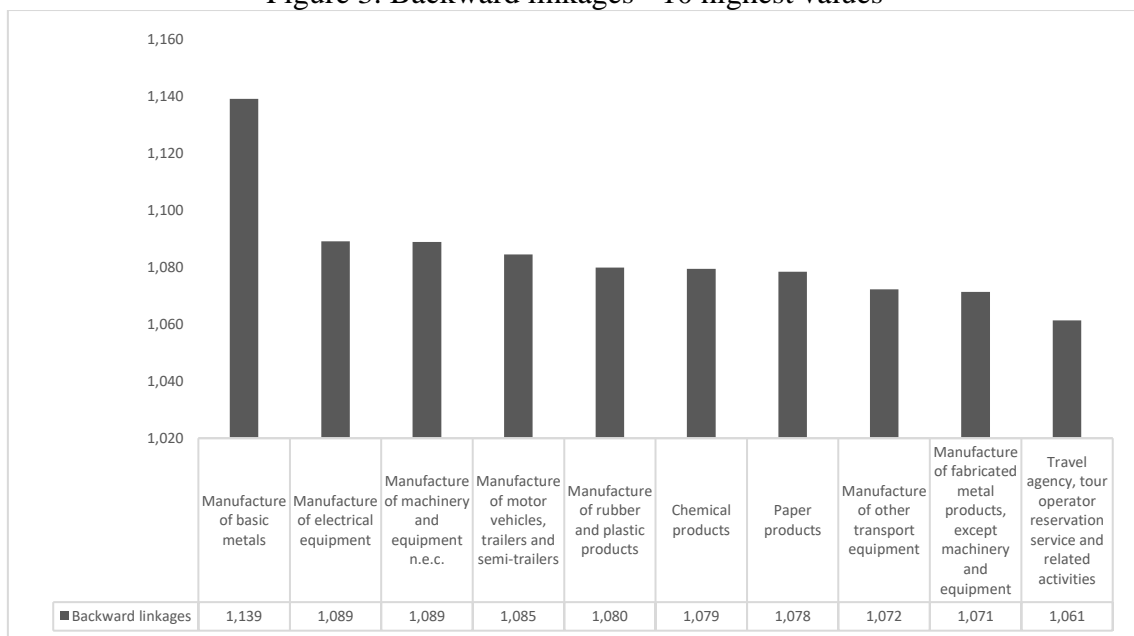
Table 1 shows the results of Backward and Forward linkages and the relative coefficients of variation calculated on the \mathbf{R} matrix for the Italian SAM. It is possible to observe that the best combination between the two indices, i.e. the maximum distance between the linkages and the coefficient of variation, is associated with the products "Air transportation" and "Water transportation", followed by the products "Repair and installation services of machinery and equipment" and "Travel agency, tour operator reservation service and related activities". Figure 3 shows the products with the greatest multiplicative effect, regardless of the level of variation.

Table 1. Backward and Forward linkages

Commodity	Backward	σ	Forward	σ
Agriculture, hunting and related service activities	0.980	1.753	1.815	0.743
Forestry and logging	0.897	1.642	0.250	5.000
Fishing and aquaculture	0.938	1.520	0.240	4.793
Mining and quarrying	0.892	1.591	0.643	1.864
Food products, beverages and tobacco products	1.040	1.999	3.986	0.383
Textile products, wearing apparel and leather products	1.024	1.942	1.694	0.995
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	1.048	1.625	0.472	3.209
Paper products	1.078	1.569	0.607	2.456
Printing and reproduction of recorded media	1.039	1.398	0.410	2.907
Coke and refined petroleum products	0.924	1.706	1.437	0.871
Chemical products	1.079	1.674	0.945	1.724
Basic pharmaceutical products and pharmaceutical preparations	1.010	1.568	0.730	1.816
Manufacture of rubber and plastic products	1.080	1.461	0.692	1.878
Manufacture of other non-metallic mineral products	1.049	1.485	0.586	2.245
Manufacture of basic metals	1.139	1.658	0.358	4.993
Manufacture of fabricated metal products, except machinery and equipment	1.071	1.606	1.255	1.193
Manufacture of computer, electronic and optical products	1.007	1.490	0.655	1.906
Manufacture of electrical equipment	1.089	1.477	0.485	2.876
Manufacture of machinery and equipment n.e.c.	1.089	1.475	0.714	1.886
Manufacture of motor vehicles, trailers and semi-trailers	1.085	1.475	0.735	1.855
Manufacture of other transport equipment	1.072	1.416	0.358	3.634
Manufacture of furniture, other manufacturing	1.032	1.548	1.071	1.225
Repair and installation services of machinery and equipment	1.050	1.371	0.677	1.684
Electricity, gas, steam and air conditioning supply	1.056	1.804	1.584	1.014

Water supply, sewerage, waste management and remediation activities	0.985	1.422	0.310	3.665
Sewerage, waste collection, treatment and disposal activities, materials recovery, remediation activities and other waste management services	1.003	1.590	0.923	1.448
Construction	1.036	1.882	3.744	0.380
Wholesale and retail trade services, repair of vehicles and motorcycles	1.015	1.410	0.619	1.832
Wholesale trade, except of motor vehicles and motorcycles	1.004	1.461	0.608	1.950
Retail trade, except of motor vehicles and motorcycles	0.967	1.465	0.143	7.937
Land transport and transport via pipelines	1.035	1.570	1.047	1.256
Water transport	1.049	1.346	0.200	5.675
Air transport	1.059	1.321	0.225	5.038
Warehousing and support activities for transportation	1.014	1.661	1.133	1.238
Postal and courier activities	1.017	1.437	0.259	4.500
Accommodation and food service activities	0.980	1.729	2.594	0.441
Publishing activities	1.009	1.427	0.446	2.634
Motion picture, video and television programme production, sound recording and music publishing activities, programming and broadcasting	1.021	1.516	0.431	3.044
Telecommunications	0.983	1.671	0.821	1.678
Computer programming, consultancy and related activities, information service activities	0.987	1.642	1.251	1.034
Financial service activities, except insurance and pension funding	0.925	1.701	1.518	0.804
Insurance, reinsurance and pension funding, except compulsory social security	0.956	1.605	0.747	1.612
Activities auxiliary to financial services and insurance activities	0.968	1.557	0.757	1.649
Real estate activities	0.887	1.995	4.663	0.239
Legal and accounting activities, activities of head offices, management consultancy activities	0.933	1.704	1.822	0.665
Architectural and engineering activities, technical testing and analysis	1.009	1.489	0.865	1.356
Scientific research and development	0.989	1.467	0.794	1.441
Advertising and market research	1.037	1.392	0.509	2.274
Other professional, scientific and technical activities, veterinary activities	0.969	1.486	0.530	2.173
Rental and leasing activities	1.008	1.440	0.679	1.734
Employment activities	0.907	1.563	0.302	3.745
Travel agency, tour operator reservation service and related activities	1.061	1.394	0.401	2.978
Security and investigation activities, services to buildings and landscape activities, office administrative, office support and other business support activities	0.995	1.540	1.299	0.908
Public administration and defence, compulsory social security	0.910	1.748	2.650	0.422
Education	0.862	1.749	1.682	0.664
Human health activities	0.948	1.773	2.884	0.416
Social work activities	0.963	1.553	0.595	2.014
Creative, arts and entertainment activities, libraries, archives, museums and other cultural activities, gambling and betting activities	0.960	1.690	0.929	1.437
Arts, entertainment and recreation	0.994	1.544	0.464	2.768
Activities of membership organisations	1.016	1.392	0.256	4.424
Repair of computers and personal and household goods	0.968	1.429	0.232	4.874
Other personal service activities	0.923	1.575	0.774	1.469
Activities of households as employers, undifferentiated goods- and services-producing activities of households for own use	0.880	1.647	0.494	2.311

Figure 3. Backward linkages - 10 highest values



It should be noted that the greatest multiplier effect is associated with the commodities "Manufacture of basic metals" and "Manufacture of electrical equipment". To these

sectors are associated a higher level of the coefficient of variation, and this indicates, as mentioned above, that the multiplication effect of these commodities on all the others is not equally distributed. Therefore these are more related to some commodities than to others. Observing the composition of the impact multiplier vector associated with the "Manufacture of electrical equipment" product, it is possible to note that the distribution is not homogeneous, but the product is strongly connected with the "Real estate activities" (c44), "Food products, beverages and tobacco products" product. (c5) and "Construction" (c27).

Figure 4. Multiplier impact of "Manufacture of basic metals"

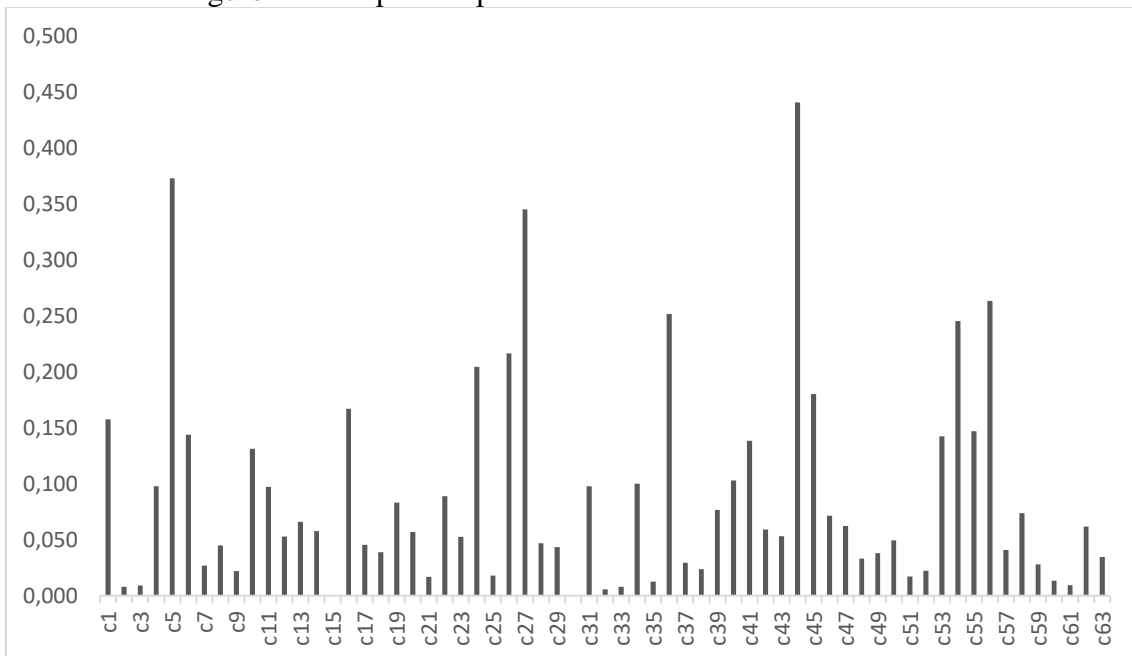
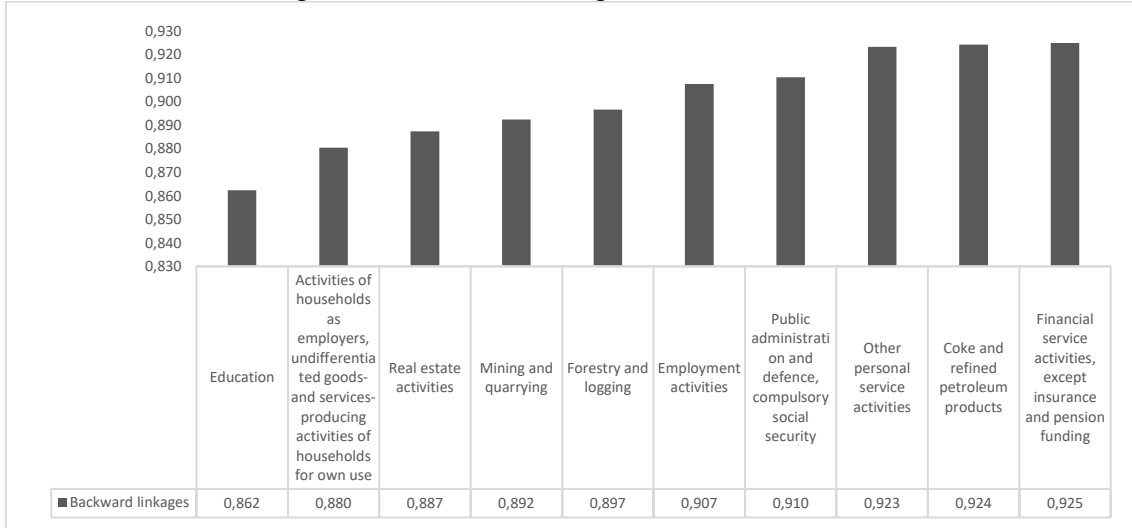


Figure 5 shows the commodities with the lowest multiplicative impact, particularly associated with the commodity "Education" e "Activities of households as employers, undifferentiated goods- and services-producing activities of households for own use".

As regards to the Forward linkages, observing the Table 1, it is possible to note that the commodities with the greatest multiplicative effect and at the same time with less

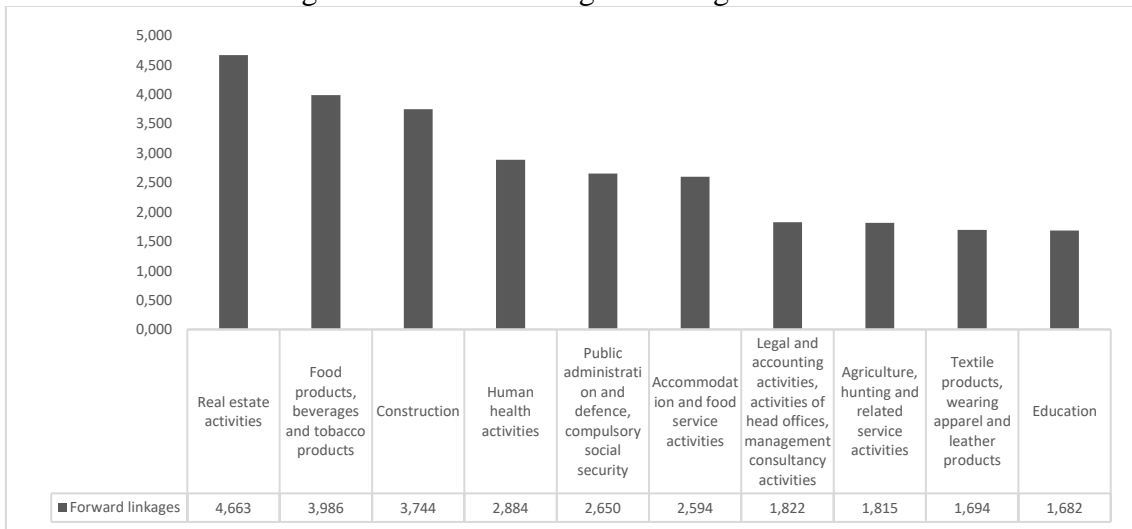
variability are "Real estate activities" and "Food products, beverages and tobacco products".

Figure 5. Backward linkages - 10 lowest values



Looking at Figure 6, these commodities, unlike what observed for Backward linkages, really have the greatest multiplicative effect compared to the others, and this implies that this type of product plays an important role as a supplier sector of the economic system.

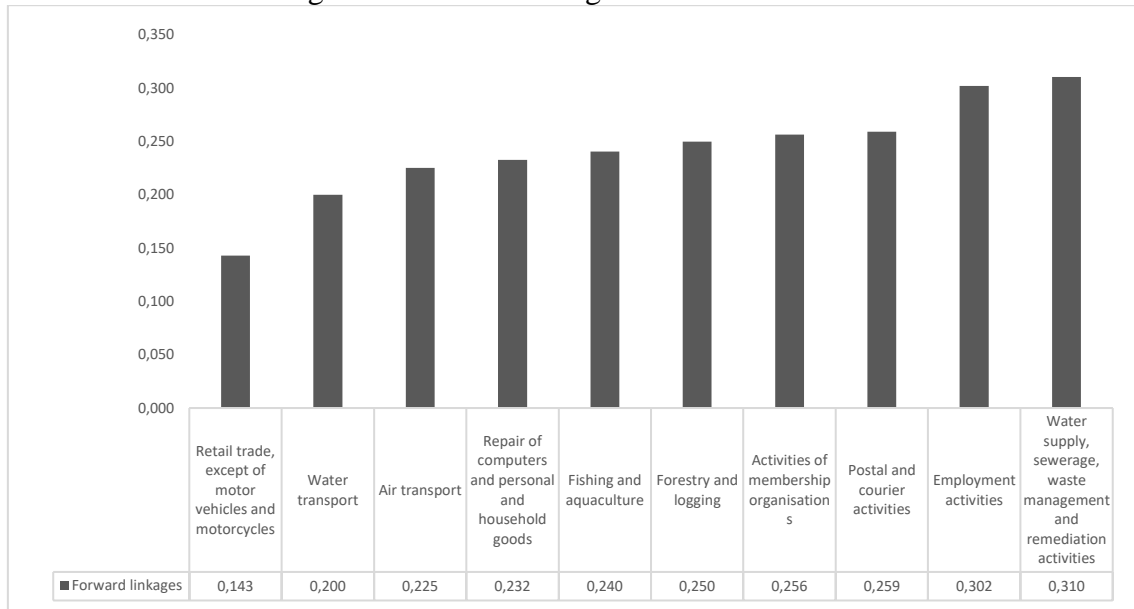
Figure 6. Forward linkages - 10 highest values



Finally, in Figure 7 it is possible to observe the commodities with the lowest multiplicative impact in terms of forward linkages; in particular, there is a low

multiplication effect with regard to the commodities "Retail trade, except of motor vehicles and motorbikes" and "Water transport".

Figure 7. Forward linkages - 10 lowest values



6. Structural changes and optimal endogenous policy tools

As seen in the previous paragraphs, through the multipliers' analysis it is possible to obtain information on the increase in sectoral production resulting from unitary shock of a single commodity demand. However, the hypothesis of a unitary shock does not apply in economic reality (Ciaschini, 1988a), but on the contrary, the increase or decrease in demand for commodities is due to a structure that is not necessarily uniformly distributed (Socci, 2004). Therefore, it is necessary to search for the optimal structure that generates the maximum multiplicative effect; this structure can be reconstructed by using the Single Value Decomposition applied to the matrix of multipliers. This methodology is based on the decomposition of the matrix of multipliers into 3 matrices made up respectively of the left eigenvectors, the singular values and the right eigenvectors:

$$\mathbf{R} = \mathbf{U} \mathbf{S} \mathbf{V}' \quad (37)$$

where $\mathbf{U}(i \times k)$ is the left eigenvector matrix, $\mathbf{S}(i \times k)$ is a diagonal matrix of singular values⁸, sorted in descending order, named macro multipliers, and $\mathbf{V}'(k \times i)$ is the right eigenvectors matrix. The decreasing structure of the singular value matrix indicates the decreasing effect of the incoming structures dictated by the incoming (right eigenvectors) and outgoing (left eigenvectors). Therefore, the structure associated with the first vector of the right eigenvector matrix has the greatest multiplicative effect and returns the output structure dictated by the first vector of the left eigenvector matrix:

$$\mathbf{R}_1 = \mathbf{u}_1 \mathbf{s}_1 \mathbf{v}_1 \quad (38)$$

Consequently, vector \mathbf{v}_1 can be considered as the multiplier optimal structure. The \mathbf{R}_1 matrix represents the matrix of multipliers associated with an exogenous final demand shock with \mathbf{v}_1 structure. It is clear that the sum of the single matrices calculated through the incoming singular vector corresponds to the R matrix, that is to say

$$\mathbf{R} = \sum_i \mathbf{R}_i \quad (39)$$

Applying the breakdown to the R matrices calculated on the Italian SAMs of 2009, 2011 and 2016⁹, it is possible to obtain the multiplicative effect of the individual \mathbf{R}_i matrices (see Table 2). From the table, it can be seen that the effect is reduced in the transition from SAM 2009 to SAM 2016; it is also evident how the first singular value, associated with the first incoming and the first outgoing car, captures almost the totality of the general multiplicative effect, making the multiplicative structures of the other vectors negligible.

⁸ Singular values are calculate as the square root of eigenvalues, $s_i = \sqrt{\lambda_i}$

⁹ SAMs for year 2009 and 2011 have been built by the research staff of Prof. Claudio Soggi

Table 2. Singular Value Decomposition on R matrix and multiplier effects

	2009	2011	2016
R	581.32	520.12	410.68
R ₁	579.60	515.89	408.11
R ₂	-0.13	2.06	-0.07
R ₃	-0.05	0.00	-0.02
R ₄	0.01	0.32	0.01
R ₅	0.01	0.02	0.17
R ₆	0.02	0.00	0.12
R ₇	-0.01	0.04	0.00
R ₈	0.12	0.00	0.00
R ₉	0.01	0.07	-0.02
R ₁₀	0.03	-0.04	0.00
R ₁₁	-0.01	0.00	0.00
R ₁₂	-0.04	0.02	0.00
R ₁₃	0.00	0.00	0.23
R ₁₄	-0.01	0.42	0.00
R ₁₅	0.00	-0.01	0.00
R ₁₆	0.00	-0.01	-0.01
R ₁₇	-0.04	0.00	0.00
R ₁₈	0.01	-0.02	0.06
R ₁₉	0.01	-0.01	0.00
R ₂₀	0.02	-0.01	0.00
R ₂₁	0.01	0.00	-0.01
R ₂₂	0.03	0.00	0.02
R ₂₃	0.00	0.00	-0.02
R ₂₄	0.03	0.01	0.02
R ₂₅	0.00	0.00	-0.01
R ₂₆	-0.01	0.00	0.00
R ₂₇	0.00	0.00	-0.01
R ₂₈	0.02	0.00	0.01
R ₂₉	0.00	0.00	0.01
R ₃₀	0.00	0.00	-0.01
R ₃₁	0.00	0.00	0.01
R ₃₂	0.01	0.00	0.00
R ₃₃	0.00	0.00	0.00
R ₃₄	0.00	0.00	0.00
R ₃₅	0.00	0.00	-0.01
R ₃₆	0.08	0.00	0.00
R ₃₇	0.00	0.00	0.00
R ₃₈	0.00	0.01	0.00
R ₃₉	0.02	0.01	0.00
R ₄₀	0.01	0.00	0.00
R ₄₁	0.00	-0.01	0.00
R ₄₂	0.00	0.00	0.00
R ₄₃	0.00	0.00	0.00
R ₄₄	0.00	0.00	0.00
R ₄₅	0.00	0.00	0.00
R ₄₆	0.00	0.01	0.01
R ₄₇	0.01	0.00	0.00
R ₄₈	0.00	0.00	0.00
R ₄₉	0.00	0.00	0.00
R ₅₀	0.00	0.04	0.01
R ₅₁	0.04	-0.01	0.00
R ₅₂	0.05	0.00	0.02
R ₅₃	0.01	0.01	0.00
R ₅₄	0.00	0.04	0.01
R ₅₅	-0.01	0.00	0.00
R ₅₆	0.01	0.06	0.01
R ₅₇	-0.02	-0.01	0.00
R ₅₈	0.01	0.00	-0.01
R ₅₉	0.02	0.02	0.00
R ₆₀	0.00	0.26	0.00
R ₆₁	0.03	0.34	0.00
R ₆₂	0.80	0.93	0.40
R ₆₃	0.62	-0.36	1.62

7. Supply side shock and Covid-19

With the Prime Minister's Decree DPCM 22th march 2020, regarding "Urgent measures for containment of infection by coronavirus on the whole national territory", Government has determined the lockdown of all "non-essential" activities, listed in the attachment 1 of the same DPCM, further modified with the decree of the Ministry of economic development 25th march 2020.

With the decree, the shutdown of 57% of industrial activities has been decided. The remaining 43% of industries has continued to produce, albeit with less intensity with respect to the pre-COVID period, given the final demand fall, difficulties in logistics and the partial lock in the main foreign partners with some exceptions as for the pharmaceutical and food industries¹⁰. A policy action, then, of relevant magnitude actually limiting the supply side. Since the measure is tied to the containment of the contagion, the date of reopening the activities is not unique, but established from time to time, for the various industries, according the evolution of the pandemic.

The shutdown of "non-essential" activities results in an actual reduction of yearly total output of around three months' loss of actual total output on yearly basis. In addition, for transport sectors, Hotels, catering services and entertainment activities, the lockdown is extended to five months. This reveals as an output contraction of 14%.

The problem is then that of establishing the impact that the shutdown will generate directly and indirectly on the value added generation, on disposable income formation of institutions, and on the utilization of disposable income.

