# Proceedings of the COVid-19 Empirical Research (COVER) Conference

## Milan, Italy, October 30th, 2020


editors
Elia Biganzoli, Giancarlo Manzi,
Alessandra Micheletti,
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# Preface

This volume collects selected paper presented at the COVER - COVid-19 Empirical Research conference - organized by the Centre of Excellence in Economics and Data Science of the Department of Economics, Management and Quantitative Methods, University of Milan, Italy, October 30th 2020.

In the early of 2020 the Europe was involved in the COVID-19 pandemic. The dramatic world situation has prompted many researchers from different fields to focus on studying the covid-19 pandemic and its economic and social implications. This conference aimed to welcome different points of view by opening an interdisciplinary discussion on the possible developments of the pandemic. Contributions were made in three main areas: social, economic and mathematical-statistical.

The program of the conference included 14 presentations, organized in 3 sessions, by breaking down the three main topics of the conference. The contributors belong to an international panorama. The Universities and Research Centres of Dublin, Germany, Hungary and the United Kingdom were involved. We thank all the contributors whose spent their time in a so particular period and all the organizers of the sessions for inviting renowned speakers.

The keynote speakers were Daniela De Angelis with the contribution ?National response to the Covid-19 pandemic: The UK experience", Massimo Galli with the contribution "The SARS-CoV-2 pandemic in Italy", Mark Chaplain and Nicola Bellomo with the contribution "Modeling of a virus pandemic in a globally connected world: A multi?scale active particles approach". We thanks these renowned speakers to open a very interesting debate on the analysis of the pandemic in different countries.

This volume collects 16 manuscripts extracted form the contributions presented at the conference and from free submission and it is structured as follows. The first contribution is the opening by the department head Carlo Fiorio. This paper introduces the problem of COVID-19 from an economic point of view. The other papers can be divided into the three main areas: Social, Economic and Management and Mathematical Statistics.

The exposition of the problem from the social point of view was treated by three contributors. Ballabio et al., highlight how the poverty situation has changed in during this period. Mecatti describes the aims of the FEN-StatS Covid19 WR, a free spontaneous association of statistical experts from

14 European countries. Finally, Negri and Mazzoleni identify some factors of contemporary urban and mobile living, which favored the spread and propagation of COVID-19 in Italy.

The economic and management issues were dealt with by five contributors. Giorgetti and Iorio analyzes the Italian manufacturing sector before and during the pandemic crisis. Iacovone analyses the factors underlying the effective response to the crisis in the Lombardy manufacturing sector. Marsilio and Prenestini investigate the role of the Italian Regional Health Care Services in the governance of Covid-19 emergency and analyse the influence on the response of Health care Organizations in managing the first wave. Pilotti studies the new alliances raised between State, market and people. Rosa et al. highlight the importance of the co-creation of public value and how the lack of integrated territorial networks of care have impacted in the management of the COVID-19 emergency.

In the end, mathematical and statistical models of the phenomenon were provided by the remaining seven contributors. In particular, Bellomo and Outanda focus on conceptual contributions that mathematical sciences can give to modelling virus pandemics over complex interconnected environments. Ferrari et al. present a time-depedent model for the spread of COVID- 19 infection at a provincial level in Italy. Gotz et al. consider a statistical model to explain the spread of those variants in Germany on small time scales. Kenett et al. use several models to analyse the mutual effect of the citizen, the policy and decision makers, and the healthcare system. Rios and Gianmoena analyse the dynamics of CoVID-19 lethality at global level. Rivieccio et al. perform a time-frequency analysis of regional emergency calls, CoVID-19-related Twitter data and daily new cases. Finally, Wijaya et al. use a mathematical model to study strategies on the use of the face mask

We gratefully acknowledge the Department of Economics, Managements and Quantitative Methods and the University of Milan and the Centre of Excellence in Economics and Data Science which organized the conference.

Elia Biganzoli
Giancarlo Manzi
Alessandra Micheletti
Federica Nicolussi
Silvia Salini

# Welcome Address

*Carlo Fiorio*

Head of the Department of Economics, Management and Quantitative Methods, University of Milan, Milan, Italy – carlo.fiorio@unimi.it

Dear all,

As the Head of the Department of Economics, Management and Quantitative Methods of the University of Milan, let me start from thanking Giancarlo Manzi and all the other colleagues who contributed to organize this important workshop. This workshop would not have been possible had we not won the “Department of excellence" funds, provided by the Italian Ministry of Education, University and Research. Our project’s title is "Understanding societal changes from the economic perspective" and the current health crisis, which is affecting our hospitals and health care system, as well as the lives of all of us, is precisely one of the phenomenon we aim at addressing with this project.

I will just use a few minutes to introduce some aspects which I am sure will be discussed thoroughly during the workshop. Figure (1) shows an analysis that I performed with Francesco Figari from the University of Insubria, in April, showing how strong was the impact of the Covid-19 crisis for the first months on Italian household budgets. In the graph, the population is grouped in quintiles of household equivalized income, where the number 1 means includes all those in the bottom 20% of income, the number 2 all those in the next 20% up to the group 5, which includes the 20% of households with higher income. On the vertical axis the percentage income loss is reported. The impact was huge, and it still is during this second wave. Overall, the original income (i.e. before tax and transfers) dropped by nearly 35%, which reduced to slightly more than 10% in terms of disposable income. The lowest-income-group average loss of original income was even larger, close to 45%, reduced to about 8% in terms of disposable income. The magnitude of this unexpected crisis is an excellent way to understand and think further on the role of the State.

The Italian government, as most developed economies governments, reacted promptly and strongly, providing large amounts of resources as income supplementation schemes, lump sum transfers and mortgage reliefs. Table 1 shows some descriptive statistics, suggesting that these measures impacted a lot on

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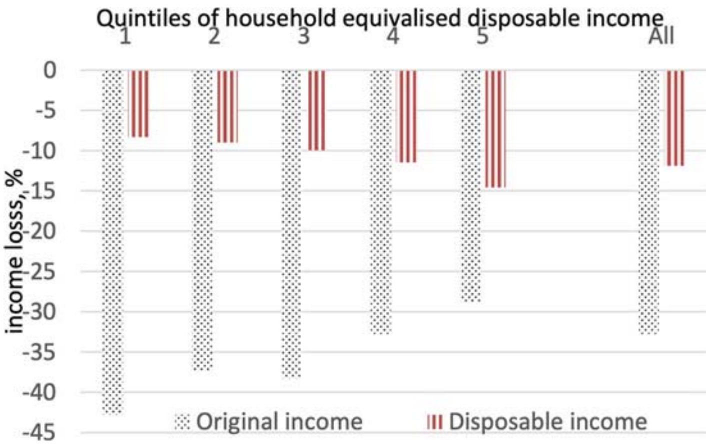


**Figure 1:** Income losses due to the economic shutdown, by household income quintile groups.

many citizens. Over ten million people were interested by these schemes, with a combined cost to contrast the effect of the first wave of over 10 billion euro (about 0.6% of the annual GDP).

In Figure (2) we decompose the public transfers to households by equivalent income quintiles and assess the relevance of government transfers to limit the disposable income loss due to the Covid-19 crisis. The red dots here show the Net Replacement Rate after the first month of the crisis, showing a decrease of about the 80% of disposable income which was much higher than what would have been were the supplementary schemes not been in place, notably for lowest income groups.

In Table 2 we show the effects of the crisis, assuming that the effects are similar to the one in the first month, remain constant throughout the year. It shows that

**Table 1:** The reaction of the State: Policies introduced by the Decree Law 18/2020: first month only.

| Policy | Simulated cost Billion Euros | % of GDP | Entitled Thousands |
|---|---|---|---|
| Wage supplementation schemes | 5.6 | 0.31 | 7.013 |
| - Credited social contributions | 2.8 | 0.16 | |
| Lump sum transfer (600 Euros) | 1.4 | 0.08 | 2.360 |
| Lump sum transfer (100 Euros) | 0.5 | 0.03 | 4.962 |
| Mortgage subsidy | 0.15 | 0.01 | 363 |

Notes: Entitled to Wage Supplementation Schemes are individuals with positive employment income, working in sectors subject to the shutdown and not in the public sector. Entitled to Lump sum transfer (600 euros) are individuals with positive self-employment income, working in sectors subject to the shutdown and not receiving employment income. Entitled to Lump sum transfer (100 euros) are 50% (randomly selected) of individuals with positive employment income, working in sectors not subject to the lockdown.

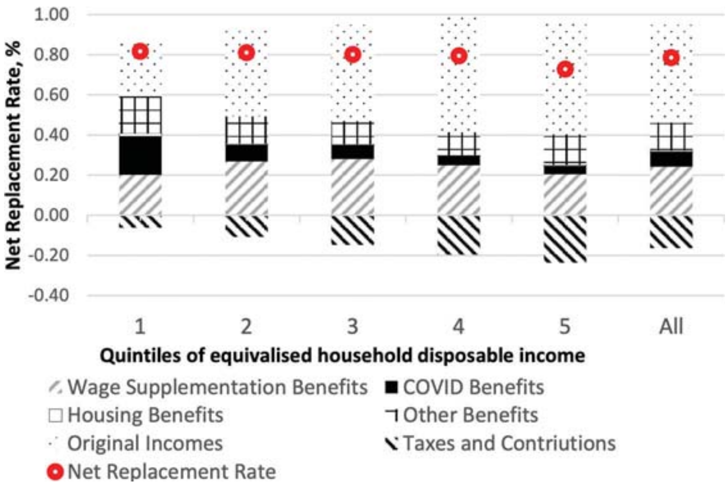


**Figure 2:** Income losses due to the economic shutdown, by household income quintile groups.

government intervention was crucial to limit the impact of the pandemic also on the distribution of income and notably on poverty rates, which is an immediate indicator of socio-economic distress. It remained large but much less than if no compensation had been introduced.

From my point of view as a public economist, this Covid-19 crisis represents also an opportunity to understand and reconsider the State intervention, which was gradually reduced for the last forty years. This progressive reduction of the role of the state has transformed our societies, also increasing the level of inequality and poverty, without much effect on the overall performance of the economy. Fighting poverty and reducing inequality might be among the next future economic challenges and reconsidering the role of the state to tackle these challenges is of key importance.

**Table 2:** Poverty rates before and after the Covid-19 pandemic.

| | Before Covid-19 | Shut-down without compensation policies | Shut-down with compensation policies |
|---|---|---|---|
| Workers in sectors subject to shut down | 12.53% | 67.97% | 28.15% |
| Workers in sectors subject to shut down and living in one-earner household | 22.13% | 80.49% | 43.71% |
| Overall population | 19.07% | 38.41% | 27.28% |
| Children | 23.27% | 49.63% | 36.34% |

Notes: Entitled to Wage Supplementation Schemes are individuals with positive employment income, working in sectors subject to the shutdown and not in the public sector. Entitled to Lump sum transfer (600 euros) are individuals with positive self-employment income, working in sectors subject to the shutdown and not receiving employment income. Entitled to Lump sum transfer (100 euros) are 50% (randomly selected) of individuals with positive employment income, working in sectors not subject to the lockdown.

This is just one of the of the many ways you can look at the impact of the ongoing crisis. This workshop will host many very interesting contributions from the point of view of social sciences. I do believe it is a great opportunity for our Department and for the University of Milan as a whole to host such a workshop. More should come because crises are often tough, in many cases, very sad times for those most affected but still interesting times for researchers, including social science researchers, to be discussed, analyzed and understood.

On behalf of the whole Department of Economics, Management and Quantitative Methods, I welcome you all to this workshop and I wish you all a productive and stimulating time together.