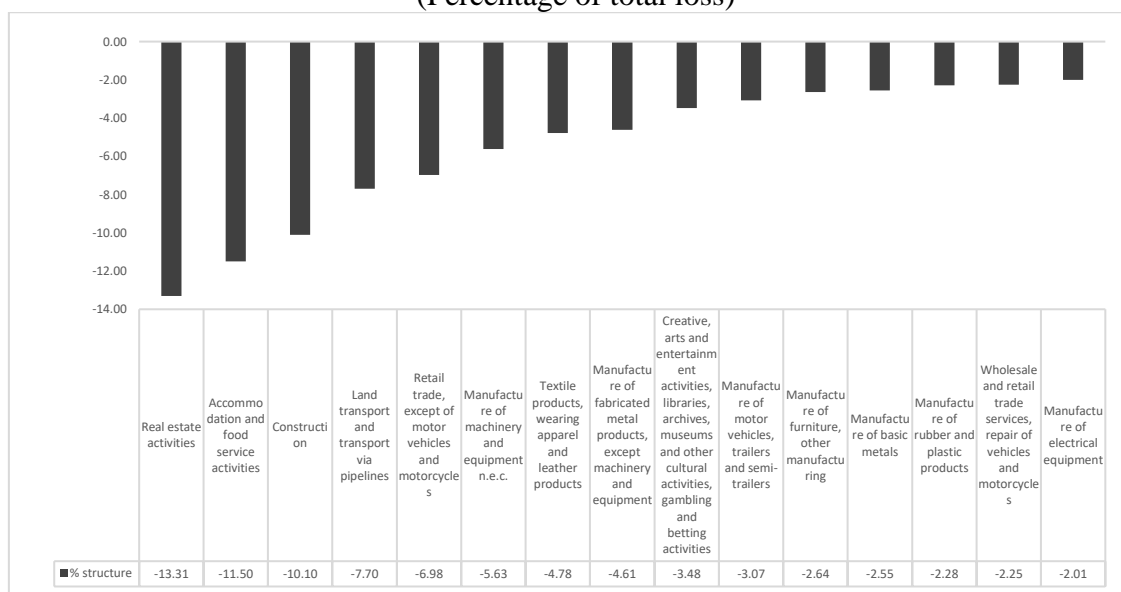
In the simulation have been deliberately neglected the measure by Government to households support, as suspension of tax payments, financial supports, deferring tax

¹⁰ Il Sole 24 ore - <https://www.ilsole24ore.com/art/csc-l-effetto-covid-19-affonda-produzione-marzo-166-e-primo-trimestre-54--ADQU7gH>.

debts; actions that act as economic impact dampener to the output lockout through supporting aggregate final demand and triggering a redistribution process.

Figure 8 shows how the total output drop due to the shutdown policy results spread among commodity outputs.

Figure 8. Distribution of total output drop by commodities (Percentage of total loss)



The greatest contraction concentrates on *Real estate activities* and *Accommodation and food service activities*, followed by *Construction* and *Land transport and transport via pipelines*. *Real estate activities* and *Accommodation and food service activities* represent respectively 15.38% and 7.21% of total production, while *Construction* and *Land transport and transport via pipelines* represent respectively 10.85% and 0.45%. Therefore, the four industries represent 33.89% of total production, i.e. more than a third. Looking at the graph, 24.81% of the decrease in production is due to the drop in the *Real estate activities* and *Accommodation and food service activities* sector and the 17.80% is due to the drop in the *Construction* and *Land transport and transport via pipelines*, indicating that the 42.61% of the drop in production is due to these 4 sectors.

The total output contraction associated with the restriction measures preventing the COVID-19 spread, which impose the compulsory inactivity of a major part of the work

force, has a direct impact on factors' demand by firms, causing a contraction in labour demand and a fall in investments.

As reported by the International Labour Organization (ILO) the policy affects immediately the quantity of labour, with a growth of unemployment and this implies a diminution of incomes of employees. In practice, these phenomena are damped by the operation of social safety nets and the extraordinary public policy measures planned. Since the aim of the research is that of isolating the actual economic damage of pandemic, the model operates without corrections.

In fact, concentrating on the impact that the health restrictions have at the level of disaggregated value added generation, in Table 1 is visible how the output contraction concentrates mainly the gross operating income and on employees incomes, as well as the drop in the government revenue.

Table 3. Impact on Value Added by components
(Percent change w.r.t. the benchmark)

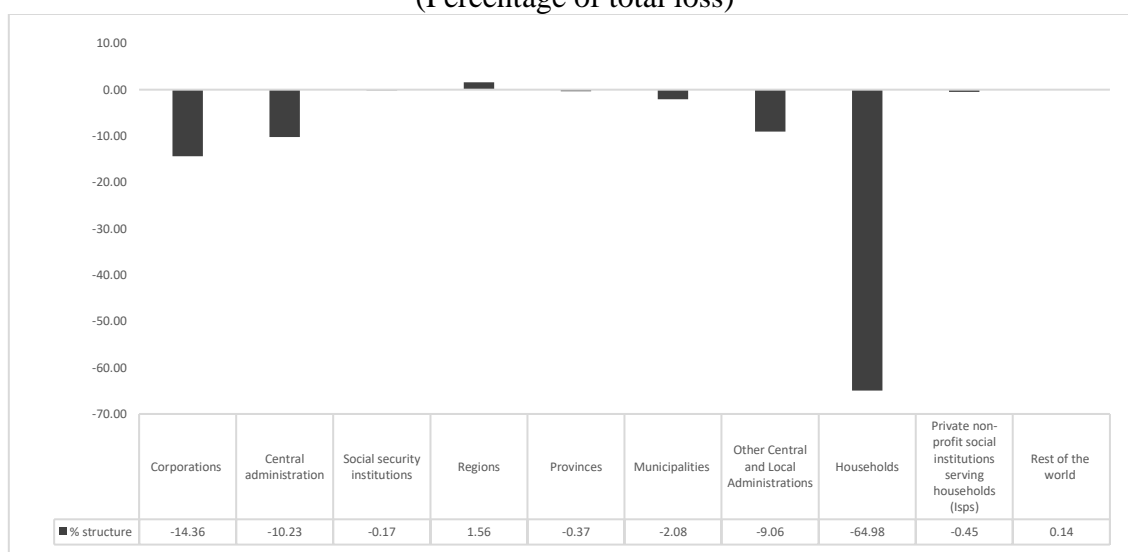
VALUE ADDED COMPONENTS	%
Compensation of employees	-11.7
Employer's Social Contributions	-10.8
Taxes on Output	-16.0
Gross Operating Surplus	-15.6
Indirect Taxes	-10.5
Value Added Change	-13.4

The selective shutdown of activities implies an aggregate contraction of employment income of 11.7%. Such a contraction can constitute the economic justification to the extension of the temporary lay-off scheme for employees by social security institutions to employees suspended by the work obligation, or with a reduced obligation. On the other hand, provisions concerning the contraction of capital remuneration should be utilized for activating the integration, at least partial, for the

remuneration of profit earners. In coherence with the reduction of total output, it is possible to observe the contraction of the tax revenue from taxes on activities, on outputs by the public Administration. Here are not considered provisions aimed to dampen the negative impacts on output and income given the aim to establish the economic impact of pandemic. With respect to disposable income of Institutional Sectors, given the value added reductions a reduction is also detected as reported in Table 3.

Total disposable income undergoes a decline of 13% consistent with the reduction of value added. A greater negative impact is registered in private Institutional Sectors, households and corporations, since they hold respectively 64.98% e 14.36% of disposable income. Such values as derived from the SAM, are displayed in Figure 9.

Figure 9. Impact on disposable income by Institutional Sector
(Percentage of total loss)



The figure shows the negative impact of the health measures on disposable incomes of institutions. These incomes, in fact, do not only undergo the direct contraction, but also the negative effects of the contraction in transfers both to private and public institutions. The reduction of employees-incomes and capital-incomes, leads to a contraction of the tax base of private operators that generates i) a decline of indirect taxes paid to the public

administration, ii) a decline of transfers paid to other Institutional Sectors (private and public).

Consequently, a contraction of disposable income of public Institutional Sectors together with the decline of indirect taxes on output and activities generates the decay of transfers towards the other Institutional Sectors (private and public). This mechanism of income redistribution justifies the decreasing effect of disposable incomes of public Institutional Sectors. No effects of possible sustaining policies that could be activated are considered.

Table 4. Impact on disposable income by Institutional Sector
(Percent change w.r.t. the benchmark)

INSTITUTIONAL SECTOR	%
Corporations	-15.6
Central administration	-11.9
Social security institutions	-15.6
Regions	-11.3
Provinces	-8.6
Municipalities	-17.7
Other Central and Local Administrations	-15.8
Households	-13.0
Private non-profit social institutions serving households (Isps)	-15.6
Rest of the world	-3.4

A main feature of the present pandemic crisis is that the shock has had an impact on the supply side, resulting from the forced interruption of on essential production activities and on the demand side, with the sudden interruption of the consumption capacity of the population. The consumption capacity undergoes the effect of the forced quarantine that limits heavily the consumption behaviours, on the other hand suffers the effect of the incomes reduction. To this outcome, the effect of diminished capacity on

investment should be added. The estimation of the effect on aggregate demand emerging from the diminishing disposable incomes of institutions is shown in Table 5.

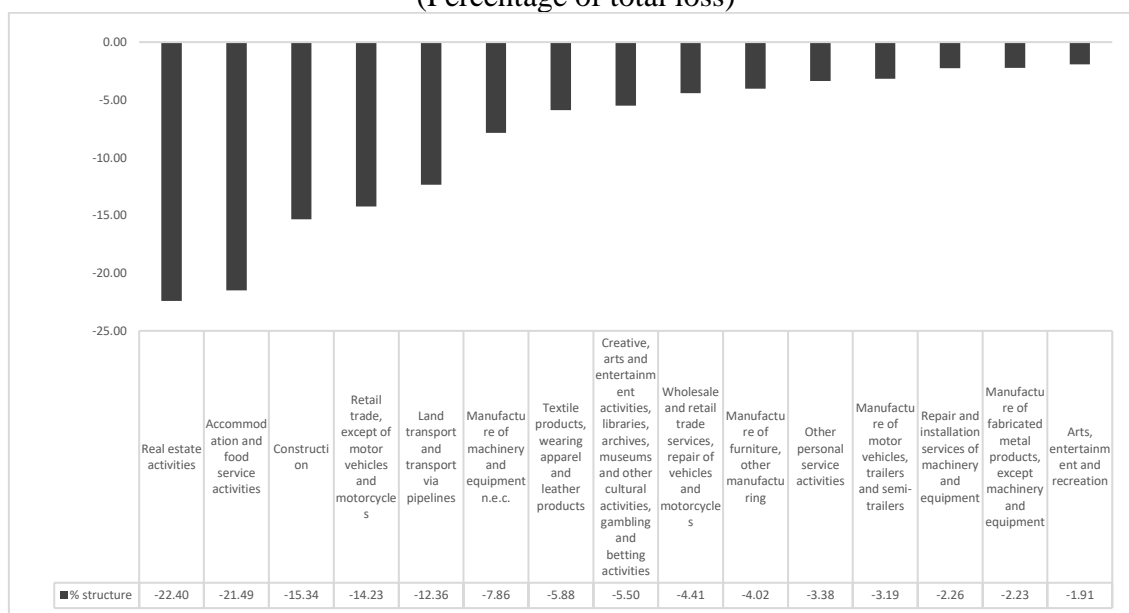
Table 5. Impact on aggregate demand
(Percent change w.r.t. the benchmark)

VARIABLES	Percent Change
GDP	-13.4
Households consumption	-14.5
Investment	-14.3
Public expenditure	-14.1
Exports	-6.7
Imports	-10.0

Households consumption represents about 61% of GDP, and as a result the 14.5% reduction compared to the benchmark identifies that the impact of the lockdown is mainly manifested in this aggregate, direct consequence of the reduction in households disposable income. Further effects of the reduction in disposable income are the saving reduction and the tax revenue reduction for the Public Administration; the first generate an important drop in investment, and the second the drop in public expenditure. Finally, there is a greater drop in exports than in imports, which identifies the loss of competitiveness of the national economic system.

In coherence with the production structure, Figure 10 shows how the greater contraction of demand is recorded in *Real estate activities* and *Accommodation and food service activities*. Moreover, the Figure evidences the decline of *Construction* and *Retail trade*.

Figure 10. Impact on aggregate demand by commodity
(Percentage of total loss)



8. Concluding remarks and policy implications

In this chapter the impact of the measure designed in the 22th march 2020 decree, regarding “Urgent measures for containment of infection by coronavirus on the whole national territory” is examined. It relates the shutdown of the production activities for specific economic sectors given the pandemic Covid-19. The specific policy problem appears somehow deceptive: public health policies, put in act following the health recommendations emerging from the present knowledge of Covid-19 pandemic, require compensating policies on the economic side, because of the damages due to the severe and extended harmful effects on economic activities. The quantification of the impact these policies can generate in the economy is a prerequisite for designing and activating regulatory mechanisms able to balance of their impact.

Through the extended multisectoral inoperability model results are obtained on the impacts on outputs, endogenous demands, value added and disposable incomes of Institutional Sectors. The pandemic effect determines a major block of production

processes in a selective way, progressively compromising the economic system as a whole through the direct, indirect and induced effects. The reduction of outputs implies, on at least the one-year time horizon, a recover only and exclusively in those activities in which output is storable and its maximum production capacity had not been reached at the beginning of the pandemic. The income distribution is affected in the first place by the coercive effect of the shutdown even if the indirect effect through the intermediate sphere and that of income is not negligible. It is necessary to stress that the inoperability model puts in evidence the non-neutrality of incomes distribution in contributing to the entire effect.

The policy measures to be implemented by Government in order to reduce the negative impact of the Covid-19 pandemic start from the consideration that the economic impact affects selectively some activities but not in the same way. Then, economic policy measures must consider this feature in order to protect the critical sectors safeguarding their supply. At the same time, they must protect employment, through the reduction of the tax wedge or through increased transfers from public administration to corporations. The wage-protection in fact has a positive outcome on aggregate demand, through the increase in consumption. Policy measures, applied to key sectors, generate a growth effect also in sectors not covered by the measures, due to cross-sectoral dependencies, through the same process by which the negative effect of the pandemic is transferred, as discussed in this paper. Of course, this does not imply that economic policy measures should not be applied to all production sectors, but it is important to apply measures of different magnitude, according to the production structure of the economic system.

Appendix 1: List of goods and activities in the Italian SAM

- 1 Agriculture, hunting and related service activities
- 2 Forestry and logging
- 3 Fishing and aquaculture
- 4 Mining and quarrying
- 5 Food products, beverages and tobacco products
- 6 Textile products, wearing apparel and leather products
- 7 Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
- 8 Paper products
- 9 Printing and reproduction of recorded media
- 10 Coke and refined petroleum products
- 11 Chemical products
- 12 Basic pharmaceutical products and pharmaceutical preparations
- 13 Manufacture of rubber and plastic products
- 14 Manufacture of other non-metallic mineral products
- 15 Manufacture of basic metals
- 16 Manufacture of fabricated metal products, except machinery and equipment
- 17 Manufacture of computer, electronic and optical products
- 18 Manufacture of electrical equipment
- 19 Manufacture of machinery and equipment n.e.c.
- 20 Manufacture of motor vehicles, trailers and semi-trailers
- 21 Manufacture of other transport equipment
- 22 Manufacture of furniture, other manufacturing
- 23 Repair and installation services of machinery and equipment
- 24 Electricity, gas, steam and air conditioning supply
- 25 Water supply, sewerage, waste management and remediation activities
- 26 Sewerage, waste collection, treatment and disposal activities, materials recovery, remediation activities and other waste management services
- 27 Construction
- 28 Wholesale and retail trade services, repair of vehicles and motorcycles
- 29 Wholesale trade, except of motor vehicles and motorcycles
- 30 Retail trade, except of motor vehicles and motorcycles
- 31 Land transport and transport via pipelines
- 32 Water transport
- 33 Air transport
- 34 Warehousing and support activities for transportation
- 35 Postal and courier activities
- 36 Accommodation and food service activities
- 37 Publishing activities
- 38 Motion picture, video and television programme production, sound recording and music publishing activities, programming and broadcasting
- 39 Telecommunications
- 40 Computer programming, consultancy and related activities, information service activities
- 41 Financial service activities, except insurance and pension funding
- 42 Insurance, reinsurance and pension funding, except compulsory social security
- 43 Activities auxiliary to financial services and insurance activities
- 44 Real estate activities
- 45 Legal and accounting activities, activities of head offices, management consultancy activities
- 46 Architectural and engineering activities, technical testing and analysis
- 47 Scientific research and development
- 48 Advertising and market research
- 49 Other professional, scientific and technical activities, veterinary activities
- 50 Rental and leasing activities
- 51 Employment activities
- 52 Travel agency, tour operator reservation service and related activities
- 53 Security and investigation activities, services to buildings and landscape activities, office administrative, office support and other business support activities
- 54 Public administration and defence, compulsory social security

- 55 Education
- 56 Human health activities
- 57 Social work activities
- 58 Creative, arts and entertainment activities, libraries, archives, museums and other cultural activities, gambling and betting activities
- 59 Arts, entertainment and recreation
- 60 Activities of membership organisations
- 61 Repair of computers and personal and household goods
- 62 Other personal service activities
- 63 Activities of households as employers, undifferentiated goods- and services-producing activities of households for own use

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Chapter 2

The Pandemic economic scenario at regional level: the Sardinia case study

1. Economic analysis and territorial dimension

The COVID-19 pandemic has led to the adoption of regulatory interventions aimed at restraining the contagion to preserve the public health and individual health care. The legislative interventions concerned restrictions on the individual freedom and the interruption of non-essential production processes. However, the imposition of the lockdown on the entire national territory has resulted in locally diversified blocks, whose consequences require a specific territorial analysis. In other words, potentially differentiated effects on regional economy are already identified in the definition phase of the blocked production processes. Despite the strong degree of integration between production and the use of local and national income, the negative effects can be strongly localized, especially in regions with a strong vocation for the production of unique goods and services. Blocking the goods and services production whose demand cannot be postponed implies a significant reduction in the output that will have an effect internally or externally localized, depending on the upstream production chain. In addition, limiting the freedom of movement for the production sectors themselves leads to a reduction in final demand inside and outside the region.

It is clear that in a regional economy, characterized by a productive structure driven by some key sectors, the lockdown generates a diversified impact, which can affect all productive sectors through the multiplier mechanism linked to sectoral interdependencies.

Recent studies show the use of a multiplicity of models that try to capture the economic effect of the pandemic. On the statistical side, the use of SIR models (Atkenson, 2020; Stock, 2020) through which the potential economic costs are estimated on the basis of different assumptions regarding the evolution of the virus. The SIR model was extended to macroeconomic aspects (Eichenbaum et al., 2020) by including the decline in consumption and in working hours in order to reduce the probability of being infected; this model therefore highlights the trade-off between containment policies and the economic crisis. Further elaborations relating to the economic analysis were carried out using cost-benefit models (Scherbina, 2020), in which pandemic containment policies are assessed through the analysis of the costs and benefits attributable to them. A further contribution has been proposed through the use of DSGE models (McKibbin and Fernando, 2020), which reproduce the general economic equilibrium with stochastic methodology, and therefore top-down, where the parameters of the model are usually estimated or chosen in such a way that the dynamics of the model similarly report macroeconomic benchmark data. However, the above models do not take into account sectoral interdependencies, with particular attention to training and income redistribution between Institutional Sectors.

From this point of view, in order to assess the consequences of the lockdown by type of commodities on the Sardinia Region, it is important to proceed with a special tool to describe the entire circular flow of income disaggregated for the various operators that characterize the sphere of production, distribution and use.

Analyzing the economic structure of the Sardinia Region in the pre-pandemic period, between 2017 and 2018 it is possible to observe an increase of GDP around 2.35%, while in the first part of 2019 there is an economic stagnation, with a deceleration

compared to the previous year. The increase in GDP is substantially supported by the increase in consumption, to which is added a growing prudence in investment activity.

The construction sector, together with the real estate services sector, is one of the key sectors of the regional economic system, and has continued to make a positive contribution to the production cycle, supported by both household demand for housing and increased investment in public works and private non-residential construction. In the services sector, on the other hand, there was a slowdown, with tourist activity showing a contraction linked to the national component of demand. Furthermore, the mining and oil sectors are key sectors for the regional production and they should not be overlooked. In particular, the mining sector production contributes to the 80% of regional exports. The decline on this sector drove the reduction in total exports in the first half of 2019 while, on the import side, the lower purchases of fossil fuels and oil products, which represent the 90% of purchases from abroad, contributed to reduce the total value of imports.

In general terms, the analysis of the economic impact of the COVID-19 in Sardinia, should take into consideration all the aspects related to the economic structure of the region and the transmission mechanisms of the shock along the entire process of formation and distribution of income. The computational general equilibrium model calibrated on a Social Accounting Matrix is certainly functional to this aim. This set of instruments allows proceeding with a selective grafting of the block on the supply side, to which is associated a contraction of the final demand also in spatial terms between inside and outside the Sardinia region.

The model provides a comprehensive macroeconomic framework for assessing the economic and social impact of policies with direct and indirect effects (Ciaschini et al., 2010); in particular, multisectoral analysis offers the possibility to identify the contribution of each activity to income generation and its distribution among the primary

factors. Moreover, it allows detecting how income is allocated to Institutional Sectors and therefore to final demanding (Severini et al., 2019). The effects of the pandemic shock indeed, spread inside and outside the regional territory and the SAM based CGE model allows highlighting how the formation of the income circular flow changes when the shock occurs. CGE models are widely used to analyze the effects of economic policy in the areas of trade, taxation, public spending, labor market, but also natural and man-made disasters, the environment and financial crises, etc. (Dixon and Jorgenson, 2013).

The subject of this chapter is therefore analyzing the impact of the production block differentiated by local production activity for the Sardinia Region to detect the different response of a region whose economic structure is mostly dependent on tourism activities and tourists' flows. The analysis highlights the strong impact of internal demand, mainly linked to traditional products, which is associated with a significant slowdown in final external demand from the rest of Italy and the Rest of the world.

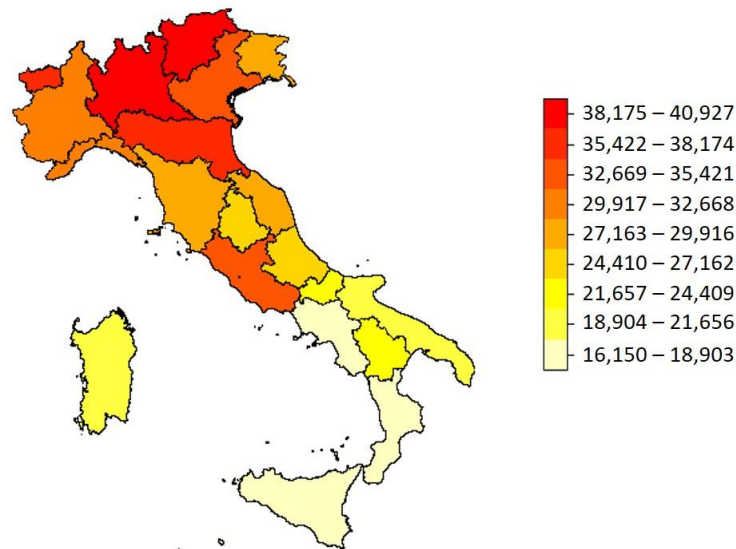
2. The Sardinian economy: A snapshot of the macroeconomic context

In 2018 the value of regional GDP in nominal terms amounts to 34.5 billion of Euro (Crenos, 2020), with growth of 2.4% compared to 2017; the result is higher than the average of the Regions of Southern Italy, which registered a growth of 1.3%, and also higher than the average of the Central-Northern Regions, which registered a growth of 1.8%. Although economic growth is positive, the gap in GDP per capita compared to other Italian regions continues to be wide, but according with the GDP per capita recorded in the Southern Regions, as shown in Figure 1, which shows the distribution of GDP per capita divided into 9 classes.

Figure 2 shows the deviation of the GDP per capita of each Region from the national average. It should be noted that the per capita GDP of Sardinia is among the

lowest in Italy, together with Puglia, Campania, Sicily and Calabria, which territorially represent the south of the country.

Figure 1. GDP per-capita in the Italian Regions
(in thousands of Euros)

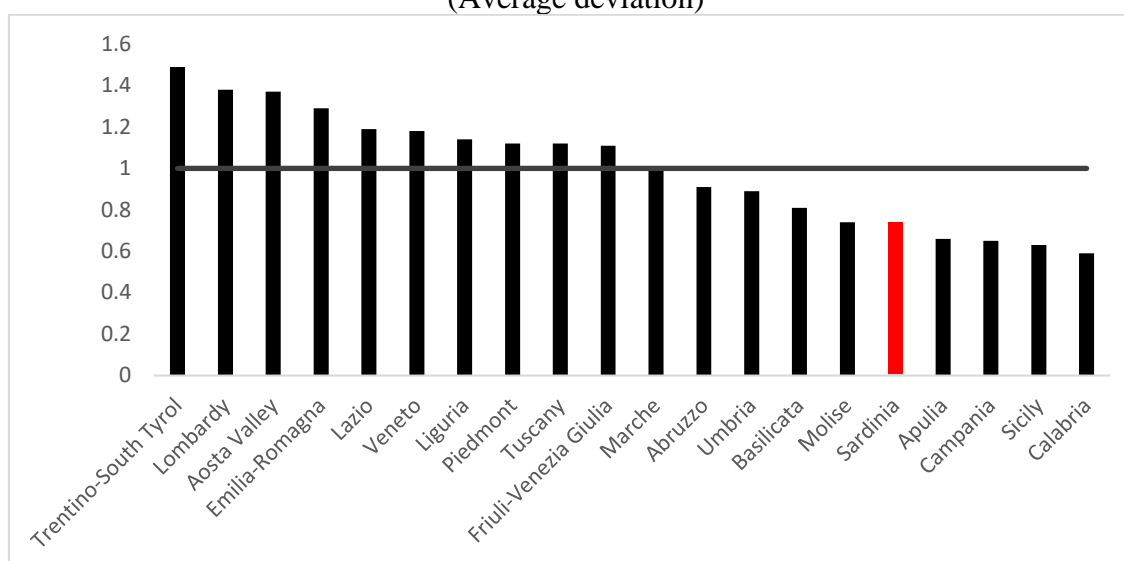


Source: ISTAT
Autohor elaboration

From this point of view, the economically weaker regions could be those most affected by the pandemic crisis, as the economies are unable to generate the resources needed to counter the economic impact. In particular, regions with a tourism-oriented production system clearly suffer from the negative effect; the World Tourism Organization has estimated that the sector could see a drop in the number of tourists in the year 2020 estimated at between 58% and 78% globally¹¹, due to restrictions on transport and therefore on travel for tourism purposes.

¹¹ <https://www.unwto.org/interational-tourism-and-codiv-19>

Figure 2. GDP per-capita in the Italian regions
(Average deviation)



Analyzing the productive structure of the regional economic system, it is evident that the housing and catering sector represents a significant component compared to the national data, together with the agriculture sector, as shown in Table 1¹²:

Table 1: Number of active enterprises by activity
(% values)

Activity	Sardinia	Italy	Deviation
Agriculture	23.9	14.2	9.7
Industry	7.4	9.8	-2.4
Constructions	13.8	14.3	-0.5
Trade	26	26.6	-0.6
Accommodation and catering	9.1	7.7	1.4
Other services	19.8	27.2	-7.4

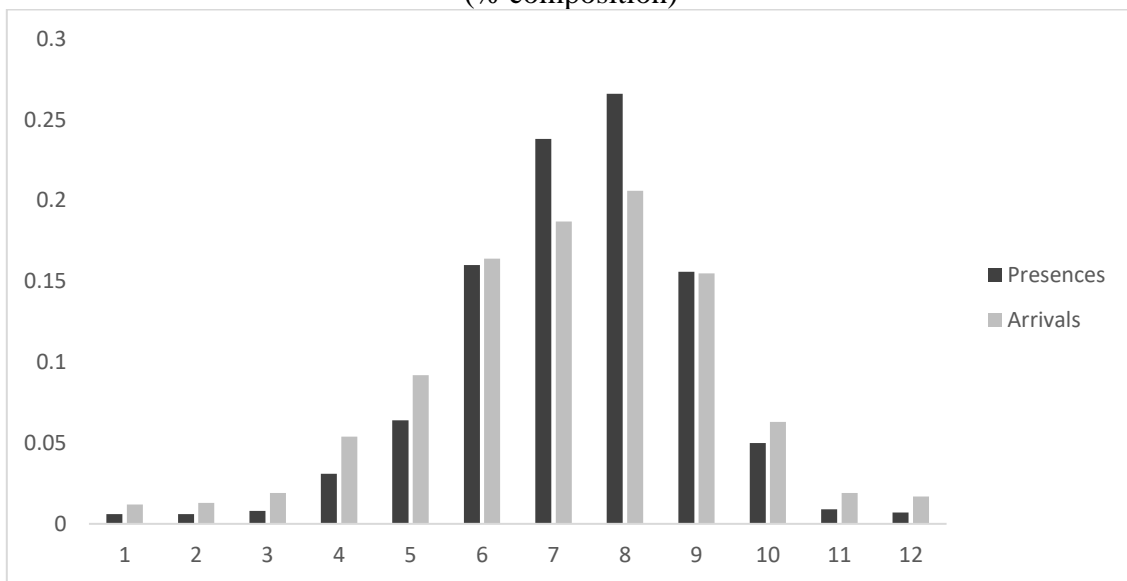
The differences compared to Italy show a productive structure based mainly on agriculture and the accommodation system. However, it should be underlined that the high value recorded by agricultural enterprises derives from their high presence in the

¹² Source: CRENOS – Centro Ricerche Nord – Sud Sardegna. The sectors sum may not correspond to the total due to the rounding

regional territory, but at the same time their size falls within the category of micro-enterprises; it is estimated that micro enterprises account for 96.4% of the total. On the contrary, industry and other services sectors¹³ tend to be lower than the national value.

Therefore, as far as the accommodation and catering sector that are largely linked to the tourism sector, is concerned, it is well known that tourism in Sardinia is based on a strong seasonal component, mostly linked to summer tourism, as shown in Figure 3:

Figure 3. Monthly presence and arrivals, year 2019
(% composition)



Source: Osservatorio del Turismo, Artigianato e Commercio – Sardegna Turismo¹⁴
Author elaboration

Since the Region of Sardinia is an island characterized by summer tourism, the increase in arrivals and presences on the regional territory begins to increase significantly from April, reaching its peak in August. In subsequent periods the phenomenon begins to decrease, remaining low throughout the winter period; this identifies that winter tourism does not have a significant impact on the economic system. Considering that the lockdown introduced to contrast the advancement of the Covid-19 pandemic took place

¹³ This item groups together all sectors of national accounting other than the sectors that belong to the previous categories.

¹⁴ <http://osservatorio.sardegnaturismo.it/>

right at the beginning of the tourist season, an analysis of the possible effects that this policy may have on the economic system becomes crucial, especially on the sector concerned and on the income distribution.

The composition and structure of the social accounting matrix (SAM) is particularly useful as a database for economic modelling. In particular, it is defined as a representation of all the transactions occurring among the different productive activities and the Institutional Sectors through the income formation, distribution and use in the economic system. Formally, it derives from the Input-Output table, completed through the representation of the entire circular income flow, from its formation to its distribution, redistribution and use. Its structure is based on sectoral interdependencies, with an important detail regarding the use of primary factors by activities, the taxes on goods and activities. The compensation to primary factors are allocated to the Institutional Sectors that collect them, generating the primary incomes. The secondary distribution occurs through income taxes and transfers among Institutional Sectors to determine the disposable income that is destined to consumption and savings. Each row of the SAM provides the input of an account, while the column indicates the output and the total of each row equals the corresponding column total, thus representing the economic equilibrium for each account and consequently the general economic equilibrium. Therefore, the SAM is the most suitable accounting scheme to represent the complex framework of links characterizing the economic system.

In the CGE model, the SAM represents the initial economic equilibrium, the benchmark, and therefore it is possible to use it as a calibration base of the model parameters, so that the economic equilibrium can be reconstructed through the resolution of simultaneous equations.

The SAM for the Sardinia Region is structured as shown in Figure 4.

Figure 4. Social accounting matrix for Sardinia Region

	Commodities (1, ..., i)	Activities (1, ..., j)	Primary Factors (L, K)	Taxes on Output	Taxes on Activity and Value Added	Private Institution al Sectors (1,...,h)	Government	Income Taxes	Investments	Rest of Italy	Rest of the world
Commodities (1, ..., i)		Intermediate Consumption				Private Final Consumptions	Government Final Consumption		Investments	Exports	Exports
Activities (1, ..., j)	Output										
Primary Factors (L, K)		Value added at factor cost								Primary Incomes	Primary Incomes
Taxes on Output	Indirect Taxes on Output										
Taxes on Activity and Value Added		Indirect Taxes on activities									
Private Institutional Sectors (1,...,h)			Primary Incomes			Transfers among Private Institutions	Public transfers to private institutions			Transfers from rest of Italy to private institution	Transfers from rest of the world to private institution
Government			Primary Incomes	Net Indirect Taxes on output	Net Indirect Taxes on activities	Private transfers to public institutions	Transfers among Public Institutions	Income Tax Revenues		Transfers from rest of Italy to public institution	Transfers from rest of the world to public institution
Income Taxes						Income Tax					
Saving						Private savings	Public savings			(+/-) Savings	(+/-) Savings
Rest of Italy	Imports		Primary Incomes			Private transfers to rest of Italy	Public transfers to rest of Italy				
Rest of the world	Imports		Primary Incomes			Private transfers to rest of the world	Public transfers to rest of the world				

The SAM structure records the flows between the different operators/accounts in the various phases of the circular income flow, indicating by line the sector inputs and by column the outputs. The index { 1 to i } indicates the 54 product types and the index { 1 to j } the 37 industries exploiting the production process ((complete list is available in Appendix 3). The value added is obtained through the combination of 2 production factors, capital (K) and labor (L). The index { 1 a h } indicates the 3 private Institutional Sectors, namely Households, non-profit Institutions and Corporations. Then there is also the public Institutional Sector (Government), the Rest of Italy and the Rest of the World. There are also 3 types of tax: taxes on output, activities and income. The primary income allocation a function determining how income from labour and capital contributes to the formation of the Institutional Sectors primary incomes. The secondary distribution of

income describes how transfers occurs among Institutional Sectors. The use of income is destined to consumption and savings. These balances the total amount of investment by commodity highlighting the circularity and complete the SAM flows.

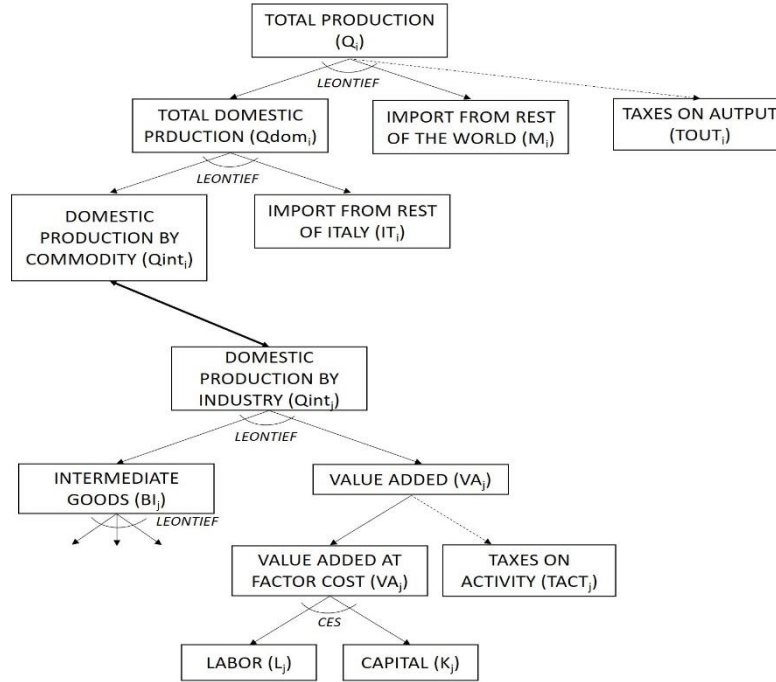
3. CGE model at regional level

The static CGE (Computable General Equilibrium) model is oriented to the analysis of the economic policy's impacts in the economic system (Scricciu, 2007). It is developed through the construction of a simultaneous non-linear system of equations, with the aim of studying the effects that exogenous shocks can have on resource allocation, efficiency and well-being, modifying prices and quantities of goods on the markets, as well as the formation and redistribution of income between Institutional Sectors. The construction and solution of a CGE model requires a process consisting of several steps (Shoven and Whalley, 1984), from the choice of the model to the equations functional forms, as well as the specification of parameters and variables, assuming a priori that the system is in equilibrium and the model solution is based on this equilibrium. Consequently, the model allows to compare an initial equilibrium situation (benchmark equilibrium) with a counterfactual equilibrium resulting from the application of new economic policy measures through the modification of the prices and quantities of each aggregate, with the possibility to provide information on the effects in nominal and real terms. In particular, the model follows the structure of the SAM by reconstructing the production structure and the behaviour of each Institutional Sector.

In this paragraph the structure of the model used is analyse, reporting the main equations. The complete list of the equations is reported in the appendix.

Total production is achieved through the multi-stage combination of inputs, through the structure according to Figure 5

Figure 5. Production function



As can be seen, the structure is based on functional forms defined as nested, which describe the production process in successive steps, in which the elasticity of substitution is considered in each stage. Every nesting level is the result of a CES function (Constant Elasticity Substitution)¹⁵ which combines the inputs generating the final output. In the first nesting stage, the total production formation and the generation of the relative prices is defined by type of product. Total production is obtained by combining domestic production with imports from the rest of the world, according to the Armington function (Armington 1969), based on imperfect substitutability between domestic and imported goods

$$P_i(1 - t_{out_i}) = \left(\delta_i^{dom} P_{dom,i}^{(1-\sigma_{Q_{dom}})} + (1 - \delta_i^{dom}) P m_i^{(1-\sigma_{Q_{dom}})} \right)^{\frac{1}{1-\sigma_{Q_{dom}}}} \quad (1)$$

¹⁵ The use of the CES function allows switching to Leontief or Cobb-Douglas production function by changing the value of the elasticities of substitution.

where P_i represents the price of goods by type of product, t_{out_i} are the taxes on output by goods, $P_{dom,i}$ are prices of domestic goods, Pm_i are prices of imports from the rest of the world, δ_i^{dom} represents the share of domestic goods in the total production by type of product and $\sigma_{Q_{dom}}$ represents the elasticity of substitution between domestic and imported goods.

In the second nesting stage it is generate the domestic production, obtained through the combination of internal production and imports from the rest of Italy

$$P_{dom,i} = \left(\delta_i^{int} P_{int,i}^{(1-\sigma_{Q_{int}})} + (1 - \delta_i^{int}) Pit_i^{(1-\sigma_{Q_{int}})} \right)^{\frac{1}{1-\sigma_{Q_{int}}}} \quad (2)$$

where $P_{int,i}$ represents prices of internal goods, Pit_i are prices of imports from the rest of Italy, δ_i^{int} represents the share of internal production on total domestic production and $\sigma_{Q_{int}}$ represents the elasticity of substitution between internal production and imports from Rest of Italy.

With regard to domestic production, generated in the third nesting stage, it is necessary to consider the relationship between goods and industries; in fact, each type of good can be produced by different types of industries, and therefore production can be seen from two different point of view. However, domestic production is obtained through the combination of intermediate goods value added, that in SAM are divided by type of industry

$$P_{int,j}(1 - t_{act_j}) = \left(\delta_j^D Pbj_j^{(1-\sigma_D)} + (1 - \delta_j^D) Pva_j^{(1-\sigma_D)} \right)^{\frac{1}{1-\sigma_D}} \quad (3)$$

where Pbj_j represents prices of intermediate goods, t_{act_j} are the taxes on activities, Pva_j represents prices of value added, δ_j^D represents the share of intermediate goods in total internal production and σ_D is the elasticity of substitution between intermediate goods and value added. In the fourth nesting stage, the formation of the intermediate

goods aggregate is obtained through the combination of the applications for the individual types of intermediate goods

$$Pbi_j = \sum_i \left(\delta_{i,j} P_j^{(1-\sigma_{BI})} \right)^{\frac{1}{1-\sigma_{BI}}} \quad (4)$$

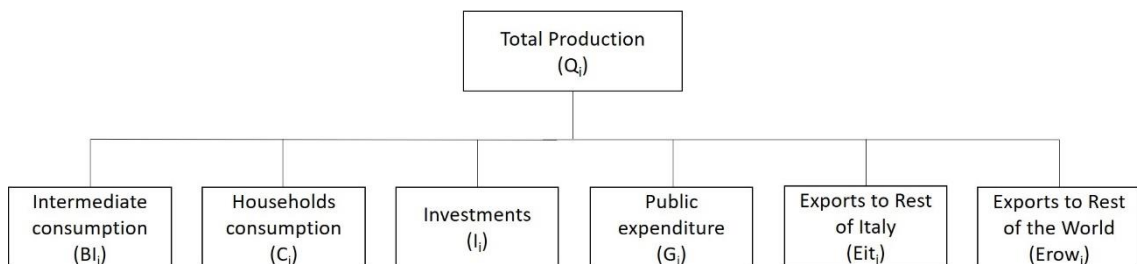
where P_j represents average price on goods market from the market clearing condition, $\delta_{i,j}$ represents share of the cost by intermediate goods in the total cost and σ_{BI} is the elasticity of substitution between intermediate goods. Finally, the value added is obtained through the combination of the productive factors labour and capital, and their price is formed according to the balance between supply and demand, using an elasticity of substitution between capital and labour set to 0.5218 (Van Der Werf, 2008)

$$Pva_j = \left(\delta_j^v \cdot PL^{1-\sigma_v} + (1 - \delta_j^v) \cdot PK^{1-\sigma_v} \right)^{\frac{1}{1-\sigma_v}} \quad (5)$$

where PL and PK are prices of labour and capital, δ_j^v represents the share of labour in the total of primary factors and σ_v is elasticity of substitution between labour and capital.

Total production, which corresponds to the overall supply of the economic system, is used among the various components of demand: intermediate consumption, final consumption by Institutional Sectors, gross investments and exports to the rest of Italy and to the rest of the world, as reported in Figure 6

Figure 6. Total production by demand components



The Institutional Sectors, in the first stage of income allocation, receive income from as compensation of employees and income deriving from gross operating surplus¹⁶, and the primary income allocation can be written with the following equations:

$$Y^{is} = L^{is}PL + K^{is}PK \quad (6)$$

where L^{is} and K^{is} represent the labour and capital supply.

From primary income formation, it is possible to move on to the disposable income formation, obtained by adding to the primary income of each Institutional Sector the income and expenditure items arising from taxes and transfers between Institutional Sectors, both calculated on the basis of primary income. The formation of disposable income is diversified according to the Institutional Sector. Transfers from the Public Administration and the Rest of the World are considered exogenous, and therefore not depending on disposable income, and then they are considered as constant.

$$Ydisp^{hh} = Y^{hh} + \sum_{is_in} Y^{hh} tr_{is_in}^{hh} + Tr_{pub} + Tr_{row} - \sum_{t_inc} Y^{hh} ty_{t_inc}^{hh} - \sum_{is_out} Y^{hh} tr_{is_out}^{hh} \quad (7)$$

$$Ydisp^{corp} = Y^{corp} + \sum_{is_in} Y^{corp} tr_{is_in}^{corp} + Tr_{pub} + Tr_{row} - \sum_{t_inc} Y^{corp} ty_{t_inc}^{corp} - \sum_{is_out} Y^{corp} tr_{is_out}^{corp} \quad (8)$$

¹⁶ The SAM shows that only the institutional household sector receives both types of income; on the contrary, enterprises and Public Administration receive exclusively income from gross operating surplus, while the Rest of Italy and Rest of the World receive exclusively income from compensation of employees.

$$\begin{aligned}
Ydisp^{rest_it} &= Y^{rest_it} + \sum_i IT_i \\
&+ \sum_{is_in} Y^{rest_it} tr_{is_in}^{rest_it} + \gamma_{t_act}^{rest_it} \sum_j tq_j^{t_act} P_j X_j \\
&+ \gamma_{t_out}^{rest_it} \sum_i tq_i^{t_out} P_i Q_i + Tr_{pub} + Tr_{row} \\
&- \sum_{is_out} Y^{rest_it} tr_{is_out}^{rest_it}
\end{aligned} \tag{9}$$

$$\begin{aligned}
Ydisp^{pub} &= Y^{pub} \\
&+ \gamma_{t_out}^{pub} \sum_i tq_i^{t_out} P_i Q_i \\
&+ \gamma_{t_act}^{pub} \sum_j tq_j^{t_act} P_j X_j \\
&+ \sum_{priv} ty_{t_inc}^{priv} Y_{priv} + \sum_{is_in} Y^{end} tr_{is_in}^{end} + Tr_{row}^{in} - Tr_{row}^{out}
\end{aligned} \tag{10}$$

$$\begin{aligned}
Ydisp^{rest_w} &= Y^{rest_w} + \sum_i M_i \\
&+ \gamma_{t_out}^{rest_w} \sum_i tq_i^{t_out} P_i Q_i \\
&+ \gamma_{t_act}^{rest_w} \sum_j tq_j^{t_act} P_j X_j + \sum_{is_in} Y^{end} tr_{is_in}^{end} + Tr_{pub} \\
&- \sum_{t_inc} Y^{rest_w} ty_{t_inc}^{rest_w} - Tr_{row}^{out}
\end{aligned} \tag{11}$$

ty_{t_inc} represents the implicit rates of income tax; tr_{is_out} are the implicit rates of transfers paid to other Institutional Sectors; tr_{is_in} represents implicit rates of transfers

collected from other Institutional Sector; $tq_i^{t_{out}}$ are the implicit tax rates on output; $tq_i^{t_{act}}$ are the implicit tax rates on activities; $\gamma_{t_{out}}^{pub}$ and $\gamma_{t_{act}}^{pub}$ represent the share of taxes on output and taxes on activities collected from the Public Administration; $\gamma_{t_{out}}^{rest_{w}}$ and $\gamma_{t_{act}}^{rest_{w}}$ represent the share of taxes on output and taxes on activities collected from the Rest of the world. Finally IT_i and M_i represent respectively the imports from Rest of Italy and from Rest of the World.

For the Institutional Sectors, Households, Corporations and the Rest of Italy disposable income represents the budget constraint on which they allocate consumption and savings, according to their utility function¹⁷, thus generating demand for consumption, investment and exports to the rest of Italy, according to the following equation

$$U_{is} = \left(C_{is}^{\frac{\sigma_U - 1}{\sigma_U}} + S_{is}^{\frac{\sigma_U - 1}{\sigma_U}} \right)^{\frac{\sigma_U}{\sigma_U - 1}} \quad (12)$$

where C_{is} and S_{is} are respectively the level of consumption and the level of savings, and σ_U is the elasticity of substitution between consumption and savings.

As far as the Institutional Sector of the Public Administration is concerned, disposable income is obtained through the sum of taxes collected and transfers received, net of transfers paid. This Institutional Sector does not maximise the utility function, and this depends on the possibility of making public expenditure choices using the deficit

$$U_{pub} = G_{pub} + S_{pub} + def_{pub} \quad (13)$$

For this reason, it is considered that public expenditure is not influenced by policy measures, and is therefore considered constant.

¹⁷ The utility function is included also for enterprises despite the fact that this sector has no final consumption. The inclusion of the utility function ensures that changes in income from policy actions are fully transferred to savings.

For the Rest of the world Institutional Sector is considered the hypothesis of not maximizing the utility function; in addition, the export price is a function of the world price, fixed exogenously and the exchange rate.

For the closure rule of the model it is considered that gross investment equals gross savings

$$\sum_i I_i = \sum_{is} S^{is} \quad (14)$$

where I_i is level of investment by product and S_{si} is level of savings by Institutional Sector. It is also considered that price flexibility in goods markets makes it possible to achieve a balance between supply and demand

$$Q_i = \sum_j b_{i,j} + \sum_{hh} C_i^{hh} + \sum_{pub} G_i^{pub} + I_i + E_i^{rest_it} + E_i^{rest_w} \quad (15)$$

where Q_i is the total production by product, $b_{i,j}$ are the intermediate goods, C_i^{hh} are households consumption, G_i^{pub} is the public expenditure, I_i are the investments, $E_i^{rest_it}$ are the export to the Rest of Italy and $E_i^{rest_w}$ are the export to the Rest of the world. Finally, the equality between supply and demand of production factors is guaranteed

$$L_d = L_s \quad (16)$$

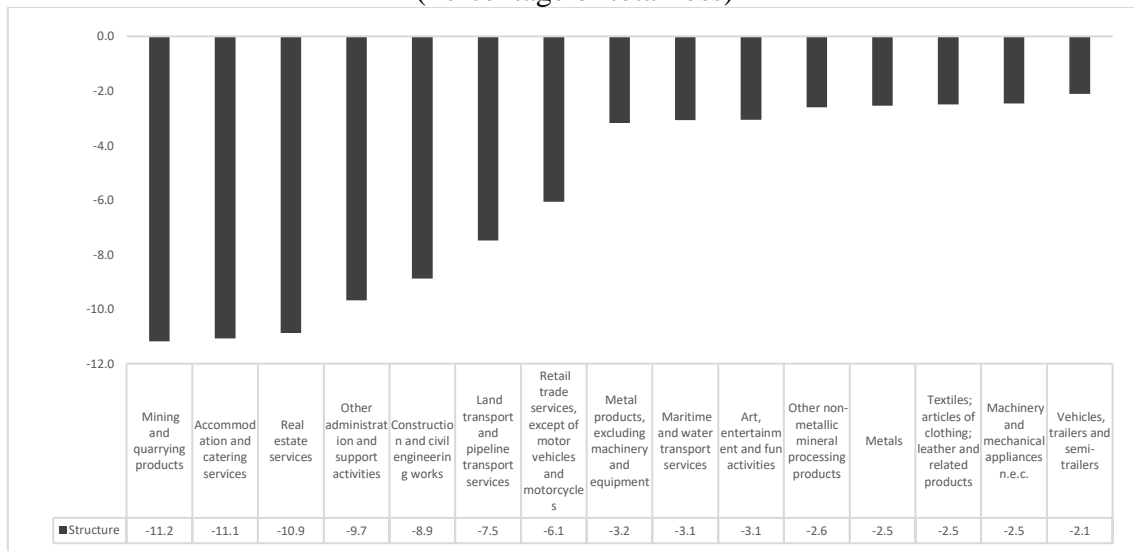
$$K_d = K_s \quad (17)$$

4. Lockdown simulation and results

The application of the SAM based CGE model for the Sardinia region to the context determined by the COVID-19 is based on the application of a selective block of certain production activities for the time set by the Prime Ministerial Decree dated 22 March 2020. This lockdown has led to a clear interruption of some production processes

with a consequent reduction in the capacity to meet final domestic and external demand (the rest of Italy and the rest of the world). In this simulation, a lockdown of 3 months is assumed for all sectors affected by the Decree, and the period is extended to 5 months for the transport sector and all activities related to tourism; the drop in production is 23.80% and Figure 7 shows the most affected sectors. The three most affected sectors by the lockdown are the sectors linked to mining, accommodation and catering services, and real estate, which together account for 32% of the drop in production. It should be pointed out that for services related to the tourism sector, the production block is extended to a time span of 5 months, so that the real impact is suffered by the mining sector and the real estate sector, linked to the construction sector.