# On the Complex Dialogue Between Mathematics and Virus Pandemics

*Nicola Bellomo*[1] *and Nisrine Outada*[2]

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This short paper focuses on the conceptual contributions that mathematical sciences can give to modeling virus pandemics over complex interconnected environments. A critical analysis of the existing literature is proposed looking ahead to research perspectives within a multiscale vision.

## 1 Motivations and Plan of the Essay

The onset of *SARS–CoV–2* responsible for the initial *COVID-19* outbreak and the subsequent pandemic, has brought to almost all countries and societies across the globe huge problems *affecting health, safety/security, economics, and all collective behaviors*. Various governments, as well as a number of scientists, have used the term *black swan*. However, this event is definitely not a black swan as it might have been predicted, but what effectively appeared is that societies were not prepared to tackle this problem. Independently on arguing about the black swan, the motivation to provide a strong scientific contribution to contrast the pandemics is crucial.

Within this framework, the contribution of mathematical sciences can play an important role. As a consequence, a large number of papers have been recently appeared. We limit our citations only to a few papers simply with the aim of a concise indication of some topics that we consider important to define how and how far mathematics can contribute to the aforementioned scientific challenge.

Accordingly, we bring to the attention of the interested reader five scientific papers focused on the following key topics: 1. Development of compartmental models to model spread and dynamics of the COVID-19 epidemic in Italy focusing on the predictive ability of models to understand the role of containment measures;[1] 2. A multiscale systems approach and models of virus pandemics in a globally connected world;[2] A highly communicative description of the complex biology of the system under consideration looking ahead to research perspectives;[3] 4. Space dependent diffusion of the epidemic are treated by the

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kinetic theory approach;[4] 5. Contagion problems in crowds and agglomeration of people modeled by methods of the kinetic theory of active particles,[5] see.[6]

The overview of these selected articles allows to contribute firstly to define a modeling strategy can be developed according to the objectives that a mathematician should chase and, subsequently, to provide some ideas towards research perspectives. These two topics are treated in the next two sections.

## 2 Modeling Strategy

We have learned by the biological interpretation of the dynamics of virus contagion and dynamics[2,3] that *SARS–CoV–2* is mainly transmitted through the respiratory route via respiratory droplets, up to 1 millimeter in diameter, that an infected person expels. If the viral charge is high, the carrier is more infective. Subsequently to contagion, large Spike proteins form a sort of crown on the surface of the viral particles and acts as an anchor allowing the virus to bind to the Angiotensin-Converting Enzyme 2 (ACE2) receptors on the host cell. After binding, the host cell transmembrane proteases cut the Spike proteins, allowing the virus surface to approach the cell membrane, fuse with it and the viral RNA enter the cell. Subsequently, the virus hijacks the cell machinery and the cell dies releasing millions of new viruses thus generating a virus infection.

COVID-19 starts with the arrival of *SARS–CoV–2* virions to the respiratory mucosal surfaces of the nose and throat that express high levels of ACE-2 receptors on the surface. When the virus manages to overcome the barrier of the mechanisms and the mucus secreted by goblet cells from a first effective reaction, a rapid release of danger signals activates the reaction of the host's innate immunity. *Corona viruses are successful at suppressing various mechanisms, but not all of them, in an immune response.*

Bearing in the mind the above brief description, some concepts, however generated by the author's bias, can be proposed towards a possible *modeling strategy*:

- Applied mathematicians should not tackle the modeling problem by a stand-alone approach. Indeed, an interdisciplinary vision is necessary through mutually enriching and beneficial interactions with scientists in other fields as virology, epidemiology, immunology and, in general, biology. In addition, interactions should also be addressed to wider aspects of other communities in our society, e.g. economists and sociologists.
- Modeling approach should go far beyond deterministic population dynamics. Thus considering that individual reactions to the infection and pandemic are heterogeneously distributed throughout the population. Spatial dynamics is generated by nonlocal interactions and transportation devices. In addition

Darwinian mutations and selection into variants should be included in the modeling approach.

- The modeling ought to be developed within a multiscale approach, specifically the macro-scale for dynamics of contagion, while the dynamics of the health state of individuals depends on the dynamics at micro-scale by the in-host competition between virus particles and the immune system. The two scales constantly interact as the contagion at the macro scale depends of the viral load of each individuals which in turn depends on the dynamics at the micro-scale. Heterogeneity appears at both scales.

The specific complexity features to be considered in the modeling are, according to the author's bias, the following: *1. Heterogeneous ability to express a strategy* as living entities are capable to develop specific strategies and organization abilities that depend on the state of the surrounding environment; *2. Nonlinear interactions and learning ability* by nonlinearly additive and nonlocal interactions which living systems learn from past experience; *3. Darwinian mutations and selection* as birth processes can generate entities more fitted to the environment, who in turn generate new entities again more fitted to the outer environment. Hence, life is evolutionary and selective.

The key strategy of the modeling approach is as follows: *The strategy consists in replacing the field theory by a mathematical structure (say mathematical theory) suitable to capture, as far as possible, the complexity features of living systems. This structure defines the conceptual framework for the derivation of models in different fields of science of living systems.* The flow chart of Figure 1, reports the rationale and sequential steps of the approach.

Finally: *Once refined and informed by empirical data, mathematical models can produce insightful provisional simulations which can even uncover dynamics which were not previously observed (cf. emergent behavior). Hence, mathematical models can provide a broad variety of scenarios of the dynamics depending to key parameters. Indeed, this is the contribution of mathematics to crisis managers.*

## 3 Research Perspectives

Research perspectives can be drawn by starting from the achievements in[2] reporting that the modeling of individual based contagion is determined by short range contacts in crowds[5] and by transportation dynamics and networks,[3,4] while the modeling of the immune competition leads to a dynamics, where the outputs are (i) need of hospitalization, (ii) recovery, or (iii) death.

Research in the field is in progress by further development of[2] by including both the strategy of vaccination and Darwinian mutations and selection which lead to the presence of more aggressive variants. This development can contribute to the aforementioned dialogue between mathematics and crisis managers. In

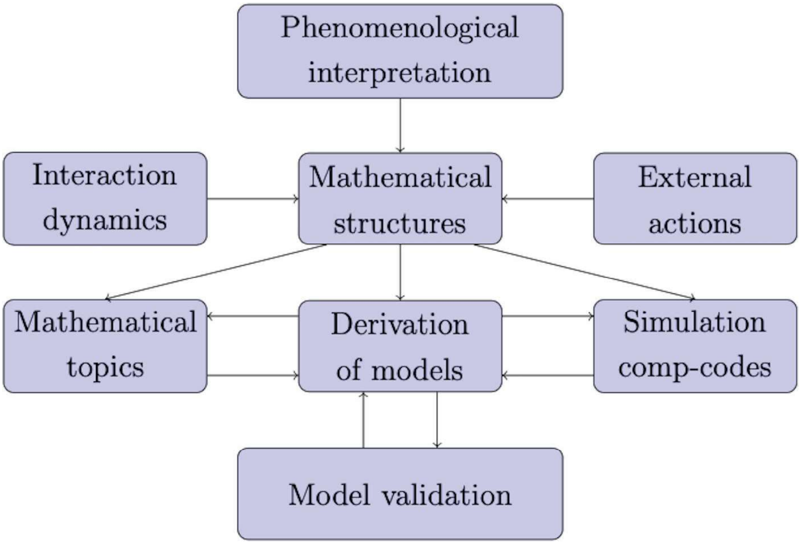


**Figure 1:** Rationale towards modeling.

fact, vaccination can reduce the lapse of time during which the epidemics is active, while the probability of mutations increases with the presence and local diffusion of the virus infection.

It is plain that the perspectives reported in Figure 2 do not depict the end of the story as a key development of a research strategy should focus on a deeper study, followed by modeling, of the highly complex immune competition.[7] We

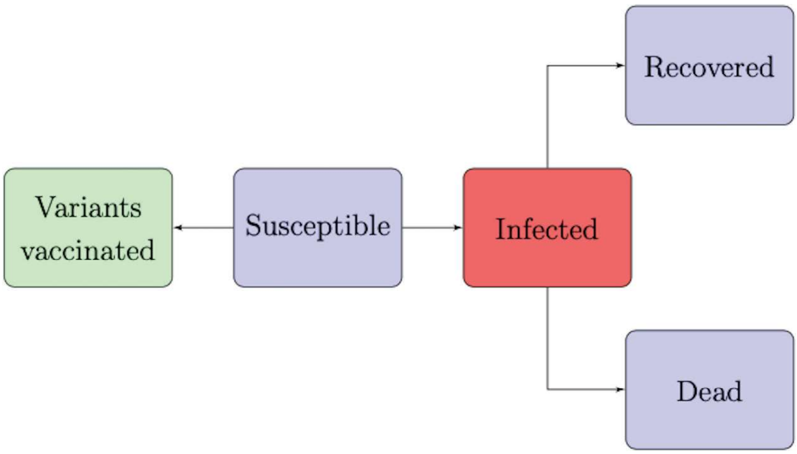


**Figure 2:** Flow chart of research perspectives.

do believe that further understanding of the immune competition can lead to significant improvement in the modeling approach.

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# A Heavily Trained Time-Dependent SIRD Model for Local Covid-19 Data in Italy

*Luisa Ferrari*[1], *Giuseppe Gerardi*[2], *Giancarlo Manzi*[2], *Alessandra Micheletti*[3], *Federica Nicolussi*[2], *Elia Biganzoli*[4], *and Silvia Salini*[2]

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We present a time-dependent SIRD model for the spread of COVID-19 infection at a provincial (i.e. EU NUTS-3) level in Italy, using official data from the Italian Ministry of Health, integrated with data extracted from daily official press conferences of regional authorities and from local newspaper websites. This integration concerns COVID-19 death data which are not available at NUTS-3 level from open official data channels. The model is trained for improved forecasting performance with similarity techniques putting together data from time series most similar to that for which the forecast is performed.

## 1 Introduction

The outbreak of the Covid-19 epidemics in early 2020 has caused an unprecedented effort of the scientific community to produce models that could monitor and predict the evolution of the epidemics in a reliable way, also to promptly advice governments in order to take actions which could mitigate the burden on hospitals in treating the affected patients and reducing the mortality rate of the infection.

The first reported Italian Covid-19 case dates back to February 20th, 2020,[1] in the city of Codogno, southern Lombardy, and the epidemics spread particularly in Italian northern regions, that is, those most commercially connected with China, where the epidemics had its origin. It was immediately clear that the initial Covid-19 outbreak in Italy was not homogeneously spreading within regions, but there were many differences from province to province in the same region. Therefore, we decided to model epidemic data at a provincial rather than at a regional level, contrary to the majority of the analyses about the virus spread in Italy published recently.

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## 2 Methods and Results

We consider here the classical approach of a model consisting of 4 compartments: susceptible (S), infected (I), recovered (R) and deaths (D), therefore adopting a classical epidemiological approach to model epidemic data. However, in adopting this approach we faced a twofold problem: (i) data at provincial level were available only for susceptible and infected people, not for recovered and dead people; (ii) parameters of epidemics, particularly the Covid-19 epidemic, evolve in time depending implicitly on external factors like the limitation of the mobility of the citizens, the measures of protection of the healthcare personnel and of the workers who kept on doing jobs which were considered essential services to the community, and on the number of swab tests performed locally to detect the infected subjects, in order to put them in strict quarantine as soon as possible.

To solve (i) we extracted the number of daily Covid-19 deaths from daily official press conferences of regional authorities and from local newspaper websites; also, we computed the number of the cumulative recovered individuals at a provincial level using the recovery rate at the regional level. The reason for estimating this number proportionally to that of the region is that patient treatment for the illness due to Covid-19 could be considered sufficiently homogeneous across the provinces (with almost the same recovery rate across provinces within the region), contrary to the number of deaths which depends more on the local level of the infection.