Figure 7. Output changes: lost by commodities
(Percentage of total loss)



The main effects on macroeconomic aggregates are shown in Table 2. An important feature of the current pandemic crisis is that it has caused a shock both on the supply side, following the forced interruption of non-essential production activities, and on the demand side, with the sudden and widespread reduction in the population's consumption capacity.

Tale 2. Lockdown impact on macroeconomics variables
(Percent change w.r.t. the benchmark)

<i>Real Variables</i>	<i>%</i>
GDP	-13.2
Households consumption	-23.4
Gross Investment	-12.7
Exports - rest of Italy	-43.2
Exports - rest of the world	-5.8
Imports - rest of Italy	-35.1
Imports - rest of the world	-26.7
GDP deflator	0.0

The latter can be traced back to two substantial cases: on the one hand, consumption capacity suffers the effect of forced quarantine, which physically prevents the possibility of being able to consume, and on the other hand it suffers the effect of reduced income. The effect on consumptions should be added to the effect on investment, which also depends on spending capacity. As can be seen, the economic impact on regional GDP of the pandemic event, based on the current duration and assuming that the health problem is solved, it should stop at a contraction of about 13.2%. The percentage reduction in real GDP is significant, and for a significant part is linked to the strong reduction in final domestic demand for household goods and services (23.4%). Despite the operation of the ordinary automatic stabilisers activated by the Central and Regional Government to deal with the emergency, the contraction in demand from households remains significant. Even real investments, albeit with less intensity, reach a considerable reduction of 12.7%. An important effect, even if with their respective weight, is the reduction of the region's exports to Italy and the Rest of the World. In particular, the commercial balance towards the rest of Italy is linked to the strong tourist vocation of the region.

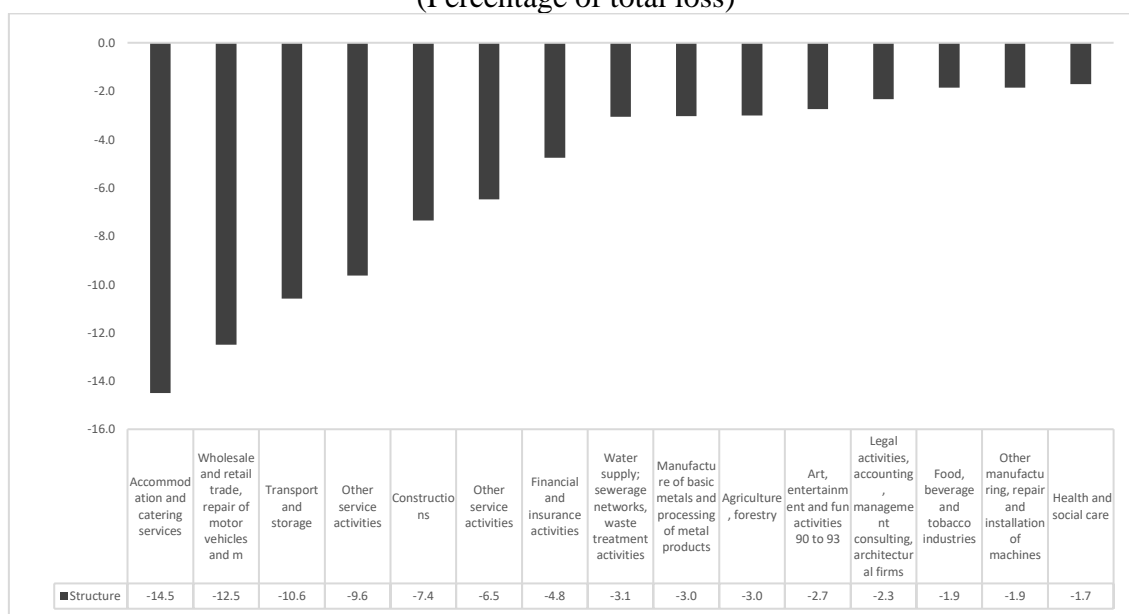
Shifting the focus to the impact that healthcare limitations can have on the generation of value added, Table 3 shows its composition by showing a sharp decline in compensation of employees and income from gross operating results:

Table 3. Lockdown impact on Value Added
(Percent change w.r.t. the benchmark)

<i>Value added components</i>	<i>%</i>
Compensation of employees	-29.1
Gross and mixed operating result	-38.9
Taxes less subsidies on products	-33.4
Other taxes less subsidies on production	-35.1

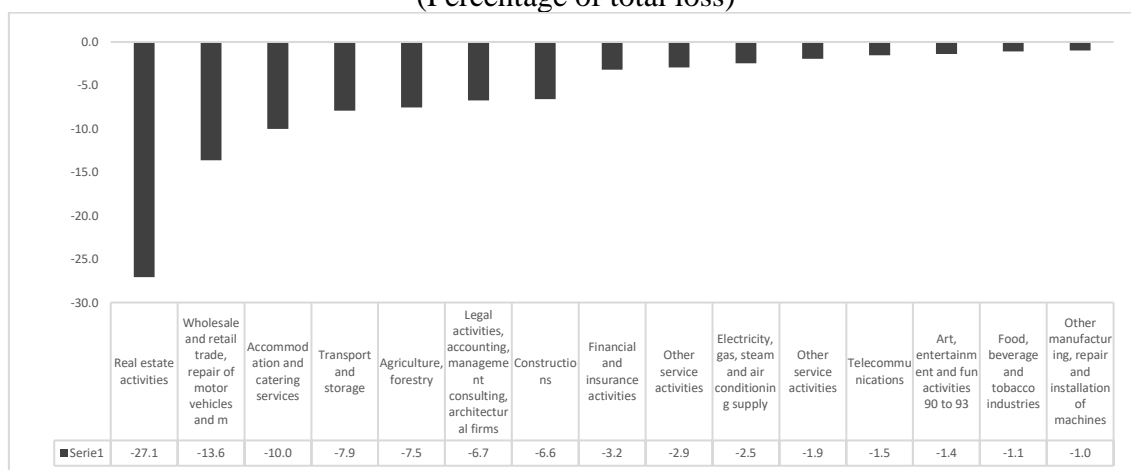
This effect justifies the drop in households consumption highlighted in Table 1 and also justifies the introduction of the “layoff” extension at national level. This measure aimed at containing the contraction, but it is not taken into account in this work, to provide an analysis net of the urgent measures implemented by central and local government to mitigate the economic impact. At sectoral level, the biggest impact on labour income is suffered by the accommodation and catering services sector, i.e. the tourism-related sector, followed by the commercial and transport sector.

Figure 8. Changes in compensation of employees distribution by industry
(Percentage of total loss)



As regard to the gross operating surplus, it should be noted that the most affected sector is the real estate sector, with a 27.1% decrease, followed by the commercial sector and the accommodation and catering services sector.

Figure 9. Reduction in gross operating result by industry
(Percentage of total loss)



Consequently, it is clear that the tourism sector is the sector that most of all suffers the effect of economic contraction resulting from the lockdown, both in terms of production and value added, thus characterizing the Sardinia region as a territory with a strongly tourism-oriented economic structure.

The contraction in production also translates into a reduction in activity taxes, thus generating a reduction in tax revenue collected by the regional government.

A further aspect related to the contraction of disposable income is the impact on related taxes, which account for about 40% of the regional government's disposable income. Table 4 shows the revenue reduction in favour of this type of tax.

Table 4. Lockdown impact on income tax revenue
(Percent change w.r.t. the benchmark)

<i>Variables</i>	<i>%</i>
Households income taxes	-33.1
Corporate income taxes	-38.9

Based on this, the disposable income of the Institutional Sectors is also suffering a far-reaching setback as a result of transfers between sectors, considering that the primary income contraction in fact reduces the transfers tax base. Results are shown in Table 5:

Table 5. Lockdown impact on disposable income
(Percent change w.r.t. the benchmark)

<i>Disposable income</i>	<i>%</i>
Non financial corporations	-32.9
Financial corporations	26.7
Public administration	-82.1
Households	-23.4
ISP	-17.5

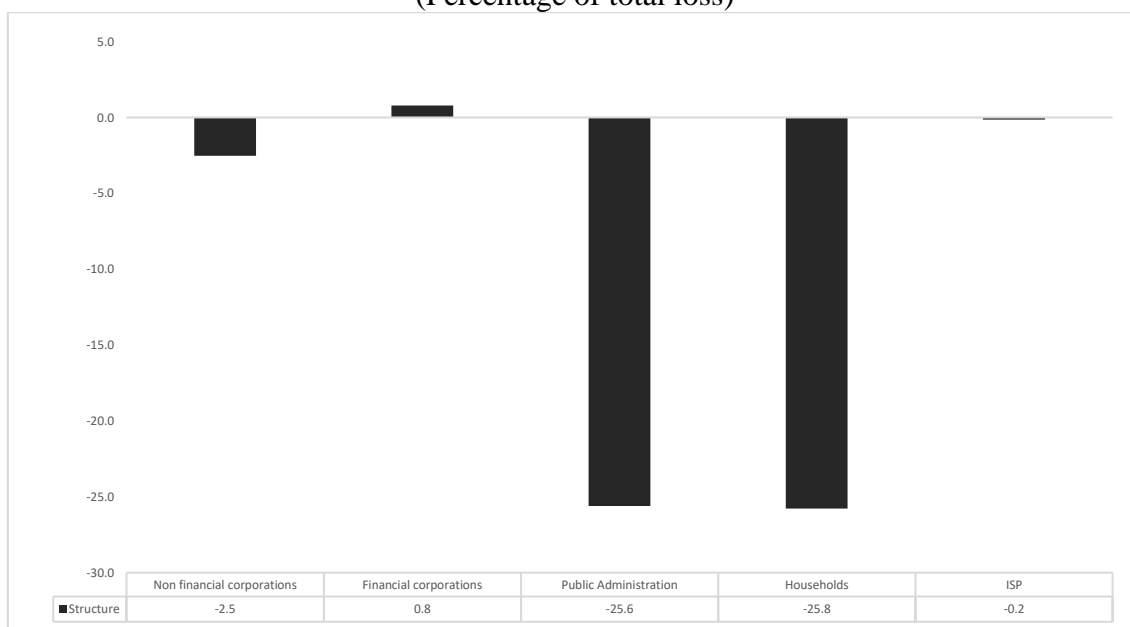
There is a general contraction in income for all Institutional Sectors, with the exception of financial corporations; for the latter, in fact, the component of incoming transfers from the Government and Rest of the World Institutional Sectors, considered fixed, represents the largest component, and therefore disposable income tends to grow. Moreover, considering fixed transfers from the Public Administration, which can operate in deficit, implies a strong reduction in its disposable income generated by the contraction of tax revenues. This implies that all actions aimed at maintaining Public Expenditure and transfers to other Institutional Sectors, in order to support their spending capacity to meet demand, can be carried out by making use of the deficit. The variation in disposable income of households and non-financial corporations are of considerable interest: the first is affected by the contraction in primary income deriving above all from compensation of employees, because of the contraction in production. The second mostly suffers the drop in income from the reduction registered by the gross operating surplus as a result of the lockdown. However, Figure 10 shows the distribution of Institutional Sectors¹⁸ according

¹⁸ The Institutional Sectors "Rest of the World" and "Rest of Italy" are not included.

to the income contraction, showing that for non-financial corporations it represents the 2.5% of the total income reduction, while households are the Institutional Sector most affected by the income contraction. It can also be seen that the increase in the disposable income of financial corporations represents only the 0.8% of the total change.

From this point of view, through the simulation of the lockdown measure enabled in order to contain contagions, its impact on the economic system is highlighted through a strong contraction in the production of key sectors, which is followed by a contraction in household spending capacity resulting from the incomes drop, which translates into an aggregate demand drop. The regional government also suffers the income contraction resulting from lower tax revenues, both on the production side and on the income Institutional Sectors side, while guaranteeing the level of public spending and transfers to households and businesses through recourse to the deficit.

Figure 10. Change in disposable income Distribution by Institutional Sector (Percentage of total loss)



5. Fiscal policy to counteract the lockdown effect

Considering the impact of the lockdown on the economic system, it is necessary to take measures capable of limiting the negative effect. As mentioned above, the impact

is far-reaching and it is entirely unrealistic to envisage reversing the trend quickly. Therefore, the actions taken by the Regional Government and the Central Government can be channeled through an analysis of the multiplicative effects that any policy has on the economic system, so as to maximize the effect of reduced scarce resources.

During the pandemic period, the Central Government focused on delivering aids to firms with the primary aim of bringing production back to a pre-lockdown level, while at the same time ensuring the employment in those activities. The most relevant actions laid down by the Government pertain to the ‘Cura Italia’ Decree-Law. This measure increased the amount of resources authorized by the Italian Parliament to address the health emergency with a series of actions aiming to protect the level of employment and reduce the burden of the taxation for the activities affected by the lockdown. Compared to the legislation in force, the measures raised the target of net borrowing to EUR 20 billion, corresponding to EUR 25 billion in budget appropriations. The subsequent Decree Law on Liquidity introduced measures to support productive activities by strengthening the provision of credit to reduce liquidity tensions and creating a temporary framework to safeguard business continuity. It provided EUR 400 billion of credit to the economy, in addition to the EUR 350 billion already activated, or preserved by means of a moratorium on loans and loans to small and medium-sized enterprises, by the ‘Cura Italia’ Decree-Law. In May, with the most controlled contagion, Italy provided itself with the necessary tools to spread its economy safely and revitalize, by means of a single and organic decree allocating EUR 155 billion in terms of net balance to be financed and EUR 55 billion in terms of net borrowing. The Legislative Decree on “Rilancio” thus uses all the resources authorized by Parliament with the approval of the 2020 Economic and Financial Document. Table 6 shows the measures taken in Italy with regard to employment protection, support to Households and measures in favor of Corporations. By means of

the Prime Ministerial Decree of 24 October 2020, the Central Government adopted new restrictive measures to contain the spread of the pandemic, following a revival of the spike in the contagion curve, which was already predicted in May 2020. These measures provide for lockdowns targeted by region and by type of production activity and therefore smaller than the general lockdown in April. The Decree was accompanied by new measures to support the undertakings concerned. The Central Government has also introduced new measures, in particular through the “Ristoro” Decree, which provides for non-repayable contributions totalling EUR 5.4 billion, as well as a measure in favour of the tax contribution, based on the partial exemption by employers of contributions to employees. In particular, for the regions of southern Italy, which are part of the ‘Less Favoured Areas’, there is a partial exemption, from 1 October 2020 to 31 December 2020, of up to 30 % of the contributions due.

Table 6. Measures adopted for the Covid-19 pandemic from Italian Government
(in millions of Euros)

Labour protection	26,589
Ordinary and extraordinary redundancy fund and other wage supplements	16,580
One-off allowances for self-employed, seasonal and fixed-term workers	5,392
Exemption from social security and welfare contributions (including SOUTH decontribution)	2,639
Parental leave, vouchers and guardianship periods spent in quarantine	1,360
Allowances for sports employees	297
Income support for workers	245
Emergence of working relationships	76
Interventions in favour of companies	21,205
Interventions for business continuity	19,657
Non-repayable grants in favour of those who have undergone reductions in turnover	7,347
IRAP cancellation of the 2019 balance and first instalment on account 2020	3,952
Fiscal benefits for sanctioning and renting of real estate properties commercial	1,743
Tax credit holiday	1,677
IMU and TOSAP/COSAP exemptions	626
Other interventions for the continuity of businesses	4,312
Interventions for relaunch and development	1,548
Interventions for the relaunch of tourism and culture	1,040
Fiscal benefits for energy efficiency, earthquake-proof adaptation, installation of photovoltaic systems and electric vehicle recharging infrastructure.	23
Tax relief for PIRs	17
Other interventions for relaunch and development	468

Source: Nota di Aggiornamento al Documento di Economia e Finanza 2020 (NADEF)

The measures adopted by the Central Government are numerous and varied in relation to the Institutional Sectors benefiting from the assistance. At regional level, the response to these measures can be quite different. Indeed, the national economic structure cannot be used as a proxy of the regional structure, especially if the region suffers from natural territorial constraints, such as insularity in the case of Sardinia. The insularity, through climatic conditions that differ from the rest of Italy, and the presence of frictions with freedom of movement, create a production system with different characteristics from the other Italian regions. It is therefore important, as stated at the beginning of the paragraph, to assess which type of intervention has a greater multiplier effect in the system, thus providing policy makers with a starting point in economic policy choices.

This paragraph proposes an impact analysis based on 4 different policy proposals, using shocks amounting to 1 % of GDP:

- Reduction in employers' social contributions (social security wedge)
- Reduction in household income tax (tax wedge)
- Increase in direct transfers to businesses
- Increase in direct transfers to households

Table 7 shows the impact of the first simulation, based on a reduction in employers' social contributes; the shock is modelled through the industrial breakdown, adjusting the value on the basis of the shares of the labour input to the total, as derived from the regional SAM. The social security contribution has a direct effect on the income formation of households (2.6 %) and non-financial corporations (1.7 %), while there is a decrease in the income of financial corporations (-2.1 %). The income structure of the latter is mainly based on transfers between Institutional Sectors, with a low input income value. This implies that economic policy measures that change the formation of primary income do not affect this Institutional Sector positively; in addition, financial corporations are

confronted with the loss of contributions by increasing transfers to other Institutional Sectors, in particular to households. However, the increase in the income of households and non-financial corporations pushes up GDP growth (0.7 %), albeit with a low multiplier effect. The increase in GDP is driven by an increase in consumption (2.6 %) as a result of rising household incomes, a share of the change in income, which is proportional to the propensity to save, but also contributes to the increase in investment (0.6 %), which is also supported by the rise in income of non-financial corporations.

Table 7. Social security decontribution equal to 1% of GDP
(Percent change w.r.t. the benchmark)

<i>Real Variables</i>	<i>%</i>
GDP	0.7
Households consumption	2.6
Gross Investment	0.6
Public Expenditure	0.0
Exports - rest of Italy	0.4
Exports - rest of the world	0.0
Imports - rest of Italy	2.1
Imports - rest of the world	0.9
GDP deflator variation	1.0
Households disposable income	2.6
Financial corporations disposable income	-2.1
Non-Financial corporations disposable income	1.7
ISP disposable income	2.6
<hr/>	
<i>Nominal Variables</i>	<i>%</i>
Households income taxes	1.7
Financial corporations income taxes	0.9
Non-Financial corporations' income taxes	0.9

As far as public expenditure is concerned, the change is null and void, as the public administration operates exogenously within the model, and therefore the choices to increase or reduce expenditure can be made in deficit. There is also a slight increase in exports to the Rest of Italy (0.4 %), while exports to the Rest of the World do not change

as they depend exclusively on the level of foreign prices¹⁹. Finally, there is an increase in imports from the Rest of Italy (2.1 %) and the Rest of the World (0.9 %), as a direct result of the increase in domestic prices, as indicated by the change in the GDP deflator (1 %). The increase in income also translates into an increase in income tax paid by households (1.7 %) and businesses (0.7 %), implying that the general government recovers a share of revenue through direct taxes. Therefore, in order to maximize the effect on GDP, the policy requires an increase in transfers from the general government to other Institutional Sectors for the part of income tax collected.

In the second simulation, the impact of a policy based on the reduction of household income taxes is estimated, as shown in Table 8.

Table 8. Households Income taxes decontribution equal to 1% of GDP
(Percent change w.r.t. the benchmark)

<i>Real Variables</i>	<i>%</i>
GDP	1.6
Households consumption	2.6
Gross Investment	1.5
Public Expenditure	0.0
Exports – rest of Italy	2.3
Exports – rest of the world	0.0
Imports – rest of Italy	1.8
Imports – rest of the world	1.7
GDP deflator	0.9
Households disposable income	2.6
Financial corporations disposable income	0.6
Non-Financial corporations disposable income	1.6
ISP disposable income	0.8
<hr/>	
<i>Nominal Variables</i>	<i>%</i>
Households income taxes	-13.1
Financial corporations income taxes	2.8
Non-Financial corporations' income taxes	2.8

¹⁹Changes in demand components are expressed in real terms; this is why exports to the Rest of the World, which are modelled solely on the level of foreign prices, are subject to no change other than in nominal terms.

In contrast to the previous simulation, the impact is multiplicative as a decrease of 1 % of GDP in income taxes shows an increase in GDP of 1.6 %. The positive effect on GDP stems substantially from an increase in consumption (2.6 %) and an increase in investment (1.5 %), in line with the increase in the disposable income of households and corporations, in particular non-financial corporations (1.6 %). However, it should be stressed that this fiscal policy action also shows an increase in the income of Financial Corporations (0.6 %); the increase in corporate income translates into an increase in income tax paid (2.8 %), partly covering the compensation of income tax paid by households (-13.1 %).

There is also an increase in exports to the Rest of Italy (2.3 %) and a decrease in imports from the Rest of Italy compared to the previous simulation (1.8 %), which contribute positively to GDP growth. Imports from the Rest of the World are increasing (1.7 %).

The third simulation assumes an expansionary exercise based on an increase in transfers from public authorities to companies. The results are shown in Table 9. The multiplier effect is almost similar to the effect of reducing household income taxes, with GDP growing by 1.5 %. In this case, the effect is generated by investment growth (7.4 %) in line with the growth in disposable income of financial corporations (1.2 %) and non-financial corporations (1.6 %); consumption also contributes positively to GDP growth (0.8 %) as a result of rising household incomes (0.9 %). Exports to the Rest of Italy show an increase compared to the previous simulation (2.6 %) as well as imports (2.1 %); imports from the Rest of the World (1.7 %) remain stable.

Table 9. Increase in Corporations transfers equal to 1% of GDP
(Percent change w.r.t. the benchmark)

<i>Real Variables</i>	<i>%</i>
GDP	1.5
Households consumption	0.8
Gross Investment	7.4
Public Expenditure	0.0
Exports – rest of Italy	2.6
Exports – rest of the world	0.0
Imports – rest of Italy	2.1
Imports – rest of the world	1.7
GDP deflator	0.9
Households disposable income	0.9
Financial corporations disposable income	1.2
Non-Financial corporations disposable income	1.6
ISP disposable income	0.8
<hr/>	
<i>Nominal Variables</i>	<i>%</i>
Households income taxes	3.9
Financial corporations income taxes	2.6
Non-Financial corporations' income taxes	2.6

Finally, the fourth simulation assumes an increase in transfers of 1 % of GDP to households, and the results are shown in Table 10. The multiplier effect on GDP is identical to the effect of an increase in transfers to enterprises (1.5 %), but changes the composition of demand; in this case, the increase in GDP is mainly driven by an increase in consumption (2.5 %), despite the lower value of household disposable income growth (0.9 %). It should be noted that in the two simulations concerning the increase in transfers from the general government, the effect on the income of households (0.9 %) and non-financing corporations (1.6 %) remains unchanged, while only the income of financial corporations (0.6 %) varies.

However, the change in consumption and investment (1.4 %) modifies, confirming that transfers to corporations generate an increase in income that expand

savings, stimulating the investments, while transfers to households generate an increase in income that feeds into the consumption channel.

Table 10. Increase in Households transfers equal to 1% of GDP
(Percent change w.r.t. the benchmark)

<i>Real Variables</i>	<i>%</i>
GDP	1.5
Households consumption	2.5
Gross Investment	1.4
Public Expenditure	0.0
Exports - rest of Italy	2.2
Exports - rest of the world	0.0
Imports - rest of Italy	1.7
Imports - rest of the world	1.7
GDP deflator	0.8
Households disposable income	0.9
Financial corporations disposable income	0.6
Non-Financial corporations disposable income	1.6
ISP disposable income	0.7
<hr/>	
<i>Nominal Variables</i>	<i>%</i>
Households income taxes	3.7
Financial corporations income taxes	2.7
Non-Financial corporations income taxes	2.7

Compared to the previous simulation, exports to the rest of Italy (2.2 %) decreased, as did imports (1.7 %), while imports from the Rest of the world remained stable (1.7 %).