The model for forecasting all the parameters involved in the SIRD model, i.e. $\beta$, the transmission rate $\gamma_R$ and $\gamma_D$, the mortality rate. From these parameters we also predicted the values for the reproduction number, i.e. the expected number of people potentially infected by an infected individual. For each of these parameters we form an autoregressive model combined with a cost function to be minimized, expressed in terms of a ridge regression. The ridge penalizing parameter $\lambda$ is obtained via cross-validation. The optimal maximum number for $J$ concerning $\beta$ is used also in the other two autoregressive models concerning $\gamma_R$ and $\gamma_D$, as to have three homogeneous time series.

However, the model features described above might struggle in producing reliable estimates in contexts where the number of cases is very low and there is considerable fluctuation or inconsistency in the data, as it happened in some provinces where the outbreak was not so intense, whilst it seems to give more robust results when data are aggregated at a higher level, as in the entire country's time series. So, we decided to implement a boosting of the model training in the following way:

- (i) *Regional-based training*. For each province, the corresponding region is selected. In order to choose the regions whose situation most resembles the one in the selected region, a time series correlation measure between all of the regions was computed: this correlation was based on the new cases' daily time series divided by the regions' population and was time-weighted, so that the most recent days have a much bigger impact than the days at the beginning of the epidemic. Weights were then normalized. The regions showing a high correlation with the region containing the province of interest were selected and their data were aggregated to compose the training set for the province of interest. The threshold used to select the regions was the median value of the correlation coefficients.

- (i) *Provincial-based training*. The training set was made up by the provinces that are highly correlated with the province of interest and the threshold chosen is again the median value of the correlation coefficient, which is computed exactly the same way as in the regional training approach. The provinces that have a correlation higher than the median value are selected and aggregated with the province of interest: this composed data set is used to train the model.

Model coefficients resulting from this training process were then applied to the local data in order to make predictions for each province: given the predictions about the future values of the parameters $\beta$, $\gamma_R$ and $\gamma_D$, the future values of the variables $S$, $I$, $R$, and $D$ are computed using the customary discrete time difference equations of the classic SIRD model.[2]

In Figures 1 and 2 an example on applying this model to the Piacenza province is shown. Piacenza is one of the provinces in northern Italy with the highest cumulative infection rate, since its main hospital is located very close to Codogno, the town with the first cluster of observed Covid-19 cases in Italy. In this case, the model is trained using the regional-based training. The vertical dashed lines represent the dates in which the Italian government's containment measures were implemented.

## 3 Discussion

The COVID-19 outbreak has made it necessary strong containment measures. The spread of this disease in Italy involved heterogeneously the whole Italian territory, see.[3] The full lock down of industrial and other productive activities (March, 22th) was legitimized by few municipalities with ever increasing number of cases (and deaths), by the inability to stop the contagion and by the emergence of new outbreaks. It is also true that the lockdown stopped municipalities barely touched from the COVID-19.

The analysis presented in this paper can be applied at the NUTS-3 region level in Italy in order to predict the future development of the epidemic in the specific provincial context. This choice is aimed at tackling the heterogeneity of the

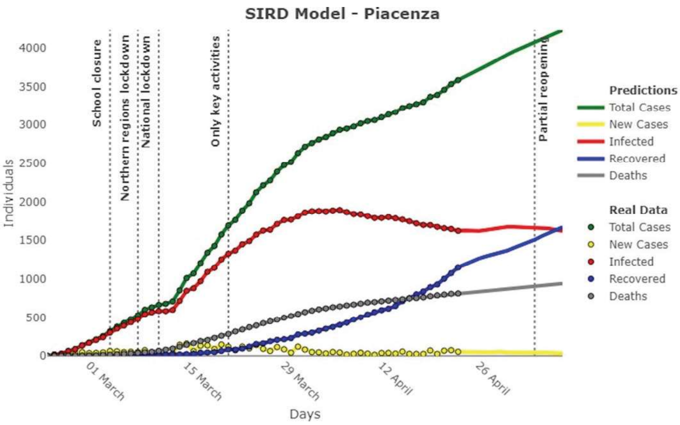


**Figure 1:** Heavily trained SIRD model for Piacenza province - April 23rd, 2020. The training set includes all of the data up to April 23rd; the model is then used to make predictions iteratively for the following 15 days. In this example, the regional aggregation training approach is implemented, and the resulting optimal number of lags is equal to 7.

COVID-19 spread on the territory. Furthermore, as expected in an emergency situation, some information may be temporarily incomplete.

The main issue found during the building of our model was the lack of detailed and consistent data about the epidemic at the provincial level, although

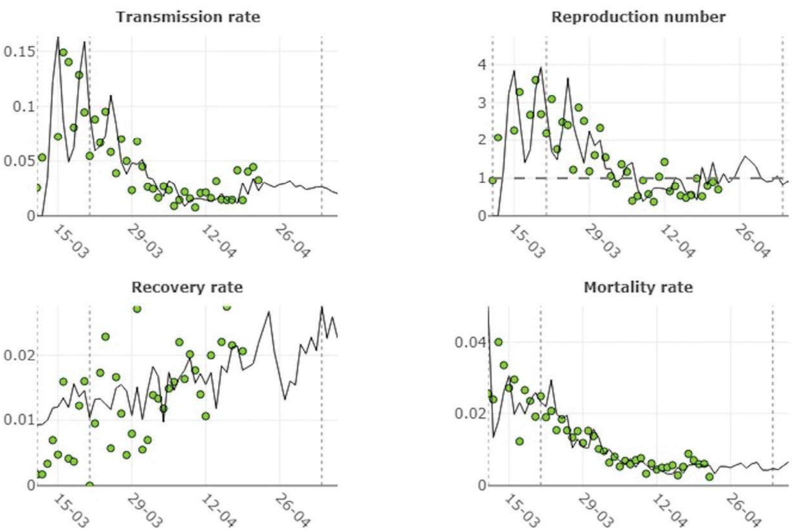


**Figure 2:** Heavily trained SIRD parameters predictions for Piacenza province - April 23rd, 2020. The green dots represent the daily values of the parameters up to April 23rd, while the solid black line represents the fitted model and the predictions for the following days.

the procedure adopted by the central government and the regional authorities was standardized in order to get similar aggregated data across regions. A full trustfulness of these aggregated data is put in doubt by the fact that some of them (deaths, recovered and number of tests) are not publicly available at a provincial level in the official daily releases by the Italian Civil Protection Agency and therefore, as in our case, they must be estimated or found in some ways. If more variables had been available, the model could have been extended to include other compartments, such as the hospitalized cases or the number of tested individuals or, again, the possibility to consider a percentage of recovered people as susceptible, or the asymptomatic cases, or the under- reporting of deaths. Indeed, we choose to implement the simplest (with the lowest number of parameters) model, which allows us to overlook strong and unlikely assumptions.

A dashboard built on this model regarding the spread of the Covid-19 virus in Italy's provinces has been implemented and can be found at http://demm.ceeds.unimi.it/covidModelling/.

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# It Never Rains but It Pours. Subjective Poverty and Income Reduction after Covid-19 in Italy

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The economic consequences of the COVID-19 pandemic might be different for different population sub-groups defined by age, educational level, working status and size of the household they live in, but also by the economic conditions before the pandemic. In this paper we use the special survey carried out by the Bank of Italy in April-May 2020 to identify which categories of individuals need more income support as they are more at risk of being in a condition of subjective poverty aggravated by the economic crisis due to the health emergency.

## 1 Introduction and Motivation of the Study

The Covid-19 pandemic has brought in most countries not only a serious health emergency, but also an economic shock. In fact, the measures to combat the spread of the virus have led to temporary closures of industries, offices, enterprises and businesses. The long-term consequences of the current crisis on production and consumption are not predictable yet as we are still living in the pandemic period with a succession of more or less severe lockdowns.[1]

However, we can reasonably expect an increase in poverty levels and inequality since the economic crisis produced by the pandemic has had and will have different effects on different population subgroups. It is likely that families that were already economically weaker and without political representation before the pandemic will suffer the most from the worsening in their economic situation.[2,3]

Italy is an interesting case to be studied as it is one of the countries that has been most affected since the first months of the pandemic and it is one of the countries that first opted for a lockdown (from the first days of March 2020). Moreover, Italy had already experienced an increase in poverty rate as a consequence of the economic recession (from 3.5% in 2005 to 7.0% in 2018 according to ISTAT data on absolute poverty) because of the weak welfare state system and the progressive deregulation "at the margins" of the labour market.[4]

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Accurate and reliable data on income reduction for different population subgroups will not be available before mid-2021. However, households are already aware of the consequences of the pandemic on their economic situation and they can provide a subjective estimation of the income loss they are facing.

During the pandemic income support policies were limited[5] and eligibility was conditional on employment status and type of contract. Therefore the income loss suffered by different families depends on the position of household members in the labour market: the self-employed have been probably hit more than dependent workers, temporary workers probably have found more difficulty in renewing their contracts, some companies have resorted to the redundancy fund (*Cassa Integrazione Straordinaria*) for their employees while others were not eligible for it while civil servants with a permanent contract and retired people have not seen their income fall at all.

Since the worker position in the labour market is correlated to individual characteristics, it is likely that the COVID-19 pandemic produced an accumulation of disadvantages with relevant long-term consequences on individuals' well-being, family consumption and investment.

In order to investigate the accumulation of disadvantages due to the pandemic, we use data collected by the Bank of Italy in April-May 2020 for a special survey on Italian households. This data contains information on the perceived economic conditions of households before the pandemic and on income reduction suffered in the first two months of the pandemic. Both indicators can be considered as subjective perceptions while no real information on income is included in the survey.

Beside objective data on income reduction, subjective perception of own economic status is relevant for the possible real effects on consumption and investment behavior.[6,7] Subjective poverty, *i.e.* the individual perception of deprivation, may result from objective poverty, but it can also go beyond that and in fact there is not a perfect overlap between the poor population identified by measures of objective and subjective poverty.[8] In Italy the percentage of individuals and households reporting subjective hardship is strikingly high compared to the levels reported in other EU areas.[9]

### 1.1 Research Questions

According to the Bank of Italy data* , almost half of the interviewed individuals declared that before the pandemic they were able to make ends meet with difficulties. Among these, 15% can be defined as subjectively poor as they declare serious difficulties. In the first two months of the most rigid measures to reduce the widespread of the pandemic (March-April 2020) more than half of the individuals affirmed they had suffered a family income reduction even considering the income support transfers received from the government.

* https://www.bancaditalia.it/pubblicazioni/note-covid-19/2020/Evi-preliminari-ind-straord-famiglie.pdf.

Given these data, we first analyze the relationship between subjective poverty and income fall. We expect those who were already suffering the most have seen their economic situation further worsened. We analyze the effect of individual and family characteristics on the relationship between feeling poor before the pandemic and suffering an income reduction during the first months of the pandemic. In particular, we focus on age, education, employment status and family size. Finally, we define some types of individuals' situations that allow the identification of the individuals most affected by the economic consequences of the pandemic that need special attention in income support policies.

# 2 Empirical Analysis

## 2.1 Data, Variables and Method

In order to investigate the subjective poverty of Italian households during the spread of Covid pandemic, we use the 2020 data of the Bank of Italy's special survey on Italian households. The survey was conducted between April and May 2020 in order to collect information on the economic situation and expectations of families at the beginning of the economic crisis due to the Covid-19 pandemic. The reference population is the Italian adult population older than 18, and the sample consists of 3,079 observations[†] . As in the literature on subjective poverty, we define "subjectively poor" (before the pandemic) those individuals that declared difficulties experienced by households in making ends meet (great difficulty or difficulty). We define as worse economic condition a reduction by 25% or more in the household income (including any income support received) as a result of the Covid-19 emergency. The intersection of the two conditions shows the degree of severity in poverty conditions of the Italian households.

First, we run a multinomial logit on the probability of having experienced an income reduction by level of subjective poverty. Then, we estimate a logistic regression on the probability of experiencing a relevant income reduction (25% or more) and we present the results as average marginal effects to show the effect of the individuals characteristic (age, educational level, household size, employment status, type of contract) considered as the most relevant variable in the poverty literature.[10] Finally, we define four distinct situations resulting from the intersection between the ability to make ends meet before the pandemic and the income reduction due to the pandemic. We estimate two multinomial logistic regressions on the probability of experiencing one of the four situations and we show the results as average marginal effects to highlight the effect of education, age and working status.

[†] For more information on Bank of Italy data see: https://www.bancaditalia.it/statistiche/tematiche/indagini-famiglie-imprese/indag-straord-famiglie-italiane/index.html (Bank of Italy's data are open access on this website).

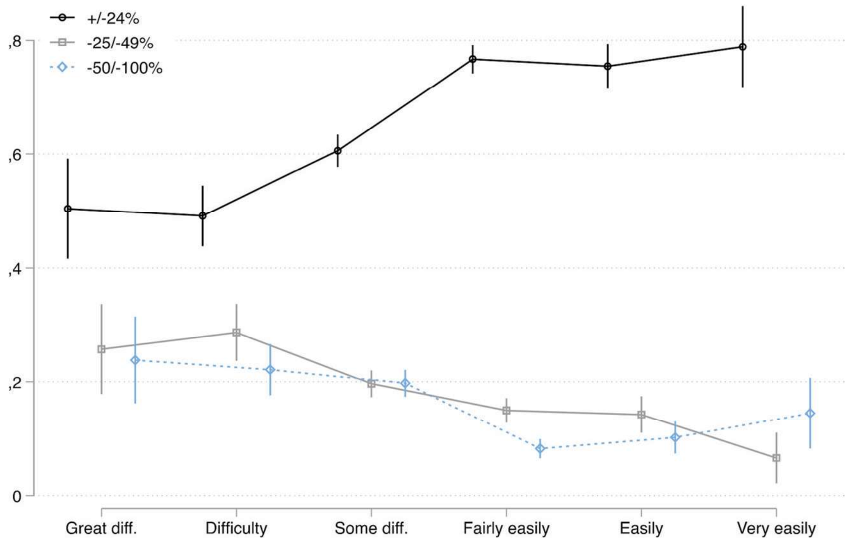


**Figure 1:** Probability of suffering an income variation by ability to make ends meet (multinomial logit, weighted linear probability). Source: authors' elaboration on Bank of Italy special survey in 2020.

## 2.2 Results

The relationship between feeling poor before the Covid-19 pandemic and experiencing an income variation is shown in Figure 1. The probability of experiencing little or no income variation increases as the ease to make ends meet increases (black line). The grey and the blue lines show that those who were already subjectively poor before the pandemic have been also more likely to suffer dramatic income falls at the beginning of the pandemic.

As Figure 2 shows, the negative correlation between subjective poverty and income fall is more pronounced for young people and adults with respect to retired individuals, for those who live in larger households (four members or more), for those with upper secondary education and for the employed.

The analysis of the subsample of the employed shows that income reduction particularly hit self-employed (Figure 3). This is the case of shopkeepers who experienced the forced shut down, of professionals who have seen a reduction in work, of small entrepreneurs in the non-essential services sector, but also of those individuals working for firms as collaborators (*partite IVA*) that represent in the Italian context the weakest and less protected category of workers. Collaborators, in fact, could not access redundancy funds as employees and received only small income support during the pandemic.

We identify four possible states (defined over subjective poverty before the pandemic and over income reduction in the first months of the pandemic)

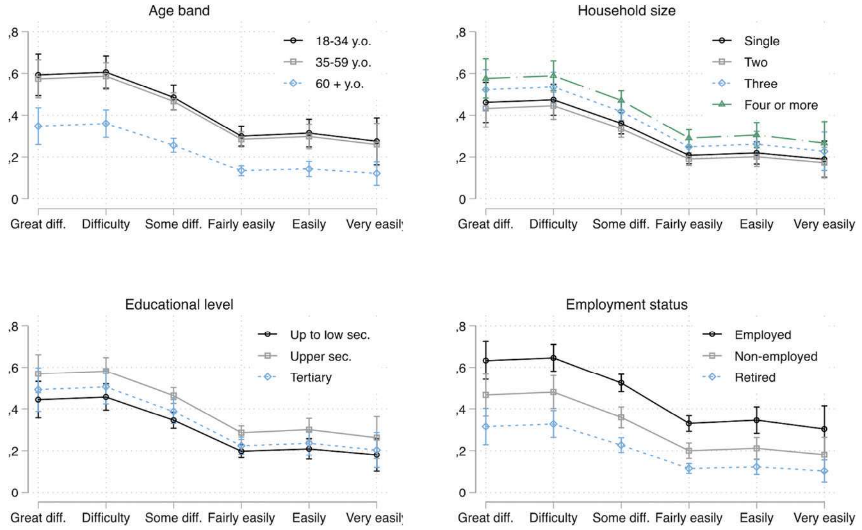


**Figure 2:** Probability of suffering from income reduction by household characteristics (logit regression, weighted linear probability). Source: authors' elaboration on Bank of Italy special survey in 2020.

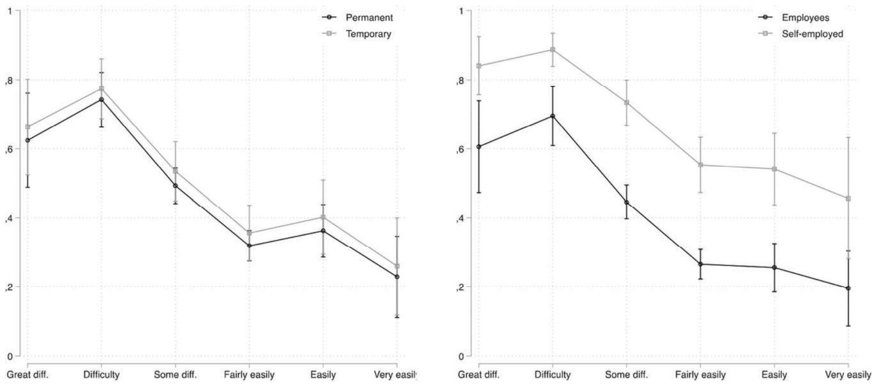


**Figure 3:** Probability of income reduction by employment characteristics household characteristics (logit regression, weighted linear probability). Source: authors' elaboration on Bank of Italy special survey in 2020.

in which individuals may find themselves. Figure 4 and Figure 5 show the probability of being in one of the four states by educational level for individuals of different age and employment status.

Having a higher educational level seems to protect individuals form being in a situation of fragility and it increases the probability of facing no difficulties. Young and adult individuals seem to have suffered more than individuals in the

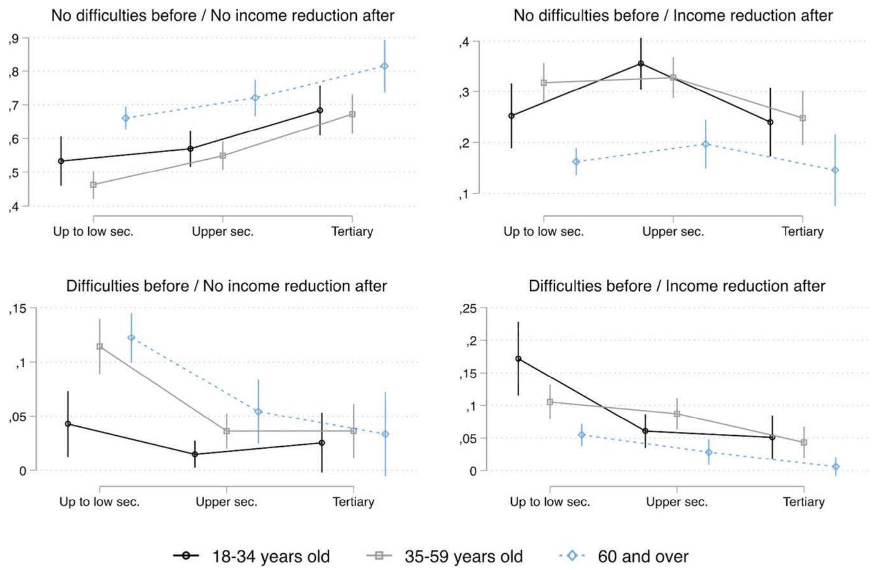


**Figure 4:** Probability of being subjectively poor before and after Covid by age and educational level (multinomial logit, weighted linear probability). Source: authors' elaboration on Bank of Italy special survey in 2020.

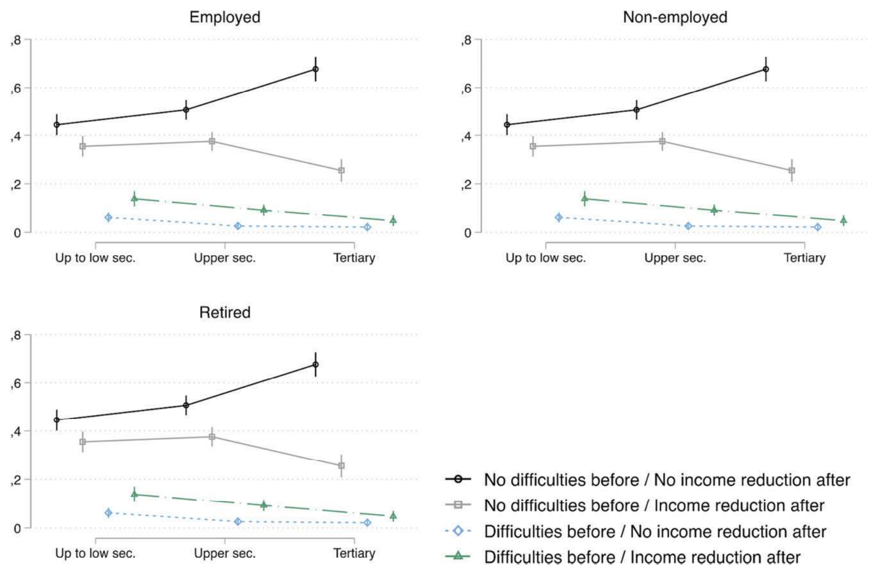


**Figure 5:** Probability of being subjectively poor before and after Covid by educational level and employment status (multinomial logit, weighted linear probability). Source: authors' elaboration on Bank of Italy special survey in 2020.

oldest age groups. If we look at the employment status, as expected, the least affected category is the one of pensioners, that were however most hit by the virus, with a high rate of mortality.

## 3 Concluding Remarks

The health emergency produced by the spread of Covid-19, with the limitations imposed on economic activities, had an overwhelming impact on Italian households' income. The weakness of anti-poverty policies and the strong public finance constraints that characterize the Italian context could have exacerbated the effect of the economic crisis due to the pandemic.

According to our data, about one third of households have seen their disposable income reduced substantially since the first month of the pandemic. This income reduction particularly hit those families that already were (or felt) poor before the pandemic and make those who were just above the poverty line at serious risk of slipping under it. Two phenomena seem to co-exist: on the one hand, the incidence of poverty has grown and, at the same time, the intensity of poverty has increased. As a consequence, some social groups have become even more vulnerable. The most fragile workers, *i.e.* youth, low educated and those working as self-employed, are more at risk of suffering a significant income reduction.

Considering this scenario, it is astonishing that during the pandemic many incentives have been introduced for instance to buy e-bikes and to renovate houses (often even second homes) instead of, for example, strengthening the guaranteed minimum income (*reddito di cittadinanza*).