6. Concluding remarks and policy recommendation

In this chapter, the impact of the measures provided for by the D.P.C.M. of 22 March 2020, concerning 'Urgent measures for the containment of coronavirus infection throughout the national territory', is analysed with application to the Sardinia region. The Decree refers to the production lockdown for specific economic sectors due to the Covid-19 pandemic. Through a SAM based CGE model the impact on production, demand and

disposable income of the Institutional Sectors that characterize the regional economy is analysed. The pandemic effect has led to a significant production lockdown processes in a selective manner, compromising the entire economic system through direct, indirect and induced effects. There is a significant decrease in real gross domestic product, and in general in all its components; there is also a sharp decrease in the disposable income of the Institutional Sectors and the related tax revenue for the Government from income taxes and taxes on productive activities. This means that the policy which will be activated by the regional government for the future restart of the economic system, cannot fail to take into account the possibility of operating in deficit. Moreover, given that the impact of the lockdown is diversified at sectoral level, economic policy measures can be geared towards safeguarding the output of the most affected activities, as well as the protection of labour income and related gross operating result, through the reduction of the tax wedge or through transfer-related instruments. The interconnection between productive sectors will therefore generate a mechanism for transmitting and propagating economic recovery to all other productive sectors through the multiplier mechanism. This does not exclude that the actions implemented cannot be oriented to the entire production system, through a structure of interventions of a proportional or progressive type. Moreover, as highlighted by the fiscal policy simulations, regional policies can be oriented by exploiting the greatest multiplier effect on GDP; the static CGE model has shown that the greatest multiplier effect is achieved through policies aimed at cutting household income taxes. Of course, maximising the multiplier effect on GDP is not the only way forward, as economic policy actions must be geared towards a specific purpose (boosting investment, stimulating consumption, reducing the tax wedge, reducing the welfare wedge, etc.). The multiplicative effects of the different economic policy assumptions are,

however, a guiding tool to ensure the application of efficient policies for the economic system.

Appendix 1: model sensitivity analysis

The substitution elasticities within the production function are established exogenously, and therefore can influence the model results through the choice of the model value. For this reason, the choice of exogenous parameters must be based on literature, but at the same time, it is necessary to verify that the model does not respond abnormally to their changes. In the CGE model, the production function for Sardinia includes the parameter of the elasticity of substitution between capital and labour that is set equal to the one for the Italian economy. The value of the elasticity at national level is estimated at 0.5218 (Van Der Werf, 2008) and, in order to evaluate the sensitivity of the model to this parameter, it is assumed to test 4 variations of the elasticity.

The results are shown in the tables below. As can be seen, by changing the elasticity of substitution between labour and capital in a range from 0.417 to 0.626 the model does not show significant variations compared to the value of the elasticity used in the simulations. This means that the greater or the less rigidity of the elasticity of substitution does not amplify the effects of the policy and, at the same time, it is possible to attribute the economic impact of the model to the policies.

Table 11. Social security decontribution equal to 1% of GDP
(Percent change w.r.t. the benchmark)

σ	% change from benchmark				
	-20%	-10%	Bench	10%	20%
Real GDP	0.8	0.7	0.7	0.6	0.6
Households consumption	2.8	2.7	2.6	2.6	2.5
Gross investment	0.9	0.7	0.6	0.5	0.4
Public expenditure	0.0	0.0	0.0	0.0	0.0
Exports to rest of Italy	0.7	0.6	0.4	0.3	0.2
Exports to rest of the World	0.0	0.0	0.0	0.0	0.0
Imports from rest of Italy	2.2	2.1	2.1	2.0	1.9
Imports from rest of the world	1.1	0.9	0.0	0.8	0.7
GDP deflator	1.3	1.1	1.0	0.9	0.8

Table 12. Households Income taxes decontribution equal to 1% of GDP
(Percent change w.r.t. the benchmark)

σ	% change from benchmark				
	-20%	-10%	Bench	10%	20%
Real GDP	1.7	1.6	1.6	1.6	1.6
Households consumption	2.6	2.6	2.6	2.6	2.6
Gross investment	1.7	1.6	1.5	1.4	1.3
Public expenditure	0.0	0.0	0.0	0.0	0.0
Exports to rest of Italy	2.5	2.4	2.3	2.2	2.2
Exports to rest of the World	0.0	0.0	0.0	0.0	0.0
Imports from rest of Italy	1.8	1.8	1.8	1.8	1.7
Imports from rest of the world	1.9	1.8	1.7	1.7	1.7
GDP deflator	1.1	1.0	0.9	0.8	0.7

Table 13. Increase in Corporations transfers equal to 1% of GDP
(Percent change w.r.t. the benchmark)

σ	% change from benchmark				
	-20%	-10%	Bench	10%	20%
Real GDP	1.6	1.5	1.5	1.5	1.5
Households consumption	0.8	0.8	0.8	0.8	0.8
Gross investment	7.6	7.5	7.4	7.3	7.3
Public expenditure	0.0	0.0	0.0	0.0	0.0
Exports to rest of Italy	2.8	2.7	2.6	2.6	2.5
Exports to rest of the World	0.0	0.0	0.0	0.0	0.0
Imports from rest of Italy	2.2	2.1	2.1	2.1	2.1
Imports from rest of the world	1.8	1.8	1.7	1.7	1.7
GDP deflator	1.1	1.0	0.9	0.8	0.7

Table 14. Increase in Households transfers equal to 1% of GDP
(Percent change w.r.t. the benchmark)

σ	% change from benchmark				
	-20%	-10%	Bench	10%	20%
Real GDP	1.5	1.6	1.5	1.5	1.5
Households consumption	0.8	2.5	2.5	2.5	2.5
Gross investment	7.3	1.5	1.4	1.3	1.3
Public expenditure	0.0	0.0	0.0	0.0	0.0
Exports to rest of Italy	2.5	2.2	2.2	2.1	2.1
Exports to rest of the World	0.0	0.0	0.0	0.0	0.0
Imports from rest of Italy	2.1	1.7	1.7	1.7	1.7
Imports from rest of the world	1.7	1.7	1.7	1.6	1.6
GDP deflator	0.7	0.9	0.8	0.7	0.7

Appendix 2: parameters, variables and equations

Model parameters and variables

i	Commodities
j	Industries
is	Institutional Sectors
hh	Households
$corp$	Corporations
pub	Public Administration
$rest_it$	Rest of Italy
$rest_w$	Rest of the world
Q_i	Output by commodity
P_i	Price of goods
Q_j	Output by industry
δ_i^{dom}	Share of domestic goods on the total production in the cost function
d_i^{dom}	Share of domestic goods on the total production
$P_{dom,i}$	Prices of domestic goods
$Q_{dom,i}$	Quantity of domestic goods
t_{out_i}	Taxes on output by commodity
Pm_i	Prices of imports from the rest of the world
M_i	Quantity of imports from the rest of the world
$\sigma_{Q_{dom}}$	Elasticity of substitution between domestic and imported goods
$\rho_{Q_{dom}}$	Exponent of the CES production function linked to $\sigma_{Q_{dom}}$
$P_{int,i}$	Prices of internal goods
Pit_i	Prices of imports from the rest of Italy
IT_i	Quantity of imports from the rest of the Italy
δ_i^{int}	Share of internal production on total domestic production in the cost function
$\sigma_{Q_{int}}$	Elasticity of substitution between internal production and imports from Rest of Italy
$Q_{int,i}$	Quantities of internal goods
d_i^{int}	Share of internal production on total domestic production
$\rho_{Q_{int}}$	Exponent of the CES production function linked to $\sigma_{Q_{int}}$
Pbi_j	Prices of intermediate goods
BI_j	Quantities of intermediate goods
t_{act_j}	Taxes on activities
Pva_j	Prices of value added
VA_j	Quantities of value added
δ_j^D	Share of intermediate goods in total internal production
σ_D	Elasticity of substitution between intermediate goods and value added
ρ_D	Exponent of the CES production function linked to σ_D
P_j	Average price on goods market from the market clearing condition
δ_{ij}	Share of the cost by intermediate goods on the total cost
σ_{BI}	Elasticity of substitution between intermediate goods

PL	Price of labor
PK	Price of capital
δ_j^v	Share of labour in the total of primary factors
σ_v	Elasticity of substitution between labour and capital
δ_j^L	Share of labour costs on added value
L_j^d	Labor endowment
K_j^d	Capital endowment
d_{ji}^q	Share of i^{th} product realized by industry j in the total production of j
d_{ij}^q	Share of goods supply by each activity in the total domestic supply
q_{ij}	Quantity of goods i produced by industry j
σ_q	Elasticity of substitution between primary and secondary production
δ_i^{it}	Share of internal production on total domestic production
δ_i^M	Share of domestic production on total production
pmw_i	Price of foreign goods
exr	Nominal exchange rate
Y^{is}	Primary income by Institutional Sectors
ty_{t_inc}	Implicit rates of income tax
tr_{is_out}	Implicit rates of transfers paid to other Institutional Sectors
tr_{is_in}	Implicit rates of transfers collected from others Institutional Sector
$tq_i^{t_out}$	Implicit tax rates on output
$tq_i^{t_act}$	Implicit tax rates on activities
$\gamma_{t_out}^{pub}$	Share of taxes on output
$\gamma_{t_act}^{pub}$	Share of taxes on activity
$\gamma_{t_out}^{rest_w}$	Share of taxes on output collected from the Rest of the world
$\gamma_{t_act}^{rest_w}$	Share of taxes on activity collected from the Rest of the world
U_{is}	Utility of Institutional Sectors
C_{is}	Consumption of Institutional Sectors
S_{is}	Saving of Institutional Sectors
$Ydisp$	Disposable income
Y	Primary income
Pu_{is}	Utility price
χ_{is}^U	Share of consumption on disposable income
Pc_{is}	Index price of the of consumption by Institutional Sector
PI	Price of investment
σ_U	Elasticity of substitution between consumption and saving
C_{is}	Aggregate consumption of Institutional Sectors
$\delta_{is,i}^C$	Share of consumption of the i^{th} good in total consumption for each Institutional Sector
σ_C	Elasticity of substitution among goods in the consumption basket
$C_{is,i}$	Quantity of consumption of each good by Institutional Sector
δ_i^I	Investment share of the i^{th} goods in total investments
σ_I	Elasticity of substitution among goods in the investment basket
I_i	Quantity of investment by goods
$e_{row,i}$	Export demand by goods from Rest of the World
$\delta_{row,i}^E$	Export share of i^{th} goods in total exports to the rest of the World

σ_E	Elasticity of substitution among goods in the export to the rest of the World basket
π	Foreign inflation rate

Equations

$$Q_i = \left(d_i^{dom} Q_{dom,i}^{\rho_{Q_{dom}}} + (1 - d_i^{dom}) M_i^{\rho_{Q_{dom}}} \right)^{\frac{1}{\rho_{Q_{dom}}}}$$

$$P_i(1 - t_{out_i}) = \left(\delta_i^{dom} P_{dom,i}^{(1-\sigma_{Q_{dom}})} + (1 - \delta_i^{dom}) P m_i^{(1-\sigma_{Q_{dom}})} \right)^{\frac{1}{1-\sigma_{Q_{dom}}}}$$

$$Q_{dom,i} = \left(d_i^{int} Q_{int,i}^{\rho_{Q_{int}}} + (1 - d_i^{int}) I T_i^{\rho_{Q_{int}}} \right)^{\frac{1}{\rho_{Q_{int}}}}$$

$$P_{dom,i} = \left(\delta_i^{int} P_{int,i}^{(1-\sigma_{Q_{int}})} + (1 - \delta_i^{int}) P i t_i^{(1-\sigma_{Q_{int}})} \right)^{\frac{1}{1-\sigma_{Q_{int}}}}$$

$$Q_{int,j} = \left(d_j^D B I_j^{\rho_D} + (1 - d_j^D) V A_j^{\rho_D} \right)^{\frac{1}{\rho_D}}$$

$$P_{int,j}(1 - t_{act_j}) = \left(\delta_j^D P b i_j^{(1-\sigma_D)} + (1 - \delta_j^D) P v a_j^{(1-\sigma_D)} \right)^{\frac{1}{1-\sigma_D}}$$

$$B I_j = \delta_j^D Q_{int,j} \left(\frac{P_{int,j}}{P b i_j} \right)^{\sigma_D}$$

$$V A_j = (1 - \delta_j^D) Q_{int,j} \left(\frac{P_{int,j}}{P v a_j} \right)^{\sigma_D}$$

$$P b i_j = \sum_i \left(\delta_{i,j} P_i^{(1-\sigma_{BI})} \right)^{\frac{1}{1-\sigma_{BI}}}$$

$$b i_{ij} = \delta_{ij}^{BI} Q_{int,j} \left(\frac{P b i_j}{P_i} \right)^{\sigma_{BI}}$$

$$P v a_j = \left(\delta_j^v \cdot P L^{1-\sigma_v} + (1 - \delta_j^v) \cdot P K^{1-\sigma_v} \right)^{\frac{1}{1-\sigma_v}}$$

$$L_j^d = \delta_j^L V A_j \left(\frac{P v a_j}{P L} \right)^{\sigma_v}$$

$$K_j^d = (1 - \delta_j^L) V A_j \left(\frac{P v a_j}{P K} \right)^{\sigma_v}$$

$$Q_j = \left(\sum_i d_{ji}^q q_{ij} \right)^{\frac{1}{1-\sigma_q}}$$

$$Pq_{dom,i} = \left(\sum_j d_{ij}^q P_{dom,j}^{(1-\sigma_q)} \right)^{\frac{1}{1-\sigma_q}}$$

$$IT_i = (1 - \delta_i^{it})Q_i$$

$$Pit_i = P_{dom,i}$$

$$M_i = (1 - \delta_i^M)Q_i \left(\frac{P_i}{Pm_i} \right)^{\sigma_{Qdom}}$$

$$Pm_i = pmw_i(1 + \pi)/exr$$

$$Y^{is} = L^{is}PL + K^{is}PK$$

$$Ydisp^{hh} = Y^{hh} + \sum_{is_in} Y^{hh} tr_{is_in}^{hh} + Tr_{pub} + Tr_{row} - \sum_{t_inc} Y^{hh} ty_{t_inc}^{hh} - \sum_{is_out} Y^{hh} tr_{is_out}^{hh}$$

$$Ydisp^{corp} = Y^{corp} + \sum_{is_in} Y^{corp} tr_{is_in}^{corp} + Tr_{pub} + Tr_{row} - \sum_{t_inc} Y^{corp} ty_{t_inc}^{corp} - \sum_{is_out} Y^{corp} tr_{is_out}^{corp}$$

$$Ydisp^{rest_it} = Y^{rest_it} + \sum_i IT_i + \sum_{is_in} Y^{rest_it} tr_{is_in}^{rest_it} + \gamma_{t_act}^{rest_it} \sum_j tq_j^{t_act} P_j X_j \\ + \gamma_{t_out}^{rest_it} \sum_i tq_i^{t_out} P_i Q_i + Tr_{pub} + Tr_{row} - \sum_{is_out} Y^{rest_it} tr_{is_out}^{rest_it}$$

$$Ydisp^{pub} = Y^{pub} + \gamma_{t_out}^{pub} \sum_i tq_i^{t_out} P_i Q_i + \gamma_{t_act}^{pub} \sum_j tq_j^{t_act} P_j X_j + \sum_{priv} ty_{t_inc}^{priv} Y_{priv} + \sum_{is_in} Y^{end} tr_{is_in}^{end} \\ + Tr_{row}^{in} - Tr_{row}^{out}$$

$$Ydisp^{rest_w} = Y^{rest_w} + \sum_i M_i + \gamma_{t_out}^{rest_w} \sum_i tq_i^{t_out} P_i Q_i + \gamma_{t_act}^{rest_w} \sum_j tq_j^{t_act} P_j X_j + \sum_{is_in} Y^{end} tr_{is_in}^{end} \\ + Tr_{pub} - \sum_{t_inc} Y^{rest_w} ty_{t_inc}^{rest_w} - Tr_{row}^{out}$$

$$U_{is} = \left(C_{is}^{\frac{\sigma_U-1}{\sigma_U}} + S_{is}^{\frac{\sigma_U-1}{\sigma_U}} \right)^{\frac{\sigma_U}{\sigma_U-1}}$$

$$Pu_{is} = \left(\chi_{is}^U P C_{is}^{1-\sigma_U} + (1 - \chi_{is}^U) P I^{1-\sigma_U} \right)^{\frac{1}{1-\sigma_U}}$$

$$C_{is} = \chi_{is}^U U_{is} \left(\frac{Pu_{is}}{P C_{is}} \right)^{\sigma_U}$$

$$S_{is} = (1 - \chi_{is}^U) U_{is} \left(\frac{Pu_{is}}{P C_{is}} \right)^{\sigma_U}$$

$$Pc_{is} = \left(\sum_i \delta_{is,i}^C P_i^{1-\sigma_C} \right)^{\frac{1}{1-\sigma_C}}$$

$$C_{is,i} = \delta_{is,i}^C U_{is} \left(\frac{Pc_{is}}{P_i} \right)^{\sigma_C}$$

$$U_{pub} = G_{pub} + S_{pub} + def_{pub}$$

$$PI = \left(\sum_i \delta_i^I P_i^{1-\sigma_I} \right)^{\frac{1}{1-\sigma_I}}$$

$$I_i = \delta_i^I I \left(\frac{PI}{P_i} \right)^{\sigma_I}$$

$$e_{row,i} = \delta_{row,i}^E Y_{row} \left(\frac{pwm_i \cdot exr}{P_i} \right)^{\sigma_E}$$

$$Q_i = \sum_j b_{i,j} + \sum_{hh} C_i^{hh} + \sum_{pub} G_i^{pub} + I_i + E_i^{rest_it} + E_i^{rest_w}$$

$$\sum_i M_i + \sum_{is_in} Y^{end} tr_{is_in}^{end} + Tr_{pub} + Y^{rest_w} = \sum_i e_i + Tr_{row}^{out} + S_{row}$$

$$\sum_i I_i = \sum_{is} S_{is}$$

$$L_d = L_s$$

$$K_d = K_s$$

Appendix 3: List of goods and activities in the Sardinian SAM

Goods

- 1 Agricultural and hunting products and related services
- 2 Products of forestry, logging and related services
- 3 Fish and other fisheries products; aquaculture products; fisheries support services
- 4 Mining and quarrying products
- 5 Food, beverages and tobacco products
- 6 Textiles; clothing; leather and related products
- 7 Wood and wood and cork products (excluding furniture); articles of straw and plaiting materials
- 8 Paper and paper products
- 9 Printing and registration services
- 10 Coke and refined petroleum products
- 11 Chemical products
- 12 Basic pharmaceutical products and pharmaceutical preparations
- 13 Rubber and plastic articles
- 14 Other non-metallic mineral processing products
- 15 Metals
- 16 Metal products, excluding machines and systems
- 17 Computer, electronic and optical products
- 18 Electrical equipment
- 19 Machines and mechanical equipment n.e.c.
- 20 Vehicles, trailers and semi-trailers
- 21 Other means of transport
- 22 Furniture; other artefacts
- 23 Repair and installation services of machinery and equipment
- 24 Electricity, gas, steam and air conditioning
- 25 Natural water; water treatment and water production and distribution services
- 26 Waste-water disposal services; sewage sludge; waste collection, treatment and disposal services; materials recovery services; decontamination and other waste treatment services
- 27 Construction and civil engineering works
- 28 Wholesale and retail trade and repair services of motor vehicles and motorbikes
- 29 Wholesale trade services, except of motor vehicles and motorbikes
- 30 Retail trade services, except of motor vehicles and motorbikes
- 31 Land transport and pipeline transport services
- 32 Maritime and water transport services
- 33 Air transport services
- 34 Warehousing and transport support services
- 35 Postal and courier services
- 36 Accommodation and catering services
- 37 Publishing services
- 38 Film, video and television programme production services; sound recording and music publishing; programming and radio and television broadcasting services
- 39 Telecommunication services
- 40 Computer programming, consultancy and related services; information services
- 41 Financial services (excluding insurance and pension funds)
- 42 Services incidental to insurance, reinsurance and pension funding, except compulsory social security
- 43 Services auxiliary to financial services and insurance services
- 44 Real estate services
- 45 Legal activities, accounting, management consulting, architectural firms
- 46 Scientific research and development services
- 47 Other professional, scientific and technical activities
- 48 Other administration and support activities
- 49 Public administration and defence services; compulsory social security services
- 50 Education services
- 51 Health and social assistance
- 52 Art, entertainment and fun activities
- 53 Other service activities

54 Activities of households as employers for domestic staff; production of undifferentiated goods and services for own use by households and private households

Activities

- 1 Agriculture, forestry
- 2 Fishing
- 3 Mining and quarrying
- 4 Food, beverage and tobacco industries
- 5 Textile, clothing, leather and accessories industries
- 6 Wood industry
- 7 Paper Printing and registration
- 8 Manufacture of coke and refined petroleum products
- 9 Manufacture of chemical substances and products
- 10 Production of pharmaceutical, chemical-medical and botanical articles
- 11 Manufacture of rubber and plastic products
- 12 Other non-metallic mineral processing products
- 13 Manufacture of basic metals and processing of metal products
- 14 Manufacture of computers, electronic and optical equipment
- 15 Manufacture of electrical appliances
- 16 Manufacture of machinery and equipment n.e.c.
- 17 Manufacture of transport equipment
- 18 Other manufacturing, repair and installation of machines
- 19 Electricity, gas, steam and air conditioning supply
- 20 Water supply; sewerage networks, waste treatment activities
- 21 Constructions
- 22 Wholesale and retail trade, repair of motor vehicles and m
- 23 Transport and storage
- 24 Accommodation and catering services
- 25 Publishing, audiovisual, radio and television activities
- 26 Telecommunications
- 27 IT and other information services
- 28 Financial and insurance activities
- 29 Real estate activities
- 30 Legal activities, accounting, management consulting, architectural firms
- 31 Scientific research and development
- 32 Other service activities
- 33 Public administration and defence; compulsory social insurance
- 34 Education 85
- 35 Health and social assistance
- 36 Art, entertainment and fun activities 90 to 93
- 37 Other service activities

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Chapter 3

Implications and repercussions of Pandemic on major economies: a USA analysis

1. A global pandemic scenario: the role of the USA

In March 2020, the President of the United States declared the federal state of emergency due to the COVID-19 pandemic, as stated by some member States of the Federation, which had already declared the public health emergency. The “emergency state” enabled Governors to access the state emergency funds, essential to support the needs of local administrations, to protect consumers from price fluctuations and to adapt the regulations to maximise the healthcare access. The most affected countries have taken further steps to slow down the spread of the virus, in particular by focusing on social distancing that is based on the restriction of free movement, the closure of non-essential businesses, the prohibition of large gatherings, school closures and limits for bars, restaurants and other public places. The duration of the adopted measures differed from one Member State to another: some have quickly lifted the measures, while others have returned to normal with great caution. As the pandemic evolved during the summer season, some restrictions were reintroduced, in particular as regards the limits imposed on gatherings, as well as accommodation, catering and travelling. At federal level, the government has taken measures to ensure access to health tests to detect positive COVID-19 virus, ensuring medical coverage for insured and uninsured residents with 100% federal funding.

However, individual states found it difficult to limit movements within the Federation as a result of the different rules adopted at state level; for this reason, the

degree of transfer of the health impact between Member States remains rather high, slowing down the brake of the pandemic. Indeed, the importance of border closure as a containment measure for the spread of the virus across national and regional level is widely reflected in literature. Since the early stages of the COVID-19 pandemic, the issue of the borders has led to strong concerns (Biancotti et al.2020²⁰, Valsecchi and Durante 2020²¹), and it was estimated that in the Schengen area their closure has mitigated the spread of the virus in the first weeks of the pandemic (Eckardt et al., 2020). Unlike EU countries, the US member States cannot close their borders, but are free to ultimately decide on their social distancing mandates. Therefore, the freedom of states to decide on their confinement policies, coupled with the impossibility of closing borders, creates a far-reaching problem. Recent research points to widespread inter-state spread of the COVID-19 pandemic following public events (Dave et al.2020).

As already highlighted in previous chapters, the pandemic phenomenon due to COVID-19 has led to various shocks across the economic system. First, health-care services are put under pressure because they are called upon to respond to the extraordinary activity to treat, prevent and combat the epidemiological fallout on individuals. The emergency health care services aimed at treating individuals infected with the virus and the continuous requests for home care have increased dramatically, albeit unevenly across the entire territory of each individual State.