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# The Italian Manufacturing Sector During the Covid-19 Pandemic: Some Lessons for a “New Industrial Policy"

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This paper analyzes the Italian manufacturing sector before and during the Covid-19 pandemic crisis. We analyze the behavior of Italian manufacturing sectors before the crisis, according to their competitiveness - the ISCO indicator, elaborated by the Italian National Institute of Statistics (ISTAT) - and their technological content, jointly elaborated by Eurostat and OECD. We observe the reaction from different sectors during the crisis and suggest to a adopt, as industrial policy, a mix of the “new horizontal approach", proposed by ISTAT, and differentiated vertical interventions for groups of sectors identified according to their technological content.

## 1 Introduction

The health crisis caused by the Covid-19 disease has created major problems to Italian manufacturing sectors. To understand and face the future challenges it is necessary to define a clear picture of the Italian manufacturing sectors in two different moments: before the Covid-19 impact and after a year in which the economy was disrupted by the pandemic.

In elaborating a recovery and restart strategy for the Italian manufacturing sectors it is important to highlight the elements of weakness and competitive advantages of the Italian manufacturing sectors, in the wake of a “New Industrial Strategy for Europe"[1] that identifies (for Europe) the strategic sectors in which to invest, in order to face future challenges and reduce the dependence from foreign countries, in particular from the People’s Republic of China. These sectors are food, infrastructure, robotics, microelectronics, pharmaceuticals, 5g communications networks, nanotechnologies, quantum technology, biomedicine, biotechnology.

It is very important for Italy during and after the Covid-19 crisis to detect the economic sectors to be supported, without top-down approaches, in coordination with the choices made by Europe. This will allow Italy to play a greater role in Europe and will enable Europe to strengthen its role in a world with

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geopolitical changes due, in particular, to the growing political and economic weight of China.

These selective interventions for groups of sectors must be accompanied by a “new kind of horizontal policies" as suggested by the Italian National Institute of Statistics (ISTAT) “for setting up a fine-tuned policy to drive the Italian firms towards profiles characterized by structural higher performance and growth potential".[2]

## 2 Literature Review

In the past any attempt to intervene into markets, and, especially, in certain sectors was highly criticized. Only since 2012, in conjunction with the Obama's US presidency, it has been possible to speak about industrial policies without problems.

Usually, it has been conventional to make a distinction between “horizontal" and “selective" (or vertical) industrial policies.[3] The selective policies were specifically aimed at improving the performance of specific industries, firms or sectors, while the horizontal policies were designed to benefit the economy more generally and improve the framework conditions of the policy. However, this distinction was not always clear-cut* . The “old" industrial policy consisted of vertical or sectoral top-down interventions. This has been for long-time criticized, in particular by the supporters of a liberal approach because these interventions could lead to favouritism and rent-seeking behaviours.

For all these reasons, before the financial crisis in 2008-2011, the mainstream avoided any interventions that could alter the economic structure and the principal interventions, from 1990 onwards, were only horizontal, i.e., mainly pro-competitive measures.

Subsequently, due to the high unemployment in many European countries caused by the financial crisis in 2008, arguments in favour of a new industrial policy emerged. The trade-off between a vertical and a horizontal definition of industrial policy was a sterile controversy for many scholars. Several conceptual developments and contributions have made it possible to go beyond this apparent trade-off: the “technological systems" identified by Carlsson and Jacobsson,[5] the “sectoral systems of innovation" proposed by Malerba,[6] and the development of industrial clusters, i.e., the promotion of institutions linking industries and universities (see[7,8]).

Another important contribution to overcoming the old dichotomy comes from the evolution of the globalisation process: the “global value chains" have

* The OECD[4] stresses that horizontal industrial policies often have a selective equivalent, e.g. targeted inward investment promotion or targeted skills policies, or sector-specific advisory services. Also, horizontal policies may turn out to be highly selective in their impact, for example, when favoring a general support for an input or activity that is used more intensively in some sectors than others (e.g., the impact of R&D tax credits is highly concentrated in the manufacturing sector).

been restructuring across countries and continents ([3,9]). This prompts companies to invest in skills enhancement and requires government interventions to support higher education and increase human capital skills. In this regard, a recent focus has been placed on capabilities; with the achievement of strong globalisation, companies are stressed by fiercer competition, so competing in capabilities is one way of dealing with the globalization process[10] and is one way of rethinking industrial policies.

This follows from the belief that increasing investment in education is necessary to compete in a globalised world, where human capital and capabilities[†] , embedded in the workforce of each company, will increasingly be the key assets with which to compete.[10]

The increasing role of capabilities as a competitive tool for companies shows the connection between investments in higher education and companies' market results.

Another important contribution to the rethinking of industrial policy is the "matrix approach" proposed by Aiginger and Sieber.[12] This approach, proposed for Europe, provides specific incentives for a numer of key macro-sectors . This could reduce the risks connected with random intervention in specific sectors and allow policy makers to take into account differences among EU countries. According to Aiginger and Sieber[12] an industrial policy for Europe should act considering the whole situation, focus on the environment and on innovation, and aim to generate systemic impacts (see[3,6,12–16]). The approach should influence the structure of the economy as a whole, not just the manufacturing sector. Industrial policy is a "series of 'high-road competitiveness strategies' based on advanced skills, innovation, supporting institutions, ecological ambition and activating social policy".[12]

Another particularly relevant dichotomy in the European case is the supposed opposition between pro-competitive measures and industrial policies. Because of the lack of significant employment results in the EU, obtained only by pro-competitive policies implementation, after the end of the financial crisis some scholars are finally considering competition and industrial policy as synergetic tools, no longer as opposing elements. Synergies appear to be particularly achievable in the most competitive sectors (see the interesting paper by Aghion et al.[17]).

An active industrial policy for the more competitive sectors can foster growth. This shows that especially in the long run there is no conflict of competition and industrial policy.[17] The weight and impact of public spending on GDP

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[†] The capabilities consist of a team of people who work together, within some framework of rules, routines and tacit understandings that have been put in place or have evolved over time.[11]

For example: food and life science, machine and systems industries, fashion and design industries, basic and intermediary industries.

have been reconsidered¶ . Moreover, during the Covid-19 crisis, because of huge and relevant economic damages, the attitude to a new state intervention in the economy has completely changed and the lesson by Mazzuccato,[8] arguing that the US economic success is a result of public and state investments in innovation and technology, rather than a result of the small state, has obtained an increasing attention. Now the debate about the definition of new industrial policies is widespread worldwide.

## 3 The Italian Pre-Covid-19 Manufacturing Sectors

To understand the impact of Covid -19 on the Italian manufacturing sectors, it is useful to analyze the manufacturing sectors in Italy before the arrival of the Covid-19 pandemic.

To give a broad picture of the manufacturing sectors we consider the analysis done by ISTAT according to the ISCO indicator in.[19]

The ISCO indicator, assessed by ISTAT, is a "synthetic indicator of competitiveness that synthesizes different variables: cost competitiveness (i.e. the ratio between added value per employee and unit labour cost), gross profitability ( i.e. the ratio between gross operating margin and added value), propensity to export (i.e. the percentage of exported turnover), variation in exports and incidence of the share of innovative firms.

The threshold value that identifies the most competitive sectors is set at 100 (see Figure 1); this helps to identify the sectors with a greater competitive advantage in adopting measures to strengthen the sectors that can create new jobs and potential growth. Moreover, according to Anderloni and Giorgetti,[20] it is important to cross-reference the information obtained by ISCO with the classification made by Eurostat-OCSE, according to the level of technology of each sector§ .

The most competitive Italian sectors, classified according to the technological content, are: for the high technology group: Pharmaceuticals (C21) and Manufacture of computer, electronic and optical products (C26). As for the medium-high tech group we find the manufacture of motor vehicles, trailers and semi-trailers (C29), the manufacture of chemicals and chemical products (C20) and the manufacture of other transport equipment (C30).[21] In the medium-low tech group Italy has other very competitive sectors: the manufacture of coke

¶ According to Florio,[18] a proper industrial policy at EU level should include huge public demand for infrastructure, high technology industries and services by revising the magnitude and the allocation of the EU budget, and learning the lesson of the impact of federal procurement on high-tech industries in USA.

§ See.[21] The Eurostat-OECD classification divides the various manufacturing sectors into four subclasses based on the technological content: (i) high technology sectors; (ii) medium-high technology sectors; (iii) medium-ow technology sectors; (iv) low technology sectors

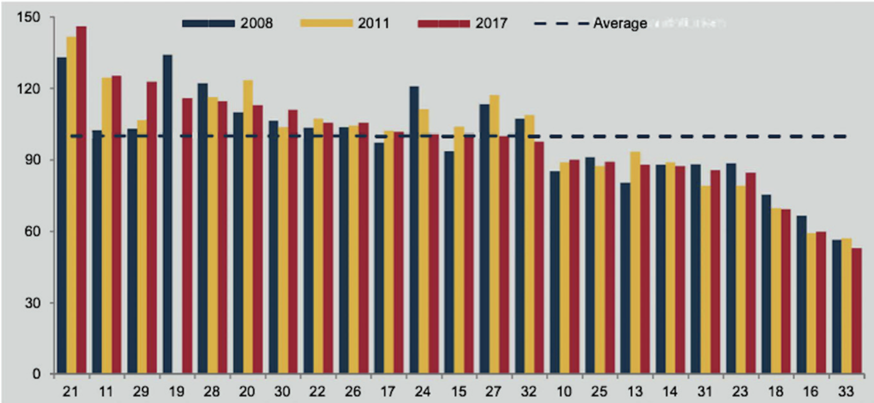


**Figure 1:** ISCO Synthetic Index of competitiveness Years: 2008, 2011, 2017. Source: ISTAT.[19] Average =100. Sectors:
10 = Food; 11 = Beverages; 13 = Textile; 14 = Clothing; 15 = Leather; 16 = Wood; 17 = Paper; 18 = Printing; 20 = Chemical; 21 = Pharmaceutical; 22 = Rubber and plastic; 23 = Non-metallic mineral; 24 = Metallurgy; 25 = Metal products; 26 = Electronics; 27 = Electrical equipments; 28 = Machinery; 29 = Automotive; 30 = Other means of transport; 31 = Furniture; 32 = Other manufacturing; 33 = Repair and maintenance of machinery and equipment.

and redefined petroleum products (C19), the manufacture of rubber and plastic products (C22) and the manufacture of basic metals (C24). Finally, in the group of low-tech sectors in Italy presents other highly competitive sectors: beverages (C11), the manufacture of paper and paper products (C17), the manufacture of leather and related products (C15).

By merging the classification made by ISTAT according to ISCO and the quoted Eurostat OECD classification we can see the technological content of more competitive sectors. This can help to give a picture of the competitive advantage of Italy and establish a framework for policies of groups of sectors.

## 4 The Italian Manufacturing Sectors: One Year with the Covid-19 Crisis

The Covid-19 crisis has affected the whole Italian economy and in particular the industrial sector. One of the most important break-grounding analysis on the Covid-19 crisis has been conducted by ISTAT using a new integrated company-level database.

This database benefits from the integration of several administrative sources such as the ISTAT Permanent Census of Enterprises, the ISTAT Integrated System of Registers, and two *ad-hoc* surveys, carried on in May 2020 and in November 2020, about the resilience of Italian firms towards the Covid-19 crisis.[22]

From the observed data through a multivariate analysis ISTAT proposes the identification of different profiles for Italian enterprises according to their resilience to shocks, i.e. a "new horizontal" approach based on firms heterogeneity "to identify drivers (both endogenous and exogenous to firms' choice) of the transition of Italian firms towards profiles characterized by structural higher performance and potential growth"[2,23] (see in particular the position papers presented at the Forum on line on "The New European Industrial Strategy after the great financial crisis and the Covid crisis oriented to new citizens needs and territory"[24]).