A non-secondary side-effect is the world economic emergency exacerbated by the strong uncertainty among economic operators regarding both the duration of the pandemic and the economic recovery, which are triggering processes of change in present and future choices. Actions against the spread of the virus based solely on social

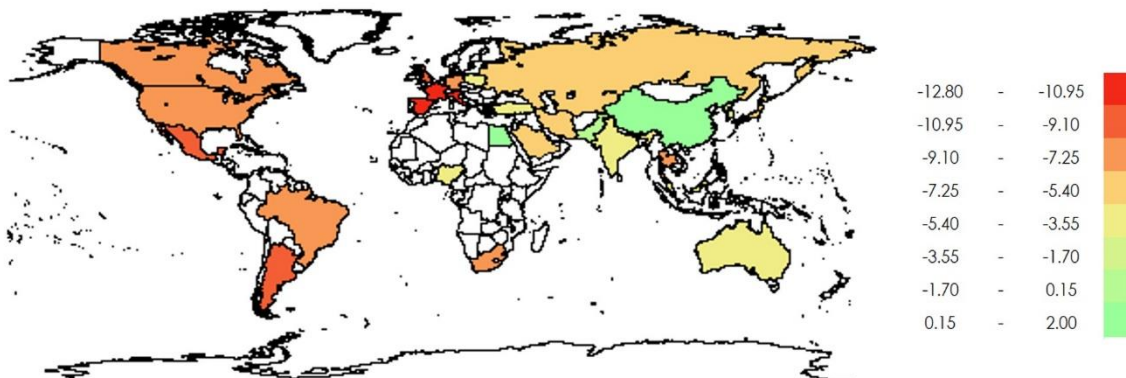
²⁰ "The case for a coordinated COVID-19 response: No country is an island" <https://voxeu.org/article/case-coordinated-covid-19-response-no-country-island>

²¹ "Internal migration and the spread of COVID-19" - <https://voxeu.org/article/internal-migration-and-spread-covid-19>

distancing and the implementation of the lockdown have significant consequences in the economic system on both the supply and the demand side. Restricting production activities to the use of inputs indirectly leads to a decline in demand for intermediate goods and primary factors (labour and capital). Some of these effects will be mitigated by the work of the automatic social shock absorbers, limited however to its technical characteristics.

The limitation of individual freedom in turn leads to a contraction in domestic final demand that can lead to a further reduction of production and, consequently, to a contraction of income generation and distribution. The change in disposable income is therefore expected and with it the change in all operators' behaviour parameters. During the pandemic evolution, it is necessary to make assumptions over the economic impact that the world economies might suffer in the short and medium term, though it can be quite complex. This is essential especially because the crisis of the economically stronger countries directly and indirectly transfers to the entire world economic system. The International Monetary Fund provided a first estimate (June 2020) of the change in GDP expected for some countries, as it is shown in Figure 1.

Figure 1. GDP percentage variation in 2020



Source: author's elaboration of IMF data

In general, the expected change in GDP depends on factors which, if not stabilised, can change the scenarios on a daily basis, aggravating the economic situation. As showed in the figure, the European countries are expected to be the most affected countries by the pandemic as well as Mexico and Argentina in the American Continent. The United States ranks among the countries with the negative economic performance even though the GDP change is expected to be lower than the European Countries. However, it is the country with the highest GDP in the world, a more attentive analysis of the economic impact due to the pandemic for this Country becomes crucial considering the possibility of the crisis transfer to the Rest of the World, further worsening the economic situation.

More precisely, the United States ranks first among the countries most affected by the pandemic in terms of contagion. On the last 15th November 2020, according to data reported by Johns Hopkins University, the contagion exceeded the threshold of 10,900,000 million confirmed cases with 245,600 victims²², and the data continues to evolve daily. Lately the situation seems to be getting worse; it can be defined as "out of control", recording a new record every day. In similar conditions, understanding the trajectory of the economic impact is of fundamental importance, since both the Federal Government and the Local Governments are called upon to take decisions that aim to simultaneously contain the contagion and keep the crisis under control.

Therefore, the choice of policy actions to combat the overall phenomenon requires the adoption of an analysis approach in which the shock attributed to the system must take on characteristics aimed at capturing selectivity. Indeed, the quantification of the pandemic economic impact ignore the precision and the accuracy that must be reserved for the construction and the inclusion of the control variable of the economic model used. The coercive selective blockade of non-essential production activities, the voluntary

²² <https://coronavirus.jhu.edu/map.html>

sectoral blockade of production activities unable to comply with health regulations and the voluntary blockade on the final demand side of deferred consumption require the adoption of a general and disaggregated approach in a mainly short-term context.

Economic modelling in this context finds ample space by proposing a multiplicity of models that analyse the economic effects from different points of view (Carrasco et al., 2013). The goal of this work is to analyse the economic impact of the pandemic in the USA through a dynamic Computable General Equilibrium (DCGE) model based on a Social Accounting Matrix (SAM) for the United States for 2017. The general equilibrium approach can properly assess the general and disaggregated economic impact of public health pandemic emergencies measures in the whole economy, following the income circular flow. This more comprehensive analysis approach overcomes the limits of the partial analysis. Indeed, focusing only on the health sector and incomes has the drawback of excluding effects on other parts of the economy generated by the risk-limiting regulations introduced by governments to contain the risk of contagion (Verikios, 2016 and 2020).

The impact analysis is based on the lockdown policy implemented by the Federal Government, aimed at the temporary closure of non-core activities to restrain the Covid-19 contagion. This type of measure hits the supply side, putting a strain on the production system. However, it implicitly encompasses also a demand side shock by triggering a drop in final demand, because of the reduction of the final consumption of selected goods or services (e.g. transports), in line with the data reported by the BEA (Bureau of Economic Analysis). Some rigidities should also be considered with regard to the public spending and the public investment capacity. The Federal Government can implement economic policy manoeuvres by resorting to deficit, and consequently does not tie choices to disposable income. The same rigidity should be considered for the Rest of the

world, that is considered an Institutional Sectors whose behaviour is exogenous. To estimate the time trajectory, a period of 5 years is considered sufficient, considering the politic cycle and the time span for the fiscal policy plans. The analysis carried out with the DCGE model does not take into account corrective measures deriving from the “anti-crisis package” implemented by the Federal and Local Governments to face promptly the negative economic impact of the pandemic. The outcome of the analysis therefore, can be considered as the strength of the pandemic on the system, or alternatively, as the worst possible results of the crisis. Within the model, therefore, only the ordinary automatic shock absorbers are active, in particular taxes and transfers among Institutional Sectors.

2. How the economic crisis impacted the USA

The current pandemic crisis has clearly set in motion the mechanisms for forecasting the fall in GDP in the world’s largest countries, with the aim of anticipating the economic impact and, above all, what short-term intervention can be put in place to counterbalance the economic crisis. The COVID-19 pandemic in the United States disrupted the longest economic expansion of this Country, causing far-reaching economic collateral damages that will require an extended period to be repaired and restored to pre-pandemic levels. The following charts show quarterly GDP²³ development from 1947 to the second quarter of 2020 and the relative growth rate. As showed in the figure, the United States experienced the largest decline in GDP since the post-war period in 2020. Since 1947 and throughout the decade of the 50s, the fluctuation in GDP shows some instability, which narrows until the 80s, before becoming stable until the present day, with a negative peak in the last quarter of 2008 and the first quarter of 2009, following the

²³Sources: Economic Research — Federal Reserve Bank of St. Louis — <https://fred.stlouisfed.org/series/GDP>

“Great Recession” crisis. However, it is noted that the 2008 financial crisis led to a much smaller fall in GDP than the Covid-19 pandemic in 2020.

Figure 2. GDP time series in the USA (billion of dollars)

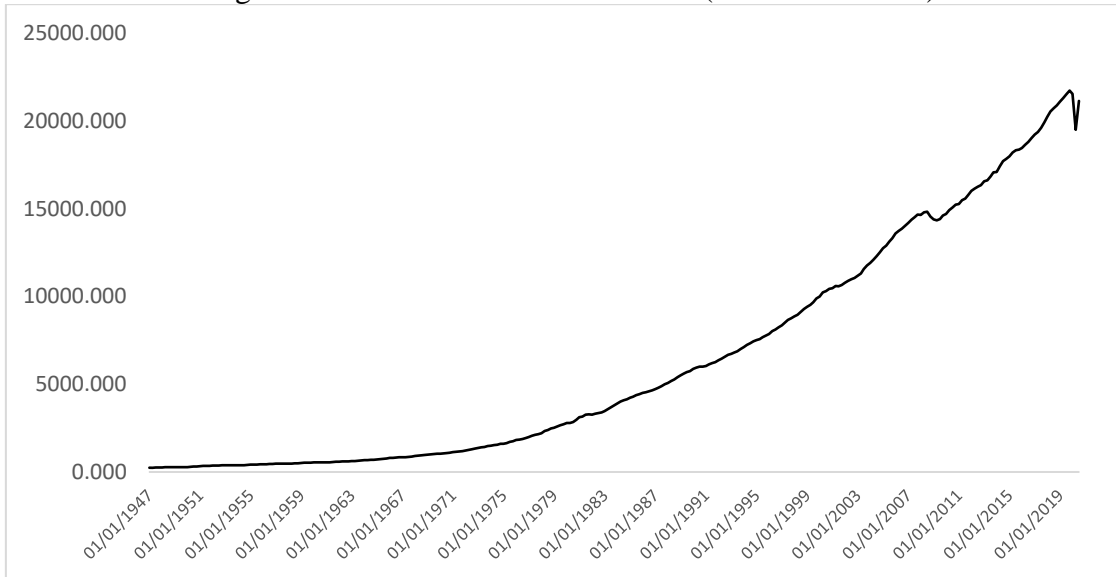
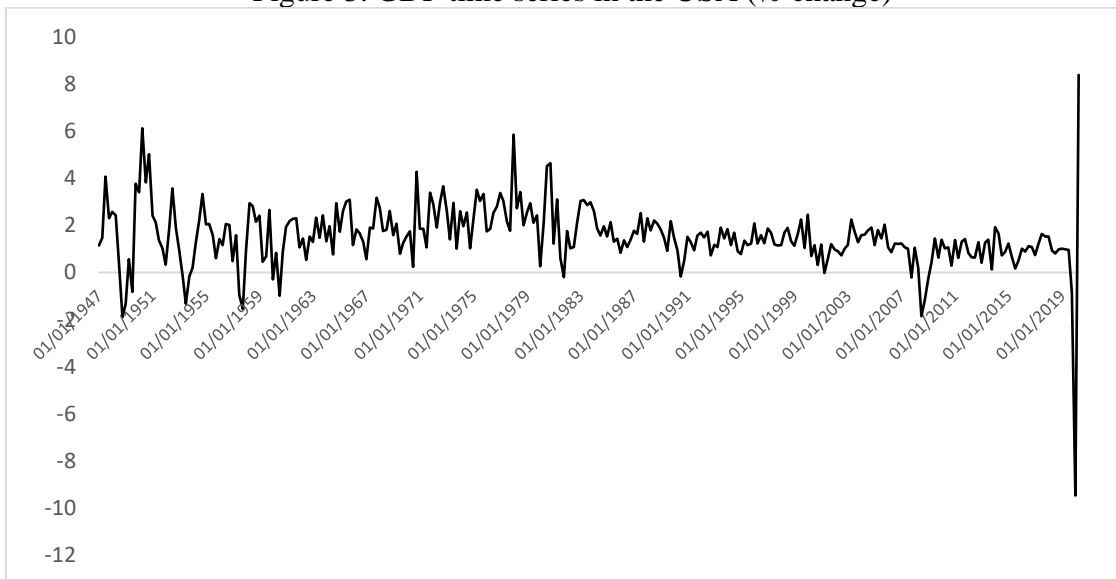


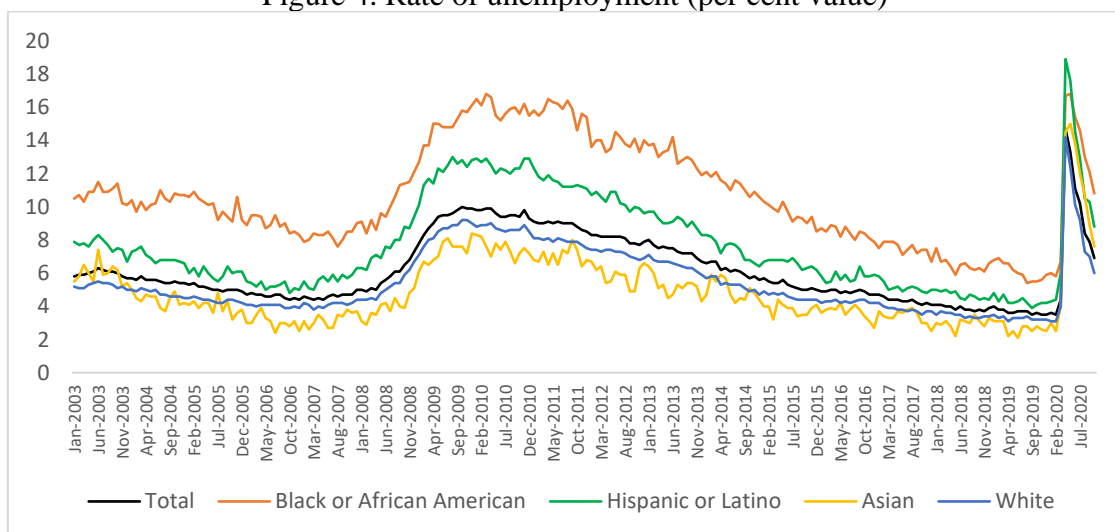
Figure 3. GDP time series in the USA (% change)



On the production side, the economic impact of Covid-19 is substantial. The total production collapsed due to the lockdown and it is likely that only partial recovery can be verified. Those activities that are more sensitive to social distancing policy will only be able to recover gradually, and to the extent that customers regain sufficient confidence to return to the previous consumption pattern. However, the latter is not only linked to

the degree of confidence, but is directly linked to the level of income and employment. According to the IMF²⁴, the poorest households bear the greatest weight of the crisis, which would imply a possible systemic increase the already high U.S. poverty rate, if compared to other advanced economies. It mainly derives from the important racial dimension, with Afro-Americans and Hispanics-Latinos that more likely could fall into poverty than white families. Indeed, the unemployment rate among Afro-Americans²⁵ in the United States was twice as high as that of the White-Caucasian population in the first quarter of 2020²⁶. The chart below shows the unemployment rate broken down by ethnicity from January 2003 to October 2020. The first information concerns the behavior of the total unemployment rate, which, immediately after the 2008 crisis, tended to decline until the spread of pandemic emergency. The unemployment rate is lower for people with Asian ethnicity, while for White-Caucasian people the unemployment rate is close to the total value. The unemployment rate is much higher for people with the Hispano-Latina ethnicity and even more for Afro-Americans.

Figure 4. Rate of unemployment (per cent value)



²⁴Sources: Annual Report of the Executive Board

²⁵Sources: <https://www.infodata.ilsole24ore.com/2020/06/05/usa-disoccupazione-doppio/>

²⁶Sources: U.S. Bureau of Labor Statistics — <https://www.bls.gov/charts/employment-situation/civilian-unemployment-rate.htm>

Among Afro-Americans, unemployed people aged 16-29 are the 22%, those aged 20-24 are the 14%, those aged 35-34 are the 8% and those aged 35-54 are the 5%. Among the Latin population, the condition is very similar, albeit with lower unemployment rates. In 2018, the 60% of the Afro-American population earned less than USD 50,000 per year, compared with the 40% of the white population in the same condition. One in five 'black' must be enough less than USD 15,000 per year, and another 12% less than USD 25 thousand. The COVID-19 pandemic furtherly affected the most vulnerable individuals. It is interesting to note that the peak in the unemployment rate is relevant for Afro-Americans and Hispanics-Latinos, while the unemployment rate for Asian ethnicity is almost similar to that of the White-Caucasian ethnicity.

The different distribution of unemployment among ethnicities does not represent the only reason for the poverty in US. There is also an increasing concern over the middle class of income that is shrinking. The share of American people in a middle-income household decreased from 61% of the total Americans in 1971 to 51% in 2019 (Pew Research data²⁷). During this period, the share of adults in the upper income group increased from 14% to 20%, while the percentage in the lower income group increased from 25% to 29%. In absolute terms, in 2018 the median income of an Afro-American household was around USD 41,000, for a Latin household USD 54,000, for a White-Caucasian household USD 70,000, while the median income of an Asian household, the richest of all, exceeds USD 87,000 per year. The poverty rate for Afro-Americans and Hispanics is particularly severe, with the 27% and the 23.5% of people below the poverty line respectively. In 1968, one third of Afro-Americans (34%) lived in poverty. In thirty years, the median income of Afro-American households has risen from USD 34,000 in 1990 to USD 41,000 today (+21%). White households' income rose from USD 56,000 in

²⁷Sources: <https://www.pewresearch.org/>

1990 to USD 70,000 thousand in 2018 (+24%). This means that in 1990 the gap between white and black incomes was USD 22,000 per year, while in 2018 it rose to USD 29,000. Overall, income inequality in the United States has widened in recent decades, while upward mobility has decreased. A small proportion of Americans hold most of the wealth in this country. This is complemented by the new fiscal efforts of the US administration to fight the pandemic, while major international organizations consider that further efforts would be needed to address a number of deep-rooted socio-economic challenges that continue to confront the US. In fact, net of economic policy measures, the OECD estimates a fall in GDP of 8.5%²⁸; of the same magnitude is the IMF's²⁹ estimate of -8 % of GDP in September 2020. According to the estimates in October 2020, the fall in GDP would stabilize at -4.3%, thus recovering 3.7 percentage points. The improvement is due to the inclusion, in the estimation model, of the expansionary policies implemented by the Federal Government and the State Governments. The fiscal space and the space for monetary policy loosening quickly deployed in support of the economy. Tax policy has strongly responded to the crisis and provided important financial relief to the unemployed and companies in difficulty during the first phase of lockdown. This fiscal support could be extended, if necessary, even in the event of successive waves, inevitably leading to a further increase in the budget deficit. The deficits indeed, were promptly financed by abundant liquidity transfers to the Federal Government through the purchase of bonds by the Federal Reserve, which, however, adds long-term challenges to public debt, creating pressure on the pension system and health expenditure. The IMF points out that the measures implemented so far have led to an increase in public debt, which is expected to rise to 160% in 2030. According to data from the Treasury Department³⁰, the federal

²⁸Sources: OECD Economic Surveys UNITED STATES

²⁹Sources: Consensus Forecasts.

³⁰Sources: <https://www.ilsole24ore.com/art/coronavirus-deficit-triplicato-stati-uniti-nuovi-poveri-sono-8-milioni-AD6hXiw>

budget deficit amounted to USD 3,100 billion in October 2020, more than tripled in the last fiscal year due to aid plans to limit the effects of the COVID-19 pandemic. The US deficit has now risen to 16% of GDP in the year to September, the highest figure since the end of World War II in 1945. The deficit/GDP ratio at the end of the financial crisis in 2009 was around 10%, and had fallen considerably in 2015. The low monetary rates allowed the Treasury to have very low borrowing costs to finance public spending and the issuance of new debt, leading to a 9% decrease in the payment of interest on the debt during the year. However, according to estimates by the non-partisan Budget Office of Congress, public debt in the US economy could be almost twice as high as US GDP in 2050, owing to an increasing ageing population and higher spending on health care and retirement and disability pensions linked to federal medical and social security programs. According to the Treasury, federal expenditure overall increased by 47.3% to USD 6,550 billion in the fiscal year 2020, driven by unemployment benefits and aid to small and medium-sized companies approved by the US President and the Congress at the end of March, with more than USD 2,200 billion in Cares Act appropriations. In the long run, there are concerns that rising debt could lead to higher inflation. Finally, as the pandemic continues, job losses due to the economic contraction can translate into an increase in household indebtedness. Corporate debt levels and the risk of default are also worrying.

3. Building a Social Accounting Matrix

According to Pyatt and Round (1985) and Reinert and Roland-Holst (1997) the SAM is the accounting scheme that can better represent the complex links of an economic system, by capturing the transactions between all economic agents. The pioneering work of Sir Richard Stone's on the construction and study of SAMs was based on the UK and some other industrialised countries, but it was extended to the analysis of

the poverty problems and income distribution in developing countries (Pyatt and Thorbecke, 1976). SAM use presents specific characteristics in an economic framework of general equilibrium, which makes it the most suitable instrument for simulations and impact analyses, because it captures all the transmission and feedback impulses in the different stages of production, distribution, accumulation and use of income. The SAM's analytical structure is the basis for modelling purposes, in particular for both fixed-price multiplier models, and the calibration of computable general equilibrium models (CGE) (Pyatt, 1988).

The structure of the SAM built for the US is summarised in Table 1. It records the flows among the different operators/accounts at the various stages of the circular flow of income. Transactions represent an inflow of resources for the operator and/or the account to which the line is headed and a loss of resources for the operator/account to which the column is headed. Thanks to this scheme, it is possible to disentangle the effects of an exogenous shock or a policy measure on the main macroeconomic variables referred to the production domain, as well as on income distribution among Institutional Sectors. They can be identified as Households, Financial and non-Financial Corporations, Local and Federal Government.

In the Input/Output portion, the U.S. SAM is characterised by a disaggregation of the production processes in 73 products and 71 industries (complete list is available in Appendix 3). The Value Added generation is related to the compensations of labour and capital, the 2 primary factors. Institutional Sectors can be split into 4 private (non-Financial Corporations, Financial Corporations, Households, Rest of the World), and 2 public: Federal Government State and Local Governments.

Table1. The structure of interactions among agents in the Social Accounting Matrix

	Commodities $i = 1, \dots, 73$	Activities $j = 1, \dots, 71$	Primary Factors $f = 1, 2$	Taxes on output	Taxes on activities	Private Inst. Sectors $r = 1, \dots, 4$	Government $g = 1, \dots, 2$	Income Taxes	Investments	Rest of the world
Commodities $i = 1, \dots, 73$		Intermediate Consumption				Private Final Consumptions	Government Final Consumption		Investments	Exports
Activities $j = 1, \dots, 71$	Output									
Primary Factors $f = 1, 2$		Value added at factors costs								Primary Incomes
Taxes on Output	Indirect Taxes on Output									
Taxes on Activity		Indirect Taxes on activities								
Private Inst. Sectors $r = 1, \dots, 4$			Primary Incomes			Transfers among Private Institutions	Transfers public to private institutions.			Transfers from Abroad
Government $g = 1, \dots, 2$			Primary Incomes	Net Indirect Taxes on output	Net Indirect Taxes on activities	Transfers private to public institutions	Transfers Among Public Institutions	Income Tax revenues		Transfers from Abroad
Income Taxes						Income Tax				
Savings						Private savings	Public savings			(+/-) Savings
Rest of the world	Imports		Primary Incomes			Transfers abroad	Transfers to abroad			

The Value added is attributed to Institutional Sectors in the primary income allocation, while transfers among Institutional Sectors form part of the secondary distribution of income. Transfers occurs from domestic private and public sectors to other private and public sectors and to the Rest of the World. Similarly, transfers from the Rest of the world goes to private and public sectors. The circular flow of income closes in the SAM with the precise description of the use of income, related to the final demand (consumption, investment, export) as well as to capital accumulation. Separate accounts distinguish the Investment and savings of public and private sectors.

The SAM also includes taxes on activities, on products and on incomes, identifying the taxpayers (products and activities) as well as the Institutional Sector that collects the revenues (federal government and State and local governments) in the primary and secondary distribution of income.

The Bureau of Economic Analysis (BEA) data on National Accounts (Supply and Use Tables) as well as on Institutional Sectors accounts have been used to construct the SAM for 2017.

The definitions of Institutional Sectors accounts respond to the logic of the System of National Accounts (SNA), which BEA submits regularly to the OECD, and some differences arise with respect to the National Income and Product Accounts (NIPAs). This required the reconciliation of some items: in the production part, some entities are included in an Institutional Sector, while in the income portion they are included in another Institutional Sector (McCulla et al., 2015). These differences have been made consistent by allocating the so-called statistical discrepancy to the gross operating surplus paid by the rest of the world.

4. A dynamic CGE model to assess effects and pandemic repercussions

The DCGE built for this analysis takes the form of a system of simultaneous linear and non-linear equations, and solves a recursive optimization problem. This type of model is widely used in the economic literature since it allows quantifying the direct, indirect and welfare effects of exogenous shocks on the entire economy (Pretaroli et al, 2018).

The application of this methodology was discussed in the recent literature as regard to the analysis of the economic impact of Covid-19. Indeed, the pandemic has led governments to design large-scale recovery plans to overcome this crisis and such interventions cannot fail to take into account the orientation in eco-friendly building projects to stimulate the economy while achieving environmental gains through the reduction of energy consumption and related greenhouse gas emissions. Through a CGE model applied to the Belgian economy (Lahcen et al., 2020), the economic impact of the pandemic is assessed through a comparative analysis of the changes occurred in the main macroeconomic variables and the CO₂ emissions. The results show that the reduction of

CO₂ emissions is less than proportional to the economic impact and that, through well-designed public policies, it is possible to reverse the trend and achieve economic growth and lower emissions.

In another study based on the Italian economy (Ahmed et al, 2018), a dynamic CGE model was used to empirically investigate the impact of the ECB's Quantitative Easing (QE) policy. In this study the Italian SAM was expanded by combining financial data with real economy data (FSAM) to assess the direct and indirect impact of the unconventional monetary expansion promoted by ECB on consumption and investment.