Our proposal is to combine the analysis presented in the previous section on data and indicators constructed by ISTAT with the new ISTAT's horizontal approach.

In particular, ISTAT[22] identifies five different firm profiles in different sectors, based on their reactions to the Covid-19 crisis:

1. *static firms in crisis*: firms with no response strategies, heavily affected by the health emergency;
2. *static resilient firms*: firms with no reaction but not suffering any strong damage;
3. *suffering proactive firms*: heavily affected firms but with reaction strategies;
4. *proactive firms in expansion*: slightly affected firms with no change along their previous expansion trajectory;
5. *advanced proactive*: slightly affected firms that increased their investments in 2020 compared to 2019.

Figure 2 shows the distribution of different company profiles in different sectors, according to the different level of resilience. The distribution is somewhat similar, with a few exceptions (manufacturing refers to sectors with the Nace classification ranging from sector 10 to sector 33). The Food sector (sector 10) presents a high percentage of "static firms in crisis (in red) together with Printing and reproduction of recorded media (sector 18) and Manufacture of furniture (sector 31), Other manufacturing (sector 32), Repair and installation of machinery and equipment (sector 33).

Sectors with the highest percentages of "advanced proactive firms" are beverages (sector 11), manufacture of coke and refined petroleum products (sector 19), manufacture of chemicals and chemical products (20), manufacture of basic pharmaceutical products and pharmaceutical preparations (sector 21), manufacture of computer, electronic and optical products (sector 26), manufacture of electric equipment (sector 27), manufacture of machinery and electric equipment (sector 28), manufacture of motor vehicles, trailers and semi-trailers (29).

Comparing this information with the previous paragraph results about the employment ISCO indicator, we may detect the most competitive sectors in

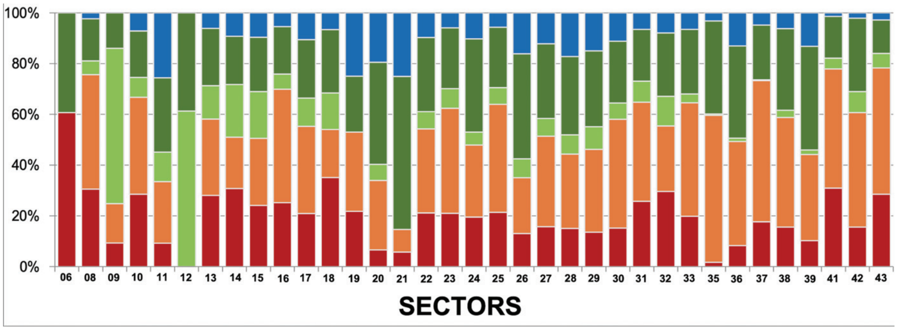


**Figure 2:** Percentage distribution of enterprises in the profiles by division of economic activity. Source: ISTAT.[22] Red: "Static firm in crisis"; Orange: "Resilient static"; Light green: "affected proactive"; Green: "proactive in expansion"; Blue: "advanced proactive". Sectors:
06 = Extractive energy; 08 = Other Extractive; 09 = Support for extractive; 10 = Food; 11 = Beverages; 12 = Tobacco; 13 = Textile; 14 = Clothing; 15 = Leather; 16 = Wood; 17 = Paper; 18 = Printing; 19: Petroleum; 20 = Chemical; 21 = Farmaceutical; 22 = Rubber and plastic; 23 = Non-metallic mineral; 24 = Metallurgy; 25 = Metal products; 26 = Electronics; 27 = Electrical equipments; 28 = Machinery; 29 = Automotive; 30 = Other means of transport; 31 = Furniture; 32 = Other manufacturing; 33 = Repair and maintenance of machinery and equipment; 35 = Energy; 36 = Water; 37; Sewage; 38= Waste; 39 = Other waste; 41= Construction; 42 = Civil engineering; 43 = Other construction.

Italy in the pre-Covid-19 situation. The highest percentage of advanced proactive firms is mainly distributed in the most competitive sectors according to the ISCO Indicator. Therefore, there is a strong correlation between the most competitive sectors in a pre-Covid-19 situation and the sectors showing the highest percentage of proactive firms during the Covid-19 crisis.

This result, therefore, gives support to the new kind of analysis carried out by ISTAT in which the focus for future policies is on new horizontal policies that should increase the transition of each company to the closest group with greater resilience: for example, the transition to group 2 from group 1 firms, to group 3 from group 2 firms, and so on.

## 5 Conclusions

The crisis has highlighted the strengths and weaknesses of the Italian manufacturing sector. After a comparison between the situation before the crisis and the picture of the manufacturing sectors during the Covid crisis, we may observe a strong correlation between the most competitive sectors before the crisis and the distribution of the more resilient and proactive companies among the most competitive sectors, during the crisis. So, the "new horizontal approach" proposed by ISTAT based on firms' heterogeneity, irrespective of sectors, is not opposed to differentiated measures for different sets of sectors. An analysis based on the ISCO indicator, (also computed by ISTAT, see section 3) allows the identification of the most competitive sectors. By cross-referencing this information with the classification (based on the technological content) computed by Eurostat and OECD, according to[20] it is possible to define different measures for the groups of the most competitive sectors. The measures will change according to the R&D intensity level: different policies for high-tech and low-tech industries. Our suggestion, therefore, is to join the "new horizontal industrial policy" suggested by ISTAT during the crisis, with different policies for macro-sectors, i.e. group of sectors with a higher level of competitiveness (with the ISCO indicator greater than the benchmark level equal to 100). Last but not least, every Italian policy makers' decision must be planned taking into account the New Industrial Strategy for Europe,[1] pointing out the strategic sectors for Europe.

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# A Two–Strain SARS–COV–2 Model for Germany - Evidence from a Linearization

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Currently, due to the COVID–19 pandemic the public life in most European countries stopped almost completely due to measures against the spread of the virus. Efforts to limit the number of new infections are threatened by the advent of new variants of the SARS–COV–2 virus, most prominent the B.1.1.7 strain with higher infectivity. In this article we consider a basic two–strain SIR model to explain the spread of those variants in Germany on small time scales. For a linearized version of the model we calculate relevant variables like the time of minimal infections or the dynamics of the share of variants analytically. These analytical approximations and numerical simulations are in a good agreement to data reported by the Robert–Koch–Institute (RKI) in Germany.

## 1 Introduction

The current COVID–19 pandemic is striking across the world and has put Europe at the dawn of its third wave. In Germany due to the rising numbers at the end of the year 2020, the non-pharmaceutical intervention (NPI) measures have been strengthened, leading to a severe lockdown with closing of the main parts of the daily life. With the reestablishment of the NPIs the reports of new strains of the SARS–COV–2 virus throughout Europe were rising.[1] Especially a variant called B.1.1.7 that was first reported in Great Britain,[2,3] showed an increased infectivity[4] with a higher attack rate especially in the younger age groups. In the last days (February 21, 2021) the incidences are stagnating or slowly increasing, although Germany has not eased the lockdown. One explanation among experts and media is the rising of incidences with the new mutations.

In various countries B.1.1.7. is rapidly spreading, see[5] for an overview.

In Figure 1 we show the share of this new strain with respect to analyzed SARS–COV–2{positive tests in a given week in five European countries. Week zero is defined as the week, when this share was approximately 1%. All five countries follow a general logistic trend. The curves for England (blue), Netherlands (orange) and Germany (black) are rather similar, where as Denmark (red) and

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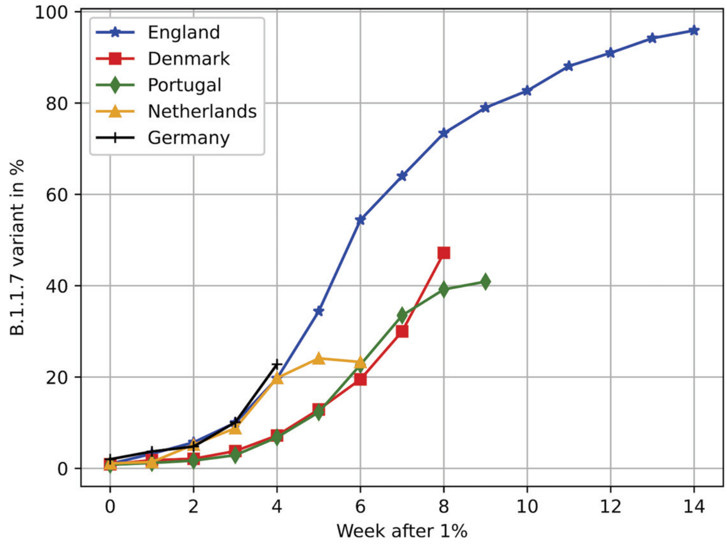


**Figure 1:** Share of the B.1.1.7 variant of the SARS–COV–2 virus in five European countries. Week zero corresponds to the week when the share is approximately 1%.

Portugal (green) also behave similar but slower than the first three. Within this paper we will formulate a SIR–based model that predicts these curves and explains well the observed data in Germany on a small time horizon.

## 2 Mathematical Model

We consider an SIR–model for the spread of two strains of the SARS–COV–2 virus within a constant and serologically naive population. The two competing strains 1 and 2 are assumed to have different transmission rates $\beta_2, \beta_1 > 0$ but the same recovery rate $\gamma > 0$. Assuming no secondary infections, the model is based on the four compartments: susceptible $S$, infected $I_1$ and $I_2$, indicating strain 1 or 2,respectively, and removed $R$. Neglecting demographic effects like birth and death, we get

$$S' = -(\beta_1 I_1 + \beta_2 I_2)\,\frac{S}{N}\,, \tag{1a}$$

$$I_1' = \frac{\beta_1 I_1}{N} S - \gamma I_1\,, \tag{1b}$$

$$I_2' = \frac{\beta_2 I_2}{N} S - \gamma I_2\,, \tag{1c}$$

$$R' = \gamma (I_1 + I_2)\,. \tag{1d}$$

For the following analysis and simulations we assume a situation that models the competition between the original SARS–COV–2 virus and mutated variants like B.1.1.7 that is currently observed in many countries throughout Europe. The second (mutated) strain has a higher infection rate, i.e. $\beta_2 > \beta_1$. However, at the initial time, the original strain 1 is still dominant in the population i.e. $I_1(0) > I_2(0)$. Current non–pharmaceutical interventions are strict enough to suppress the original strain, i.e. to force its reproduction number below the epidemic threshold $\mathcal{R}_1 := \frac{\beta_1}{\gamma} < 1$. However the mutated strain 2, due to its higher infectivity, might reach a reproduction number $\mathcal{R}_2 > 1$ and hence drives the epidemic.

Typical questions that might arise in this setting:

- When will strain 2 dominate the dynamics? After what time $T^*$ do we observe $I_2(T^*) > I_1(T^*)$?
- How does the total number of infected $I = I_1 + I_2$ evolve in time? At what time $\check{T}$ do we observe a local minimum of the infections?

In our model, we neglect the effect of possible vaccinations, that might have different efficiency with respect to the two strains.

## 3 Analysis

Let $N$ denote the constant total population. We rescale the populations $s = S/N$, $x = I_1/N$, $y = I_2/N$ and $r = R/N$ and introduce a non–dimensional time $\gamma t$. Then we get

$$s' = -(\mathcal{R}_1 x + \mathcal{R}_2 y)\, s \tag{2a}$$
$$x' = (\mathcal{R}_1 s - 1)\, x \tag{2b}$$
$$y' = (\mathcal{R}_2 s - 1)\, y \tag{2c}$$
$$r' = x + y \tag{2d}$$

where $\mathcal{R}_i = \beta_i/\gamma$. Setting $y = zx$, where $z$ denotes the ratio between infected with strains 1 and 2, we get

$$z' = (\mathcal{R}_2 - \mathcal{R}_1)\, s z \tag{3a}$$

with the solution

$$z(t) = z_0 \exp\left[(\mathcal{R}_2 - \mathcal{R}_1) \int_0^t s(t)\, dt\right] . \tag{3b}$$

In case of $\mathcal{R}_2 > \mathcal{R}_1$, the ratio between the two strains is going to tend towards strain 2, i.e. $z > 1$.