The CGE model was also used to analyse the economic impact of an influenza pandemic (Smith et al., 2011). This study analysed the impact that a global pandemic of infectious diseases had in particular on the financial system for the U.K.

Through the application of a quarterly CGE model, the economic impact of a hypothetical H1N1 pandemic was also simulated (Dixon et al., 2010). The quarterly periodicity made it possible to analyse the short-term behaviour of a pandemic, highlighting potentially serious economic effects in the peak quarter; fading over the year. The results show that economic effects are more sensitive to shocks on the demand side than on the supply side, such as reduced productivity, and this suggests that demand stimulation policies could be an appropriate economic response to a major epidemic.

The present study develops a dynamic CGE model based on the intertemporal maximisation of households utility function subject to the constraints represented by the total availability of resources over the time and the capital accumulation condition. The complete specification of quantities and prices is determined by the equilibrium between demand and supply in goods and factors, as well as by the zero-profit condition in all the markets. However, the model includes some rigidities in relation to the behaviour of the Public Sectors (Local and Federal Governments) and the Rest of the World (Paltsev,

2004). The main features of the model are described below, while a complete specification of the main equations of the model is detailed in Appendix 1.

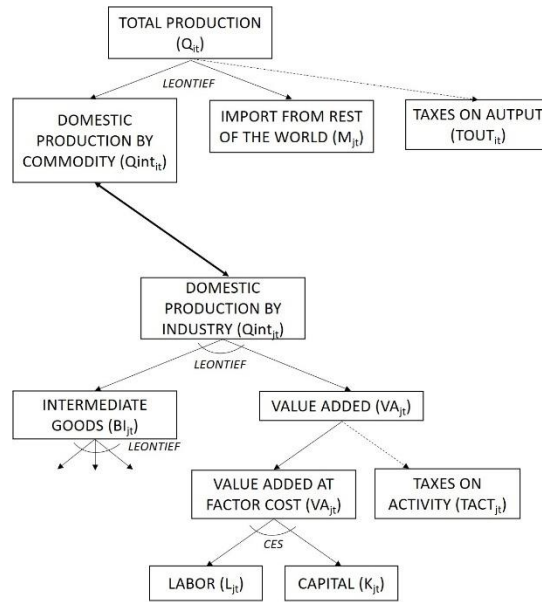
The model dynamism is governed by the condition of capital accumulation, assuming that the total value of the capital stock in each period is obtained from the sum of the capital stock and investments generated in the previous time. Thus, the model follows the Ramsey analysis of optimal economic growth under certainty (Lau, Pahlke, Rutheford, 2000). Since the model is calibrated on the SAM flows, the definition of the steady state growth path requires the calibration of selected parameters that should be consistent with the initial SAM equilibrium. In particular, the exogenous economic growth, the depreciation of capital and the interest rates should be consistent with the initial level of investments and capital stock. For this reason, the exogenous growth rate and the interest rate compatible with the steady state path are assumed to be 1% and 2.5% respectively. These figures are consistent with the OECD Economic Outlook forecasts of November 2019, coupled with the OECD Interim Economic Outlook Forecasts of March 2020. The depreciation rate is derived to make the exogenous parameters and the SAM flows on Investment consistent. The model is characterised by a finite time horizon (Paltsev, 2004), set in 5 years. This represents a closing condition that allows the model to converge to a stable equilibrium in the last period, establishing the constraint that the level of growth of aggregate investment must equal the growth rate of savings in the last period.

The DCGE takes the line of structuralist models, i.e. models that consider as fundamental structural factors such as the distribution of income and wealth, the type and degree of specialization in foreign trade, the density of production chains, the functioning of financial intermediaries. Indeed, basing the analysis on institutions and economic policy is the main feature of the structuralist approach (Taylor, 1990).

On the supply side, production is modelled through a nested production function by stages of aggregation, according to the scheme shown in Figure 5.

Starting from the first stage, total production by goods is obtained through the combination of the domestic production³¹ and imported goods from the rest of the world, using the imperfect substitutability assumption (Armington, 1969). The aggregation is obtained using a CES function, which allows to easily switch to other functional forms (Leontief, Cobb-Douglas), through the setting of the elasticity parameters³².

Figure 5. Production function



The aggregation also takes into account the presence of taxes on output that influence the price of the goods. The first stage aggregation is shown in equations 1

$$P_{it}(1 - Tax_{it}^{out}) = \left(\delta_i^{dom} P_{dom,it}^{(1-\sigma_{Q_{dom}})} + (1 - \delta_i^{dom}) P m_{it}^{(1-\sigma_{Q_{dom}})} \right)^{\frac{1}{1-\sigma_{Q_{dom}}}} \quad (1)$$

³¹ The domestic production by goods is obtained adding up the production by industries.

³² Leontief function is obtained by setting the elasticity value of zero, and this implies non-substitutability between domestic production and imported goods.

where P_{it} represents the price of goods, $P_{dom,it}$ are prices of domestic goods, Pm_{it} are prices of imports from the rest of the world, δ_i^{dom} represents the share of domestic goods in the total production by type of product and $\sigma_{Q_{dom}}$ represents the elasticity of substitution between domestic and imported goods. Tax_{it}^{out} represents the level of taxes on output.

In the second stage the domestic production is modelled. As already seen in the previous chapter, with regard to the static CGE model, with regard to domestic production, it is necessary to consider the relationship between goods and industries. In fact, different types of industries can produce several type of goods and therefore the production can be seen from two different point of view. Considering that for each industry the total value of production is equal to the value of primary factors used in the production process, the domestic production is obtained through the combination between intermediates goods and value added following a Leontief function

$$P_{dom,jt}(1 - Tax_{jt}^{act}) = \left(\sum_i \delta_{ij}^D Pbi_{jt}^{(1-\sigma_a)} + \sum_i (1 - \delta_{ij}^D) Pva_{jt}^{(1-\sigma_a)} \right)^{\frac{1}{1-\sigma_a}} \quad (2)$$

where Pbi_{jt} represents prices of intermediate goods, Pva_{jt} represents prices of value added, δ_{ij}^D represents the share of intermediate activity in total production and σ_a is the elasticity of substitution between intermediate goods and value added. Tax_{jt}^{act} represents the level of taxes on activities

Value added and intermediate goods are modelled in the third nesting stage. The formation of the intermediate goods aggregate is obtained through the combination of individual types of intermediate goods

$$Pbi_{jt} = \sum_i \left(\delta_{ij} P_{jt}^{(1-\sigma_{BI})} \right)^{\frac{1}{1-\sigma_{BI}}} \quad (3)$$

where P_{jt} represents average price on goods market from the market clearing condition, δ_{ij} represents share of the cost by intermediate goods in the total cost and σ_{BI} is the elasticity of substitution between intermediate goods.

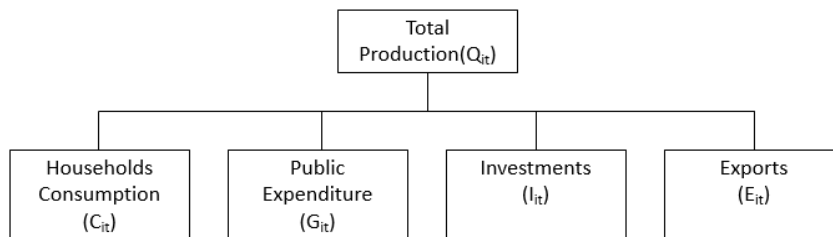
Finally, the value added is obtained through the combination of the primary factors, labour and capital, and their price is formed according to the balance between supply and demand, using an elasticity of substitution between capital and labour equal to 0.3194 for the USA (according to Van der Werf, 2007). The Value Added formation also includes taxes on activities.

$$Pva_{jt} = (\delta_j^v \cdot PL_t^{1-\sigma_v} + (1 - \delta_j^v) \cdot rk_t^{1-\sigma_v})^{\frac{1}{1-\sigma_v}} \quad (4)$$

Where PL_t is the price of labour and rk_t is the return on capital, δ_j^v represents the share of labour in the total of primary factors and σ_v is elasticity of substitution between labour and capital.

The overall supply of the economic system, which corresponds to the total production, is distributed among the demand components, as shown in Figure 6.

Figure 6. Total production by demand components



Household consumption derives from the maximisation of the intertemporal utility function, which establishes the level of consumption and savings in each period:

$$\max U^{hh} = \sum_{t=0}^T \left[\left(\frac{1}{1+\rho} \right)^t C_t^{hh} \right] \quad (5)$$

ρ is the exogenous preferably intertemporal parameter according to Ramsey's model, that in steady state is equal to the interest rate, and the aggregate consumption by institutional sector is obtained as:

$$C_t^{hh} = \sum_i cons_{it}^{hh} \quad (6)$$

Then, the formation of household consumption is based on the combination of the quantity demanded and the consumption price index. This latter is obtained as:

$$P_t^C = \left(\sum_i \delta_i^C \cdot P_{it}^{(1-\sigma_C)} \right)^{\frac{1}{1-\sigma_C}} \quad (7)$$

where δ_i^C is the share of each good consumption on the total consumption and σ_C is the elasticity of substitution between goods in the consumption aggregate. The total consumption is thus a function of the consumption price index and consumer utility, depending on consumption and savings. Thus, the demand for aggregate consumption by Institutional Sector is represented as follows:

$$c_{it}^{hh} = \delta_i^C \cdot U^h \cdot \left(\frac{P_t^C}{P_{it}} \right)^{\sigma_C} \quad (8)$$

The constraint is represented by present and future disposable income.

The Public consumption expenditure is considered exogenous, and represents an element of rigidity of the model. In fact, it is assumed that public expenditure does not vary endogenously because the government can finance expenditure from the deficit, and consequently, government choices are not linked to the utility function maximisation

$$U^g = \sum_{t=0}^T (G_t^g + def_t^g) \quad (9)$$

where def_t^g is the government saving/indebtedness, and G_t^g is the total public expenditure for each public Institutional Sector, that is

$$G_t^g = \sum_i pe_{it}^g \quad (10)$$

where pe_{it}^g is the public expenditure by public Institutional Sector and by goods.

Financial and non-financial corporations shift their disposable income to savings, being consumption equal to zero.

$$S_t^{fc,nfc} = F(K_t, L_t) \quad (11)$$

The final demand for investment is generated through the combination of the goods demanded for investment according to the breakdown in the SAM, using a CES function:

$$P_t^I = \left(\sum_i \delta_i^I \cdot P_{it}^{(1-\sigma_I)} \right)^{\frac{1}{1-\sigma_I}} \quad (12)$$

where δ_i^I is the investment share of each goods in the total gross investment in the benchmark, and σ_I is the elasticity of substitution between investment goods. Then, demand of each investment good is obtained as:

$$I_{it} = \delta_i^I \cdot I_t \cdot \left(\frac{P_t^I}{P_{it}} \right)^{\sigma_I} \quad (13)$$

The demand of goods for export is a function of a number of exogenous parameters, namely the income of the Rest of the World, the nominal exchange rate, the level of foreign prices, and the rate of foreign inflation; it also depend on national prices, which, on the contrary, are formed endogenously

$$e_{it} = \delta_i^E \cdot E_t \cdot \left(\frac{pmw_t(1 + \pi^t)/exr_t}{P_{it}} \right)^{\sigma_E} \quad (14)$$

where δ_i^E is the export share of each goods in the total export in the benchmark, σ_E is the elasticity of substitution between export goods, pmw_t is the price of foreign goods, π is the level of foreign inflation and exr_t is the nominal exchange rate.

With regard to the composition of income by Institutional Sector, in the first stage of income allocation, they receive income from primary factors (compensation of employees and gross operating surplus) according to their property share. From the formation of primary income, it is possible to move on to the disposable income by adding the net transfers from/to other Institutional Sectors minus taxes on income. The disposable income for private Institutional Sectors in each period is calculated as follows

$$Y_t^{is} = YF_t^{is} \left(1 - \sum_{inc} ty_{inc}^{is} - \sum_{tras} tr_{tras}^{is}\right) + \sum_{is} \sum_{tras} tr_{tras}^{is} YF_t^{is} + \sum_g Tr_t^g + Tr_t^{row} \quad (15)$$

where the income from primary factors in each period $YF_t^{is} = L_t^{is} p l_t + K_t^{is} r k_t$, is net of income taxes and transfers to other Institutional Sectors, and adds transfers from other Institutional Sectors ($tr_{tras}^{is} YF_t^{is}$) as well as transfers from government (Tr_t^g) and from the rest of the world (Tr_t^{row}). Private Institutional Sectors' gross disposable income at present value derives from the actualisation of disposable income in each period plus the stock of capital accumulated during the time horizon of the model, as follows:

$$Y^{is} = \sum_t Y_t^{is} \left(\frac{1}{1+r}\right)^t + KS_{tfirst}^{is} p k_{tfirst} - KS_{tlast}^{is} p k_{tlast} \left(\frac{1}{1+r}\right)^{tlast} \quad (16)$$

Transfers from the Public Administration and the Rest of the World are considered exogenous, and therefore not depending on disposable income.

The closure rule of the model is generated by market balances, both of goods and of primary factors, through price adjustments as follows:

$$q_{it} = \sum_j b_{ijt} + \sum_{hh} c_{it}^{hh} + \sum_g p e_{it}^g + I_{it} + e_{it} \quad (17)$$

where Q_{it} is the total production by product in each period, b_{ijt} are the intermediate goods, C_{it}^{hh} are households consumption, G_{it}^g is the public expenditure, I_{it} are the investments, E_{it} are the exports to the Rest of the world.

Gross investment equals gross savings:

$$I_t = \sum_{si} S_t^{si} \quad (18)$$

A ‘special treatment’ of capital in the last period of the model is needed, to approximate infinite horizon with model’s finite periods, following Rutheford (1997). Capital level of terminal period is a variable, with endogenous capital accumulation. This allows to avoid that in the last period all capital would be consumed, and nothing would be invested. In this model, investment in the terminal period is constrained to grow at the same rate as saving

$$\frac{I_T}{I_{T-1}} = \frac{S_T}{S_{T-1}} \quad (19)$$

This has the advantage of imposing a balanced growth in the terminal period, without requiring that the model achieve the steady-state growth. In addition, it is respected the condition that the total value of the capital stock in each period is obtained from the sum of the capital stock and investments at the previous time:

$$K_{t+1} = K_t(1 - \delta) + I_t \quad (20)$$

where δ represents the capital depreciation rate, and this rule guarantees the model dynamism.

5. A Demand-Supply shock scenario

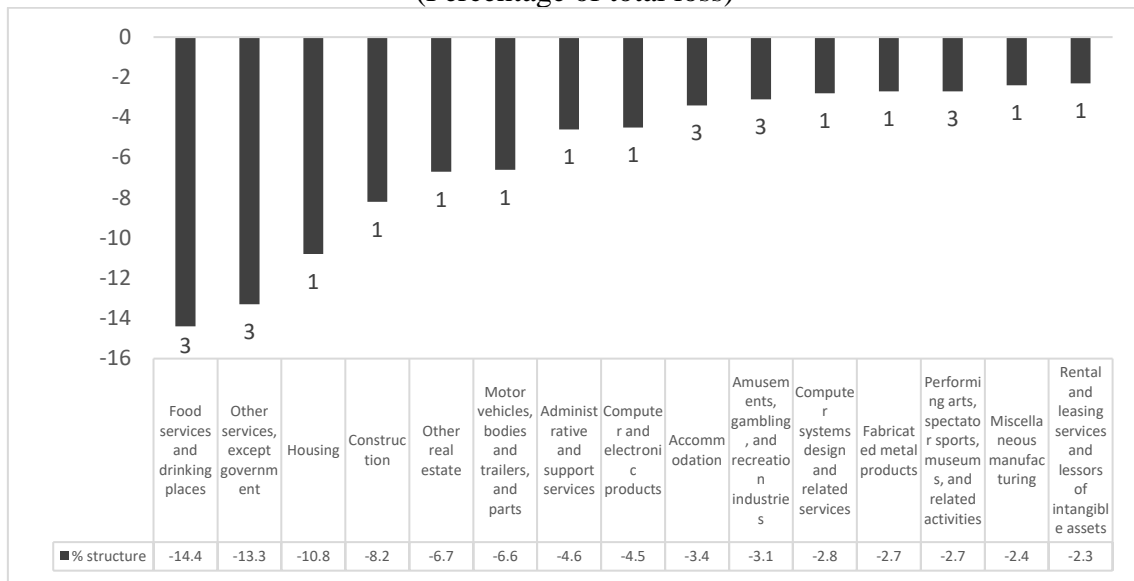
The DCGE SAM based model for USA is constructed to simulate and analyse the context determined by the COVID-19. In particular, a set of selective blocks on activities are introduced in the first period as a typical shock affecting the supply side of the economy. The interruption of the production processes is for one-month for non-essential activities and for three months for entertainment-related activities, accommodation and catering services related to tourism, as reported in Table 2. The productivity loss of the entire economic system is estimated at 4.42%. Figure 7 presents the percentage

contributions of the top 15 activities with the greatest impact in terms of production losses; the figure also shows the lockdown months for each activity. It is possible to note that the activities related to "Food services and drinking places" and "Other services, except government" suffer the greatest impact in terms of lost productivity, and this result is due to the prolonged lockdown time. For the most affected activities by the one-month lockdown, there is a strong impact in "Housing" and "Constructions", key productive activities of the U.S. economy, which together account for 10.1% of total production.

Table 2. Activities affected by lockdown

Activities	Months of lockdown
Construction	1
Wood products	1
Nonmetallic mineral products	1
Fabricated metal products	1
Computer and electronic products	1
Electrical equipment, appliances, and components	1
Motor vehicles, bodies and trailers, and parts	1
Other transportation equipment	1
Furniture and related products	1
Miscellaneous manufacturing	1
Air transportation	1
Rail transportation	1
Water transportation	1
Transit and ground passenger transportation	1
Other transportation and support activities	1
Housing	1
Other real estate	1
Rental and leasing services and lessors of intangible assets	1
Computer systems design and related services	1
Administrative and support services	1
Performing arts, spectator sports, museums, and related activities	3
Amusements, gambling, and recreation industries	3
Accommodation	3
Food services and drinking places	3
Other services, except government	3
Non-comparable imports and rest-of-the-world adjustment	1
Scrap, used and second-hand goods	1

Figure 7. Output changes - lost by commodities
(Percentage of total loss)



The lockdown measure also generated a reorganisation of people's daily life, changing the size of consumption, the composition of the consumer basket and the choices between consumption and saving for precautionary purposes. Table 3 shows the percentage changes in household consumption by comparing the 2019 values with the 2020 values.

Comparing household consumption in April 2019 with household consumption in April 2020, allows observing that a decrease in the number of goods for all types of products is recorded, with the exception of food, housing, insurance and financial services. The same result is obtained by comparing the total consumption in March, April and May 2019 with the same months in 2020.

Moreover, the BEA, in its first estimates of household consumption, showed a decrease between March and April 2020 of about 13%, with a significant impact on aggregate demand.

Table 3. Household consumption change between 2019 and 2020

Consumption	April 2019 / 2020 % change	March - April - May 2019 /2020 % change
Goods	-14.6	-9.3
Durable goods	-23.8	-19.0
Motor vehicles and parts	-31.8	-28.4
Furnishings and durable household equipment	-21.1	-15.1
Recreational goods and vehicles	-7.5	-3.6
Other durable goods	-38.3	-30.4
Nondurable goods	-10.0	-4.4
Food and beverages purchased for off- premises consumption	1.6	8.9
Clothing and footwear	-49.0	-42.0
Gasoline and other energy goods	-34.7	-26.1
Other nondurable goods	-0.8	2.2
Services	-18.5	-14.8
Household consumption expenditures (for services)	-22.8	-18.3
Housing and utilities	1.9	1.7
Health care	-39.1	-30.8
Transportation services	-47.5	-39.3
Recreation services	-59.2	-49.0
Food services and accommodations	-51.4	-43.0
Financial services and insurance	3.4	3.1
Other services	-18.8	-14.0

As reported in a recent webinar held by Princeton University³³, in the first months of the pandemic, spending declined much more for the rich than for the poor (top 25% vs. bottom 25%). The highest reduction depends upon the lower spending on personal services, both in percentage and absolute terms, and indicates that there was not a reduction in purchasing power but rather a reduction related to the virus fear.

Considering that the change in consumption occurs in the very short term, with the possibility of reversal in the following months, it is necessary to include in the model this pandemic effect. Therefore, together with the supply-side shock, a shock on the demand side is also considered when implementing the pandemic scenario. Clearly, the above mentioned change in consumption refers to the drop in consumption in April alone,

³³ Webinar: Chetty R., 2020. The economic impact of Covid-19. Real-Time evidence from private sector data, Bendheim Center for Finance, Princeton University.

while consumption in the SAM represents the annual total. It is therefore necessary to make a transformation that considers this change as an acquired value and carried forward on an annual basis.

The main effects on macroeconomic aggregates are shown in Table 4. As can be seen, the pandemic event based on the supply and demand shocks, generates a contraction of the GDP of about 10.7% in the first period, and the negative effect continues over the next four periods, although the contraction remains rather slight.

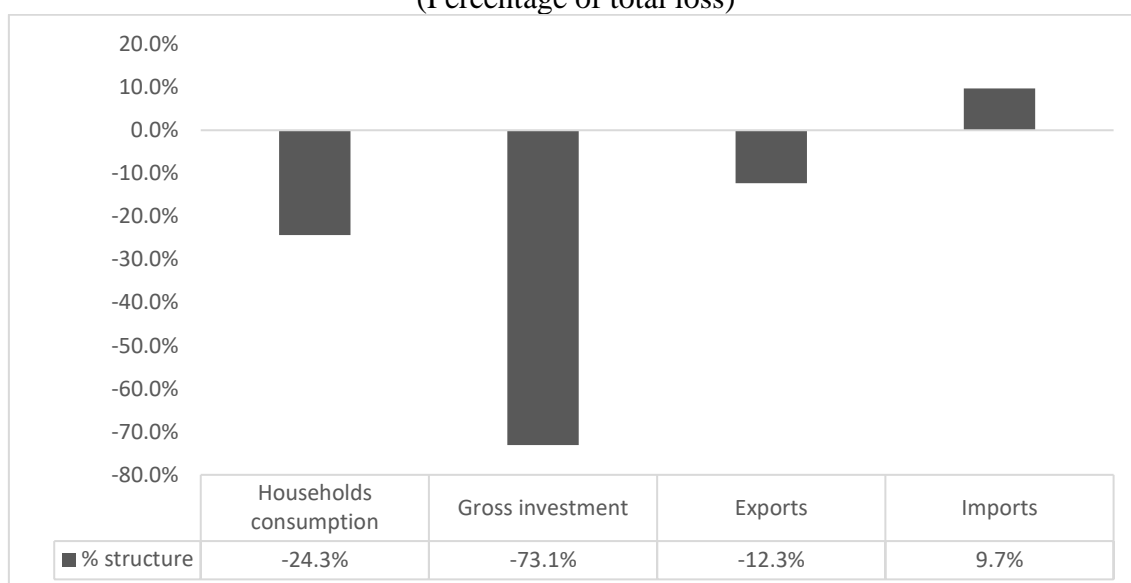
Table 4. Lockdown impact on macroeconomics variables
(Percent change w.r.t. the benchmark)

Real Variables	t1	t2	t3	t4	t5
GDP	-10.7	-0.4	-0.4	-0.4	-0.4
Households consumption	-4.2	-0.5	-0.5	-0.5	-0.5
Gross investment	-35.1	0.6	0.6	0.6	0.6
Exports	-11.3	0.0	0.0	0.0	0.0
Imports	-7.4	-0.4	-0.4	-0.4	-0.4

The decrease in GDP is mainly due to the decline in investments, who are suffering a contraction of 35.1% compared with the benchmark and account for more than 70% of the drop in aggregate demand, as shown in Figure 8, but in subsequent periods, however, there is a recovery.

As far as household consumption is concerned, in the first period the contraction settled at 4.2%, and in subsequent periods continues to maintain a negative value, albeit minor. However, the increase in investments in the periods after the first one cannot compensate for the consumption decline, thus keeping GDP growth below zero. Finally, consistent with the WTO's hypothesis of a collapse in global trade, the current account balance shows a sharp decline in foreign trade. In particular, exports are falling by 11.3%, with a trend over time that settles around zero growth; imports, on the other hand, decreased by 7.4%, and tend to settle around zero growth in subsequent years.

Figure 8. Composition of GDP
(Percentage of total loss)



The lockdown leads directly and indirectly to a reduction in the real disposable income of Institutional Sectors, associated mainly with the component of labour income for households and profits for businesses, as shown in Table 5.