### 3.1 Linearized Setting

In case of dominating susceptibles, i.e. $s \approx 1$ the ODEs (2) linearize

$$x' = (\mathcal{R}_1 - 1)\,x \tag{4a}$$
$$y' = (\mathcal{R}_2 - 1)\,y\ , \tag{4b}$$

and we are able to solve them explicitly for the infected compartments $x, y$. For both compartments we observe an exponential behavior; however since $\mathcal{R}_1 < 1$ the compartment $x$ is dying out and compartment $y$ is exponentially growing due to $\mathcal{R}_2 > 1$. The ratio $z$ of the two strains exhibits an exponential increase

$$z(t) = z_0 e^{(\mathcal{R}_2 - \mathcal{R}_1)t}\ . \tag{5}$$

In this setting we can easily answer the initial questions posed in section 2:

1. Strain 2 will "overtake" strain 1 at time $T^*$, i.e. $z(T^*) = 1$. In the linearized model (4) this time $T^*$ is given by

$$T^* = -\frac{\ln z_0}{\mathcal{R}_2 - \mathcal{R}_1} > 0 \tag{6}$$

   since $z_0 < 1$ and $\mathcal{R}_2 > \mathcal{R}_1$.
2. The total infected attain a local minimum at time $\check{T}$ when $(x+y)'(\check{T}) = 0$. In the linearized model (4) it holds that

$$x' + y' = (\mathcal{R}_1 - 1)x + (\mathcal{R}_2 - 1)zx$$

   and hence $z(\check{T}) = z_0 e^{(\mathcal{R}_2 - \mathcal{R}_1)\check{T}} = \frac{1-\mathcal{R}_1}{\mathcal{R}_2 - 1} > 0$. So we arrive at

$$\check{T} = \frac{1}{\mathcal{R}_2 - \mathcal{R}_1} \ln \frac{1 - \mathcal{R}_1}{z_0(\mathcal{R}_2 - 1)} = T^* \cdot \ln \frac{1 - \mathcal{R}_1}{\mathcal{R}_2 - 1} \tag{7a}$$
$$\check{z} = z(\check{T}) = \frac{1 - \mathcal{R}_1}{\mathcal{R}_2 - 1}\ . \tag{7b}$$

The minimal number of infected is given by

$$
\begin{aligned}
(x+y)_{\min} &= x_0 e^{(\mathcal{R}_1-1)\check{T}}\,(1+\check{z}) \\
&= x_0 \left[\frac{1-\mathcal{R}_1}{z_0(\mathcal{R}_2-1)}\right]^{(\mathcal{R}_1-1)/(\mathcal{R}_2-\mathcal{R}_1)} \cdot \frac{\mathcal{R}_2-\mathcal{R}_1}{\mathcal{R}_2-1}
\end{aligned} \tag{7c}
$$

The relative share $p = y/(x+y) = z/(1+z)$ of the second strain $y$ with respect to the total infected $x+y$ satisfies in the linearized setting the following logistic relation

$$
p = \frac{z_0 e^{(\mathcal{R}_2-\mathcal{R}_1)t}}{1+z_0 e^{(\mathcal{R}_2-\mathcal{R}_1)t}} = \frac{z_0}{z_0 + e^{-(\mathcal{R}_2-\mathcal{R}_1)t}} \in [0,\,1]\;. \tag{8}
$$

In the linear, single strain model $x' = (\mathcal{R}_1 - 1)x$ the reproduction number satisfies the relation

$$
\mathcal{R}_1 = 1 + \frac{d}{dt}\ln x\;.
$$

Hence we may define analogously the current reproduction number $\mathcal{R}(t)$ for the total infected as

$$
\mathcal{R}(t) := 1 + \frac{d}{dt}\ln(x+y)\;. \tag{9}
$$

Using the solution of the linear model $x + y = x_0 e^{(\mathcal{R}_1-1)t} + x_0 z_0 e^{(\mathcal{R}_2-1)t}$ we obtain the convex combination

$$
\mathcal{R}(t) := (1-p)\mathcal{R}_1 + p\mathcal{R}_2 = \mathcal{R}_1 + \frac{\mathcal{R}_2-\mathcal{R}_1}{1+\frac{1}{z_0}e^{-(\mathcal{R}_2-\mathcal{R}_1)t}}\;, \tag{10}
$$

i.e. a logistic behavior switching between $\mathcal{R}_1$ for $t \to -\infty$ and $\mathcal{R}_2$ for $t \gg 1$. At time $\check{T}$, when the total number of infected attains its minimum, the current reproduction number crosses the stability threshold, i.e. $\mathcal{R}(\check{T}) = 1$. For the non–linear model, the overall behavior of the reproduction number is similar, despite the saturation effect due to the decreasing pool of susceptibles.

## 4 Simulations

For our simulations, we assume the following data roughly resembling the situation in Germany by mid of January to mid of February:

1. The total population equals to $N = 83$ millions including 3 millions of recovered or vaccinated and $x_0 \simeq 78.000$ infected with variant 1 and $y_0 = z_0 \cdot x_0$ infected with strain 2.
2. The recovery period is assumed to be $1/\gamma = 5$ days.
3. Strain 1 has a reproduction number of $\mathcal{R}_1 = 0.85$, i.e. the current lockdown measures are strict enough to mitigate the original strain.
4. The mutated strain 2 is assumed to be 50% more infectious, i.e. $\mathcal{R}_2 = 1.5 \cdot \mathcal{R}_1 = 1.275$ and hence spreads in time.
5. At the initial time (25 January) we assume that only 3% of cases belong to strain 2, i.e. $z_0 = 0.03$.
6. Lab experiments[9] report in week 4 around 5.6% and in week 6 already around 22% of infections with strain 2.

Using the approximations (6) and (7) from the linearized model, strain 2 will dominate strain 1 at $T^* = -\frac{\ln z_0}{\mathcal{R}_2 - \mathcal{R}_1} = 8.2 \equiv 41$ days. The minimal number of infected is expected to be $(x + y)_{\min} = 0.69 \cdot x_0$ at time $\check{T} = 6.8 \equiv 34$ days.

The non–linear model (2) cannot be solved analytically; hence we perform numerical simulations based on the parameter given above. Figures 2, 3 show the dynamics of both strains and the current reproduction number based on

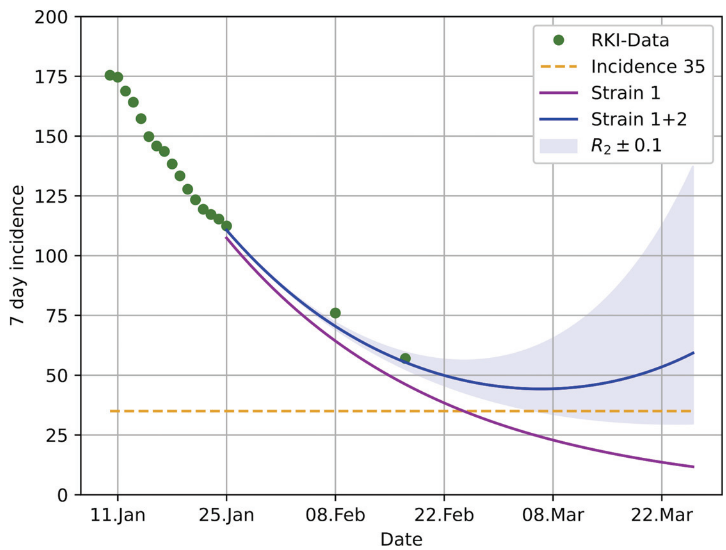


**Figure 2:** Incidence (per 100.000 inhabitants in 7 days) of strain 1 (violet) and of both strains combined (blue) as predicted by the SIR–model (2). Parameters are $\mathcal{R}_1 = 0.85$, $\mathcal{R}_2 = 1.275$, $\gamma = 1/5$. The green dots indicate incidences for entire Germany. The shaded area indicates the simulation range, if $\mathcal{R}_2 = 1.275 \pm 0.1$. The orange dash line indicates an incidence of 35 that is viewed in Germany as a limit for relaxing the current lockdown.

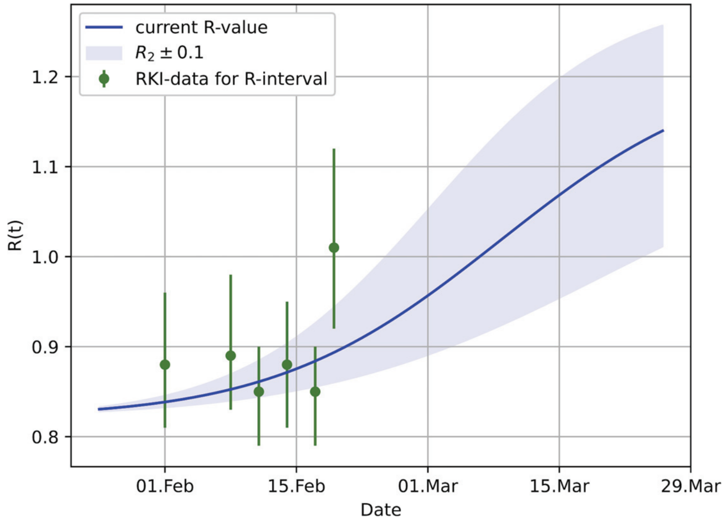


**Figure 3:** Current value of the effective reproduction number (9) for both strains. The green dots indicate the RKI–data for the 7day–R0 together with the reported confidence interval. The shaded area indicates the simulation range, if $\mathcal{R}_2 = 1.275 \pm 0.1$.

Eqn. (9). The weekly incidences (new infections per 100.000 inhabitants within 7 days) are shown in Figure 2. The green dots indicate the reported data, see.[10] The violet curve shows the decay of the original strain 1 with is reproduction number $\mathcal{R}_1 = 0.85 < 1$. The blue curve shows the total incidence of both strains combined. At around 8 March, i.e. 6 weeks after the starting time of the simulation (25 January), the total number of infected reaches its minimum with an incidence of about 44 per 100.000. The time at which the minimum occurs is slightly larger than for the linear model (41 days for the nonlinear model compared to 34 days for the linearized approximation). Our scenario and its parameters match quite well with the observed incidences, here shown for 8 and 17 February. The shaded area indicates the prediction uncertainty due to variations ($\mathcal{R}_2 \pm 0.1$) of the reproduction number of the second strain. Based on this simulation, the political target to push the infections below the threshold of 35 before introducing relaxation measures seems questionable; at least on a short time horizon.