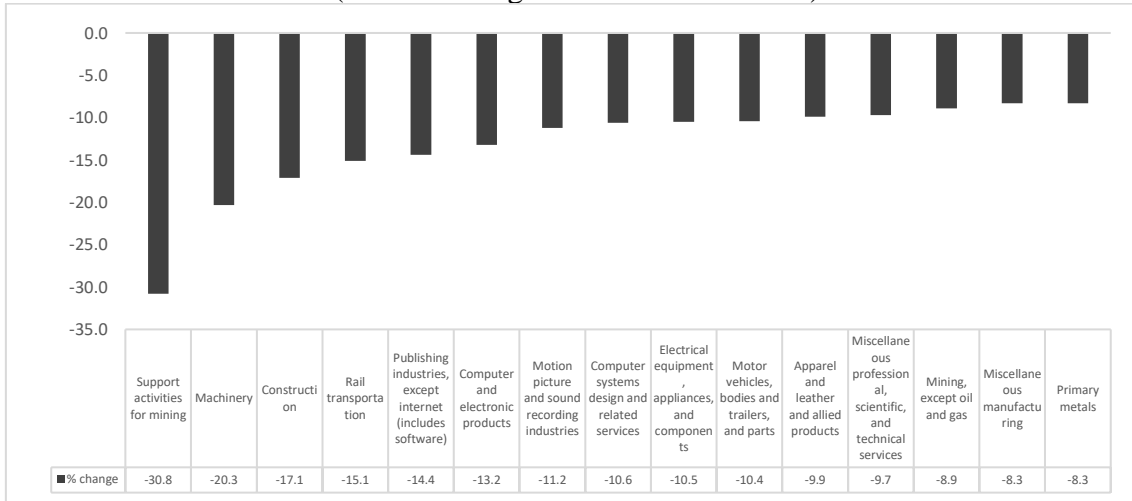
Table 5. Incomes and savings change
(Percent change w.r.t. the benchmark)

Real Variables	t1	t2	t3	t4	t5
Households compensation of employees	-1.3	-0.4	-0.4	-0.4	-0.4
Households disposable income	-0.6	-0.4	-0.4	-0.4	-0.4
Households savings	16.5	0.5	0.5	0.6	0.6
Corporations disposable income	-0.2	-0.3	-0.3	-0.3	-0.3

Real compensation of employees contracted by 1.3% in the first year, and the trend remains negative in subsequent years, and in figure the changes compared to the benchmark of the most affected activities are reported. It is possible to observe that the main changes are recorded in the mining and machinery sectors, followed by construction and rail transportation.

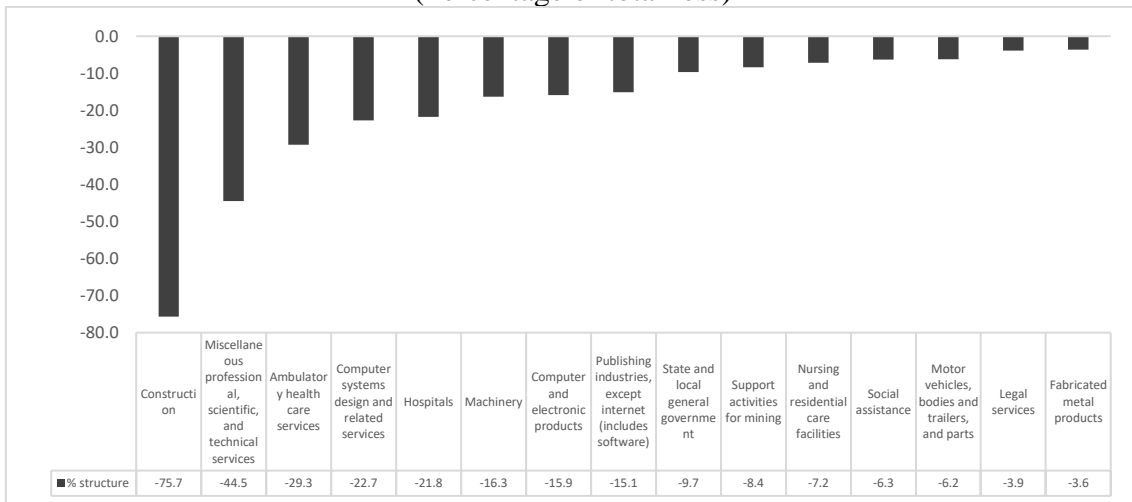
The change in the real compensation of employees by activity, as shown in Figure 9, show that the greatest impact is due to the construction and professional scientific services sectors.

Figure 9. Real compensations of employees
(Percent change w.r.t. the benchmark)



It is also interesting to note that among the activities with the highest drop in labour income are the health care sectors, Ambulatory health care services and Hospital, consistent with the above mentioned decline in consumption.

Figure 10. Composition of Real compensations of employees
(Percentage of total loss)



However, the reduction in real terms is not far-reaching and this confirms what was said earlier about the reduction in consumption, which occurs more out of virus fear than loss of purchasing power. In fact, households' savings raise by 16.9%, triggering a

substitution effect between consumption and savings that contributes to accentuate the depressive effect. This implies the presence of a strong uncertainty among consumers and this is mainly due to an extreme perplexity about the timing of the exit from the health crisis, favouring a prudent attitude. In addition, a further driver for precautionary saving is the uncertainty about labour market prospects, which worsened sharply during the pandemic period. The increase in the marginal propensity to save of households, which rose to 33% between April and May³⁴, triggers a friction to economic recovery, decreasing the consumption multiplier effect.

The general contraction in disposable income generates a contraction in taxes collected by central and local governments. Therefore, considering the inclusion of rigidities aimed at keeping public expenditure, public investment and transfers constant, both central and local governments must necessarily resort to deficit and therefore debt. No economic policy actions taken to combat the economic crisis can disregard this aspect.

6. Concluding remarks: the crisis will be long lasting

In this study the impact of the lockdown for the containment of the infection by coronavirus on the whole USA territory is analysed. Through the dynamic CGE model results of the shutdown on production activities for specific economic sectors given the pandemic Covid-19, are highlighted. As outlined in the paper, health public policies adopted following the sanitary recommendations emerging from the present knowledge of the Covid-19 pandemic, need to be counterbalanced, due to deep and extensive harmful effects on economic activities.

Quantifying the impact that these policies can have on the economy is a prerequisite to programme and activate regulation mechanisms able to counterbalance

³⁴ Source: Il sole 24 ore - <https://www.ilsole24ore.com/art/deflazione-globale-ecco-l-eredita-pandemia-covid-ADPH3fZ>

their impacts on outputs, endogenous demands, value added and disposable incomes of Institutional Sectors. The pandemic effect leads to a major blockage of production processes selectively, progressively compromising the entire economic system through direct, indirect and induced effects. The distribution of income is influenced primarily by the coercive effect of closure, although the indirect effect through the intermediate and income spheres is not negligible.

It is necessary to stress that the model highlights the non-neutrality of income distribution in contributing to the whole effect. The policy measures to be implemented by the Government to reduce the negative impact of the Covid-19 pandemic start from the consideration that the economic impact selectively affects some activities but not in the same way. Economic policy measures must therefore take this into account in order to protect critical sectors by safeguarding their supply. At the same time, they must protect employment by reducing the tax wedge or increasing transfers from public administration to business. Wage protection has a positive effect on aggregate demand through increased consumption. Moreover, policy measures applied to key activities most impacted from lockdown, generate a growth effect also in activities not covered by the measures, thanks to cross-sectoral dependencies. Of course, this does not mean that economic policy measures should not apply to all activities, but it is important to apply targeted measures, depending on the production structure of the economic system.

Appendix 1: model sensitivity analysis

As already analysed in the previous chapter, based on the static CGE model application, also for the dynamic CGE model it is necessary to perform a sensitivity analysis on the exogenous parameters of the model. In fact, within the production function, the substitution elasticity between capital and labour is established exogenously, and therefore it can influence the model based on the choice of the initial value. In particular, the value initially set is equal 0.3194 (Van Der Werf, 2008). To test the model's response to changes in elasticity, it is assumed to simulate a policy based on the increase in household transfers by the Federal Government, equal to 1% of GDP; the elasticity parameter is then made to vary from 0.2715 to 0.3673.

The results are shown in the tables below. As can be seen, by changing the elasticity of substitution between labour and capital the model does not show significant variations compared to the value of the elasticity used in the simulations. This means that the greater or lesser rigidity of the substitution elasticity does not amplify the effects of the policy, and at the same time it is possible to attribute the economic impact of the model to the policy.

Table 6. Real GDP change
(Percent change w.r.t. the benchmark)

σ	t1	t2	t3	t4	t5
-15%	0.231	0.236	0.240	0.245	0.250
-10%	0.236	0.241	0.245	0.250	0.254
-5%	0.241	0.245	0.250	0.254	0.259
Bench	0.245	0.250	0.254	0.258	0.263
5%	0.250	0.254	0.258	0.262	0.267
10%	0.254	0.258	0.262	0.266	0.271
15%	0.258	0.262	0.266	0.270	0.274

Table 7. Real Households Consumption change
(Percent change w.r.t. the benchmark)

σ	t1	t2	t3	t4	t5
-15%	0.276	0.279	0.282	0.285	0.287
-10%	0.282	0.285	0.287	0.290	0.293
-5%	0.287	0.290	0.293	0.295	0.298
Bench	0.292	0.295	0.298	0.300	0.303
5%	0.297	0.300	0.302	0.305	0.307
10%	0.302	0.304	0.307	0.309	0.312
15%	0.306	0.309	0.311	0.314	0.316

Table 8. Real Investments change
(Percent change w.r.t. the benchmark)

σ	t1	t2	t3	t4	t5
-15%	0.478	0.480	0.482	0.485	0.489
-10%	0.482	0.484	0.487	0.490	0.494
-5%	0.487	0.489	0.491	0.494	0.498
Bench	0.491	0.493	0.495	0.498	0.502
5%	0.496	0.497	0.499	0.502	0.506
10%	0.500	0.501	0.503	0.506	0.509
15%	0.504	0.505	0.506	0.509	0.513

Table 9. Real Exports change
(Percent change w.r.t. the benchmark)

σ	t1	t2	t3	t4	t5
-15%	-0.228	-0.216	-0.205	-0.195	-0.185
-10%	-0.220	-0.209	-0.199	-0.189	-0.179
-5%	-0.214	-0.203	-0.193	-0.183	-0.174
Bench	-0.207	-0.197	-0.187	-0.177	-0.168
5%	-0.201	-0.191	-0.181	-0.172	-0.163
10%	-0.196	-0.186	-0.176	-0.167	-0.158
15%	-0.190	-0.180	-0.171	-0.162	-0.154

Table 10. Real Investments change
(Percent change w.r.t. the benchmark)

σ	t1	t2	t3	t4	t5
-15%	0.250	0.252	0.255	0.258	0.261
-10%	0.254	0.256	0.259	0.262	0.265
-5%	0.258	0.260	0.263	0.266	0.269
Bench	0.262	0.264	0.266	0.269	0.272
5%	0.265	0.267	0.270	0.273	0.275
10%	0.269	0.271	0.273	0.276	0.279
15%	0.272	0.274	0.276	0.279	0.282

Table 11. GDP deflator change
(Percent change w.r.t. the benchmark)

σ	t1	t2	t3	t4	t5
-15%	0.269	0.255	0.242	0.230	0.218
-10%	0.261	0.247	0.235	0.223	0.211
-5%	0.253	0.240	0.228	0.216	0.205
Bench	0.246	0.233	0.221	0.210	0.199
5%	0.239	0.226	0.215	0.204	0.193
10%	0.232	0.220	0.209	0.198	0.188
15%	0.226	0.214	0.203	0.192	0.182

Appendix 2: parameters, variables and equations

Model parameters and variables

t	Time index
T	Last time
i	Commodities
j	Industries
is	Institutional Sectors
priv	Households, Corporations
gov	Public Administration
row	Rest of the world
Q_{it}	Output by commodity
P_{it}	Price of goods
Q_{jt}	Output by industry
δ_i^{dom}	Share of domestic goods on the total production in the cost function
d_i^{dom}	Share of domestic goods on the total production
$P_{dom,jt}$	Prices of domestic activities
$Q_{dom,jt}$	Quantity of domestic activities
Tax_{it}^{out}	Taxes on output by commodity
Tax_{jt}^{act}	Taxes on activities
Pm_{it}	Prices of imports from the rest of the world
M_{it}	Quantity of imports from the rest of the world
$\sigma_{Q_{dom}}$	Elasticity of substitution between domestic and imported goods
$\rho_{Q_{dom}}$	Exponent of the CES production function linked to $\sigma_{Q_{dom}}$
Pb_{ijt}	Prices of intermediate goods
BI_{jt}	Quantities of intermediate goods
Pva_{jt}	Prices of value added
VA_{jt}	Quantities of value added
δ_{ij}^D	Share of intermediate goods in total domestic production
σ_D	Elasticity of substitution between intermediate goods and value added
ρ_D	Exponent of the CES production function linked to σ_D
P_{jt}	Average price on goods market from the market clearing condition
δ_{ij}^{BI}	Share of the cost by intermediate goods on the total cost
σ_{BI}	Elasticity of substitution between intermediate goods
PL_t	Price of labor
PK_t	Price of capital
δ_j^v	Share of labour in the total of primary factors
σ_v	Elasticity of substitution between labour and capital
δ_j^L	Share of labour costs on added value
L_{jt}^d	Labor endowment
K_{jt}^d	Capital endowment
d_{ji}^q	Share of i^{th} product realized by industry j in the total production of j
d_{ij}^q	Share of goods supply by each activity in the total domestic supply

q_{ijt}	Quantity of i^{th} good produced by j^{th} industry
σ_q	Elasticity of substitution between primary and secondary production
δ_i^M	Share of rdomeestic priduction on total production
pmw_{it}	Price of foreign goods
exr_t	Nominal exchange rate
γ^{is}	Primary income by Institutional Sectors
ty_{inc}	Implicit rates of income tax
tr	Implicit rates of transfers between Institutional Sectors
tq_i^{out}	Implicit tax rates on output
tq_i^{act}	Implicit tax rates on activities
γ_{out}^{gov}	Share of taxes on output
γ_{act}^{pub}	Share of taxes on activity
U^{is}	Utility of Institutional Sectors
C_t^{is}	Consumption of Institutional Sectors
S_t^{is}	Saving of Institutional Sectors
Y_t^{is}	Disposable income
YF_t^{is}	Primary income
Pu^{is}	Utility price
Pc_t^{is}	Index price of the of consumption by Institutional Sector
P_t^I	Price of investment
δ_i^C	Share of consumption of the i^{th} good in total consumption for each Institutional Sector
σ_C	Elasticity of substitution among goods in the consumption basket
c_{it}^{is}	Quantity of consumption of each good by Institutional Sector
δ_i^I	Investment share of the i^{th} goods in total investments
σ_I	Elasticity of substitution among goods in the investment basket
I_{it}	Quantity of investment by goods
e_{it}	Export demand by goods from Rest of the World
δ_i^E	Export share of i^{th} goods in total exports to the rest of the World
σ_E	Elasticity of substitution among goods in the export to the rest of the World basket
π_t	Foreign inflation rate
r	Interest rate
τ	Capital depreciation rate
g	Growth rate of production in the steady state
KS_t^{priv}	Capital endowment by Institutional Sector
rk_t	Return on capital
ρ	Parameter of intertemporal preference
$alpha(t)$	Coefficient of intertemporal preference in consumption

Equations

$$Q_{it} = \left(d_i^{dom} Q_{dom,it}^{\rho_{Q_{dom}}} + (1 - d_i^{dom}) M_{it}^{\rho_{Q_{dom}}} \right)^{\frac{1}{\rho_{Q_{dom}}}}$$

$$P_{it}(1 - Tax_{it}^{out}) = \left(\delta_i^{dom} P_{dom,it}^{(1-\sigma_{Q_{dom}})} + (1 - \delta_i^{dom}) Pm_{it}^{(1-\sigma_{Q_{dom}})} \right)^{\frac{1}{1-\sigma_{Q_{dom}}}}$$

$$Q_{dom,jt} = (d_j^D BI_{jt}^{\rho D} + (1 - d_j^D) VA_{jt}^{\rho D})^{\frac{1}{\rho D}}$$

$$P_{dom,jt}(1 - Tax_{jt}^{act}) = \left(\sum_i \delta_{ij}^D Pbi_{jt}^{(1-\sigma_a)} + \sum_i (1 - \delta_{ij}^D) Pva_{jt}^{(1-\sigma_a)} \right)^{\frac{1}{1-\sigma_a}}$$

$$BI_{jt} = \delta_j^D Q_{dom,jt} \left(\frac{P_{dom,jt}}{Pbi_{jt}} \right)^{\sigma D}$$

$$VA_{jt} = (1 - \delta_j^D) Q_{dom,jt} \left(\frac{P_{dom,jt}}{Pva_{jt}} \right)^{\sigma D}$$

$$Pbi_{jt} = \sum_i (\delta_{ij}^D P_{jt}^{(1-\sigma_{BI})})^{\frac{1}{1-\sigma_{BI}}}$$

$$bi_{jt} = \delta_{ij}^{BI} Q_{dom,jt} \left(\frac{Pbi_{jt}}{P_i} \right)^{\sigma_{BI}}$$

$$Pva_{jt} = (\delta_j^V \cdot PL_t^{1-\sigma_v} + (1 - \delta_j^V) \cdot rk_t^{1-\sigma_v})^{\frac{1}{1-\sigma_v}}$$

$$L_{jt}^d = \delta_j^L VA_{jt} \left(\frac{Pva_{jt}}{PL_t} \right)^{\sigma_v}$$

$$K_{jt}^d = (1 - \delta_j^L) VA_{jt} \left(\frac{Pva_{jt}}{rk_t} \right)^{\sigma_v}$$

$$Q_{jt} = \left(\sum_i d_{ji}^q q_{ijt} \right)^{\frac{1}{1-\sigma_q}}$$

$$Pq_{dom,it} = \left(\sum_j d_{ij}^q P_{dom,jt}^{(1-\sigma_q)} \right)^{\frac{1}{1-\sigma_q}}$$

$$M_{it} = (1 - \delta_i^M) Q_{it} \left(\frac{P_{it}}{Pm_{it}} \right)^{\sigma_{Qdom}}$$

$$Pm_{it} = pmw_{it}(1 + \pi_t)/exr_t$$

$$YF_t^{priv} = L_t^{priv} pl_t + K_t^{priv} rk_t$$

$$Y_t^{priv} = YF_t^{priv} \left(1 - \sum_{inc} ty_{inc}^{priv} - \sum_{tras} tr_{tras}^{priv} \right) + \sum_{priv} \sum_{tras} tr_{tras}^{priv} YF_t^{priv} + \sum_g Tr_t^g + Tr_{row}^t$$

$$Y^{priv} = \sum_t Y_t^{priv} \left(\frac{1}{1+r} \right)^t + KS_{tfirst}^{priv} PK_{tfirst} - KS_T^{priv} PK_T \left(\frac{1}{1+r} \right)^T$$

$$PK_t = (1 - \tau) PK_{t+1} + rk_t$$

$$I_{tfirst} = \frac{(\tau + g) \sum_{priv} KS_{tfirst}^{priv} rk_{tfirst}}{\tau + r}$$

$$\tau = \frac{g \sum_{priv} KS_{tfirst}^{priv} rk_{tfirst} - r I_{tfirst}}{I_{tfirst} - KS_{tfirst}^{priv} rk_{tfirst}}$$

$$YF_t^{priv} = KS_t^{priv} rk_t$$

$$YF_t^{gov} = KS_t^{gov} rk_t + \lambda_{act}^{gov} \sum_{act} \sum_j (ta_j^{act} P_{dom,jt} Q_{jt}) + \lambda_{out}^{gov} \sum_{out} \sum_i (tq_i^{out} P_{it} Q_{it}) + \sum_{priv} \sum_{inc} ty_{inc}^{priv} YF_t^{priv}$$

$$Y_t^{gov} = YF_t^{gov} - \sum_{gov} T_T^{gov} - T_T^{row}$$

$$Y^{gov} = \sum_t Y_t^{gov} \left(\frac{1}{1+r} \right)^t + KS_{tfirst}^{gov} PK_{tfirst} - KS_T^{gov} PK_T \left(\frac{1}{1+r} \right)^T$$

$$\max U^{priv} = \sum_{t=0}^T \left[\left(\frac{1}{1+\rho} \right)^t C_t^{priv} \right]$$

$$C_t^{priv} = \sum_i c_{it}^{priv}$$

s.t.

$$\sum_{priv} C_t^{priv} = \sum_i Q_{it} - \sum_i \sum_j bi_{ijt} - \sum_{gov} G_g - \sum_i I_{it} - \sum_i e_{it}$$

$$KS_{t+1} = KS_t(1 - \tau) + I_t$$

$$\sum_t \left(\frac{1}{1+\rho} \right)^t C_t^{priv} P C_t^{priv} = Y^{priv}$$

$$P U^{priv} = \prod_t \left(\frac{P C_t^{priv}}{1+r} \right)^{\alpha(t)}$$

$$\alpha(t) = \frac{\left(\frac{1+g}{1+r} \right)^{t-1}}{\sum_t \left(\frac{1+g}{1+r} \right)^{t-1}}$$

$$C_t^{priv} = \frac{U^{priv}}{1+r} \left(\frac{P U^{priv}}{P C_t^{priv} (1+r)} \right)^{\alpha(t)}$$

$$P C_t = \left(\sum_i \delta_i^c P_{it}^{(1-\sigma_c)} \right)^{\frac{1}{1-\sigma_c}}$$

$$c_{it}^{priv} = \delta_i^c U^{priv} \left(\frac{P C_t}{P_{it}} \right)^{\sigma_c}$$

$$U^{gov} = \sum_t G_t^{gov} + def_t^{gov}$$

$$P_t^l = \left(\sum_i \delta_i^l P_{it}^{(1-\sigma_l)} \right)^{\frac{1}{1-\sigma_l}}$$

$$I_{it} = \delta_i^l I_t \left(\frac{P_t^l}{P_{it}} \right)^{\sigma_l}$$

$$e_{it} = \delta_i^E Y_{tfirst}^{row} (1 + g^{row})^t \left(\frac{pmw_i(1 + \pi_t)/exr_t}{P_{it}} \right)^{\sigma_E}$$

$$Q_{it} = \sum_j b_{ij} + \sum_{hh} C_{it}^{hh} + \sum_{pub} G_{it}^{pub} + I_{it} + E_{it}^{rest_w}$$

$$\sum_i I_{it} = \sum_{is} S_t^{is}$$

$$\begin{aligned} \sum_i M_{it} + \sum_{priv} tr^{priv,row} Y F_t^{priv} + \sum_{gov} Tr_t^{gov,row} + L^{row} P L_t + K^{row} P K_t \\ = \sum_i e_{it} + \sum_{row} Tr^{priv,row} + \sum_{row} Tr_t^{gov,row} + S_t^{row} \end{aligned}$$

$$L_t^d = L_t^s$$

$$K_t^d = K_t^s$$

$$KS_{t+1} = (1 - \tau)KS_t + I_t$$

$$\frac{I_T}{I_{T-1}} = \frac{S_T}{S_{T-1}}$$

Appendix 3: List of goods and activities in the US SAM

1	Farms
2	Forestry, fishing, and related activities
3	Oil and gas extraction
4	Mining, except oil and gas
5	Support activities for mining
6	Utilities
7	Construction
8	Wood products
9	Non-metallic mineral products
10	Primary metals
11	Fabricated metal products
12	Machinery
13	Computer and electronic products
14	Electrical equipment, appliances, and components
15	Motor vehicles, bodies and trailers, and parts
16	Other transportation equipment
17	Furniture and related products
18	Miscellaneous manufacturing
19	Food and beverage and tobacco products
20	Textile mills and textile product mills
21	Apparel and leather and allied products
22	Paper products
23	Printing and related support activities
24	Petroleum and coal products
25	Chemical products
26	Plastics and rubber products
27	Wholesale trade
28	Motor vehicle and parts dealers
29	Food and beverage stores
30	General merchandise stores
31	Other retail
32	Air transportation
33	Rail transportation
34	Water transportation
35	Truck transportation
36	Transit and ground passenger transportation
37	Pipeline transportation
38	Other transportation and support activities
39	Warehousing and storage
40	Publishing industries, except internet (includes software)
41	Motion picture and sound recording industries
42	Broadcasting and telecommunications
43	Data processing, internet publishing, and other information services
44	Federal Reserve banks, credit intermediation, and related activities
45	Securities, commodity contracts, and investments
46	Insurance carriers and related activities
47	Funds, trusts, and other financial vehicles
48	Housing
49	Other real estate
50	Rental and leasing services and lessors of intangible assets
51	Legal services
52	Computer systems design and related services
53	Miscellaneous professional, scientific, and technical services
54	Management of companies and enterprises
55	Administrative and support services
56	Waste management and remediation services
57	Educational services

58	Ambulatory health care services
59	Hospitals
60	Nursing and residential care facilities
61	Social assistance
62	Performing arts, spectator sports, museums, and related activities
63	Amusements, gambling, and recreation industries
64	Accommodation
65	Food services and drinking places
66	Other services, except government
67	Federal general government (defense)
68	Federal general government (nondefense)
69	Federal government enterprises
70	State and local general government
71	State and local government enterprises

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