Figure 3 shows the current reproduction number for both strains combined as defined in Eqn. (9). Again, the green dots and error bars show the 7–day reproduction number as reported by RKI in its daily situation reports.[11] The blue curve shows our simulation results based on the non–linear model (2) and again the shaded area indicates the uncertainty due to variation of the reproduction number of the second strain ($\mathcal{R}_2 \pm 0.1$). Currently, RKI is reporting an increase of the reproduction number breaking through the epidemic threshold of $\mathcal{R}(t) =$

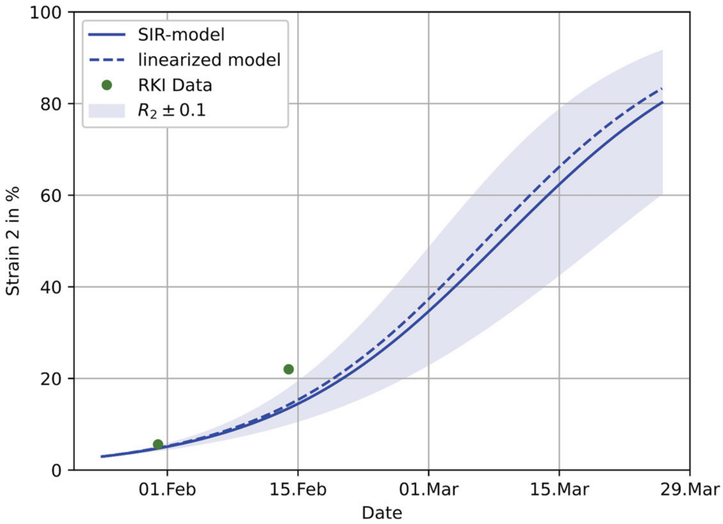


**Figure 4:** Simulation for of the relative share $p = y/(x + y)$ of the second strain. Reproduction numbers $\mathcal{R}_1 = 0.85$, $\mathcal{R}_2 = 1.275$. The green dots indicate the RKI data for the percentage of "variants of concern", see.[9] The solid blue line shows the non–linear SIR–Model (1d) whereas the dashed line is the linearized approximation. The shaded area indicates the simulation range of the non–linear SIR–model, if $\mathcal{R}_2 = 1.275 \pm 0.1$.

1 as predicted by our model. The non–pharmaceutical interventions imposed by the government have not been altered in during the time span covered by the simulations, hence we may explain the increase of the overall reproduction number by growing influence of the second strain.

Figure 4 shows the relative share $p$ of strain 2 with respect to the total infections with SARS–COV–2 in Germany. The green dots indicate the data reported by RKI for week 4 and week 6, see.[9] The blue curves show our predictions; the dashed one corresponds to the approximation (10) in the linearized setting and the solid one corresponds to the non-linear SIR model. Both results do not differ significantly and the linearized model already predicts quite well the dynamics of the relative share of the second strain compared to all infections. Both results are within the range of the given data. Again, the shaded area indicates the uncertainty caused by variations in the reproduction number for the second strain. For the beginning of March we expect more than 40% of infections with the second strain.

## 5 Conclusions and Outlook

In this work we have presented a two–strain SIR model to explain the spread of SARS–COV–2 variants like B.1.1.7 in Germany. For a linearized version of the model we were able to calculate relevant variables like the time of minimal infections or the dynamics of the share of variants analytically. These analytical approximations as well as simulations for the non–linear SIR model are compared to infection data reported by RKI. Our model shows a good level of agreement and gives rise to some concern regarding the near term future of the dynamics. For mid of March we expect to see in Germany a share of at least 40% of variants. Moreover, the figure of an incidence of 35 per 100.000 and 7 days, which was introduced by politics as limit for easing the current lockdown measures, seems out of reach.

In a follow–up study we will try to investigate the effect of the current ramping up of mass vaccinations. One might expect, that vaccinations will help to slow down the spread of the disease and hence force the level of incidence below a threshold that allows contact tracing by public health authorities.

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# The Effects of the Covid-19 Pandemic on the Italian Economic System: the Factors Underlying the Resilience of the Lombard Manufacturing Sector

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Italy was the first country in the western world to be officially hit by the pandemic in February 2020. Government interventions aimed at regulating the necessary lockdowns and restrictions of social behavior initially blocked all productive activities, except for activities relating to essential goods and services, with a particularly significant impact in sectors related to people's free time and social life. As is well known, this has had evident negative repercussions on the gross domestic product (GDP), above all on companies and sectors already in difficulty before the pandemic; on the disposable income of people employed in companies blocked by the measures; and, therefore, on the general levels of consumption. In this context, the Lombard manufacturing sector, the engine of the Italian economy, has shown a great capacity for resilience. The paper focuses on the factors underlying the effective response to the crisis, as they most likely represent the same elements that can allow or accelerate the post-Covid regrowth.

## 1 Introduction

Due to the Covid-19 pandemic that marked the whole of 2020 and which is still affecting the entire planet, there have been falls in in Western economies' GDP that had not been recorded since the end of the Second World War, see Figure 1. Despite the drama of the situation at a social, economic and health level, the objective of the paper is to demonstrate how the pandemic and the related crisis have contributed to initiating important changes and transformation processes, both in terms of demand and production supply, that could indicate some possible ways of development for the future, as soon as the vaccination campaign will make it possible to secure the population in each country. Despite the drama of the situation at a social, economic and health level, the objective of the paper is to demonstrate how the pandemic and the related crisis have contributed to initiating interesting changes and transformation processes, both in terms of supply and demand - relevant for the

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| | Year over Year | | | | | | Q4 over Q4 2/ | | |
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| | 2019 | 2020 | 2021 | 2022 | 2021 | 2022 | 2020 | 2021 | 2022 |
| **World Output** | **2.8** | **–3.5** | **5.5** | **4.2** | **0.3** | **0.0** | **–1.4** | **4.2** | **3.7** |
| **Advanced Economies** | **1.6** | **–4.9** | **4.3** | **3.1** | **0.4** | **0.2** | **–3.9** | **4.6** | **1.9** |
| United States | 2.2 | –3.4 | 5.1 | 2.5 | 2.0 | –0.4 | –2.1 | 4.0 | 2.0 |
| Euro Area | 1.3 | –7.2 | 4.2 | 3.6 | –1.0 | 0.5 | –6.8 | 5.8 | 2.0 |
| Germany | 0.6 | –5.4 | 3.5 | 3.1 | –0.7 | 0.0 | –5.3 | 5.2 | 1.7 |
| France | 1.5 | –9.0 | 5.5 | 4.1 | –0.5 | 1.2 | –8.2 | 7.4 | 2.0 |
| Italy | 0.3 | –9.2 | 3.0 | 3.6 | –2.2 | 1.0 | –8.3 | 4.2 | 2.3 |
| Spain | 2.0 | –11.1 | 5.9 | 4.7 | –1.3 | 0.2 | –9.8 | 7.1 | 2.0 |
| Japan | 0.3 | –5.1 | 3.1 | 2.4 | 0.8 | 0.7 | –2.3 | 2.7 | 1.6 |
| United Kingdom | 1.4 | –10.0 | 4.5 | 5.0 | –1.4 | 1.8 | –8.3 | 6.0 | 1.9 |
| Canada | 1.9 | –5.5 | 3.6 | 4.1 | –1.6 | 0.7 | –4.0 | 3.7 | 2.7 |
| Other Advanced Economies 3/ | 1.8 | –2.5 | 3.6 | 3.1 | 0.0 | 0.0 | –2.2 | 4.5 | 1.9 |
| **Emerging Market and Developing Economies** | **3.6** | **–2.4** | **6.3** | **5.0** | **0.3** | **–0.1** | **0.9** | **3.7** | **5.4** |
| Emerging and Developing Asia | 5.4 | –1.1 | 8.3 | 5.9 | 0.3 | –0.4 | 3.2 | 3.8 | 6.4 |
| China | 6.0 | 2.3 | 8.1 | 5.6 | –0.1 | –0.2 | 6.2 | 4.2 | 6.0 |
| India 4/ | 4.2 | –8.0 | 11.5 | 6.8 | 2.7 | –1.2 | 0.6 | 1.7 | 7.8 |
| ASEAN-5 5/ | 4.9 | –3.7 | 5.2 | 6.0 | –1.0 | 0.3 | –3.2 | 5.2 | 6.1 |
| Emerging and Developing Europe | 2.2 | –2.8 | 4.0 | 3.9 | 0.1 | 0.5 | –2.7 | 4.8 | 3.0 |
| Russia | 1.3 | –3.6 | 3.0 | 3.9 | 0.2 | 1.6 | –4.6 | 5.3 | 2.6 |
| Latin America and the Caribbean | 0.2 | –7.4 | 4.1 | 2.9 | 0.5 | 0.2 | –4.8 | 2.3 | 2.8 |
| Brazil | 1.4 | –4.5 | 3.6 | 2.6 | 0.8 | 0.3 | –1.9 | 1.6 | 2.6 |
| Mexico | –0.1 | –8.5 | 4.3 | 2.5 | 0.8 | 0.2 | –5.4 | 2.2 | 2.4 |
| Middle East and Central Asia | 1.4 | –3.2 | 3.0 | 4.2 | 0.0 | 0.2 | ... | ... | ... |
| Saudi Arabia | 0.3 | –3.9 | 2.6 | 4.0 | –0.5 | 0.6 | –3.1 | 3.5 | 4.0 |
| Sub-Saharan Africa | 3.2 | –2.6 | 3.2 | 3.9 | 0.1 | –0.1 | ... | ... | ... |
| Nigeria | 2.2 | –3.2 | 1.5 | 2.5 | –0.2 | 0.0 | ... | ... | ... |
| South Africa | 0.2 | –7.5 | 2.8 | 1.4 | –0.2 | –0.1 | –6.2 | 2.8 | 0.6 |
| *Memorandum* | | | | | | | | | |
| Low-Income Developing Countries | 5.3 | –0.8 | 5.1 | 5.5 | 0.2 | 0.0 | ... | ... | ... |
| World Growth Based on Market Exchange Rates | 2.4 | –3.8 | 5.1 | 3.8 | 0.3 | 0.0 | –2.0 | 4.3 | 3.1 |
| **World Trade Volume (goods and services) 6/** | **1.0** | **–9.6** | **8.1** | **6.3** | **–0.2** | **0.9** | ... | ... | ... |
| Advanced Economies | 1.4 | –10.1 | 7.5 | 6.1 | 0.4 | 1.0 | ... | ... | ... |
| Emerging Market and Developing Economies | 0.3 | –8.9 | 9.2 | 6.7 | –1.0 | 0.8 | ... | ... | ... |
| **Commodity Prices (US dollars)** | | | | | | | | | |
| Oil 7/ | –10.2 | –32.7 | 21.2 | –2.4 | 9.2 | –5.4 | –27.6 | 13.5 | –2.2 |
| Nonfuel (average based on world commodity import weights) | 0.8 | 6.7 | 12.8 | –1.5 | 7.7 | –2.0 | 15.4 | 2.0 | –0.1 |
| **Consumer Prices** | | | | | | | | | |
| Advanced Economies 8/ | 1.4 | 0.7 | 1.3 | 1.5 | –0.3 | –0.1 | 0.5 | 1.5 | 1.6 |
| Emerging Market and Developing Economies 9/ | 5.1 | 5.0 | 4.2 | 4.2 | –0.5 | –0.1 | 3.2 | 3.8 | 3.7 |
| **London Interbank Offered Rate (percent)** | | | | | | | | | |
| On US Dollar Deposits (six month) | 2.3 | 0.7 | 0.3 | 0.4 | –0.1 | –0.1 | ... | ... | ... |
| On Euro Deposits (three month) | –0.4 | –0.4 | –0.5 | –0.6 | 0.0 | –0.1 | ... | ... | ... |
| On Japanese Yen Deposits (six month) | 0.0 | 0.0 | –0.1 | –0.1 | –0.1 | –0.1 | ... | ... | ... |

**Figure 1:** World Economic Outlook Growth Projections: Real GDP, annual percent change. Source: IMF[1]).

economic development in the future, as soon as the vaccination campaign will make it possible to secure the world population.

The paper is structured in three main moments. The first concerns a brief examination of the health and economic context that characterized 2020 and which still seems to continue in 2021, with particular regard to the effects on GDP, on the economic and industrial sectors, on the income (and saving) capacity of families, as well as on the overall level of consumption according to official sources and the research carried out in the last year by the main national institutions.

The increase in poverty, the closure of schools with the relative learning gap of an entire generation, social disintegration and the increase in psychological pathologies are leading many to denounce, in addition to the health and economic crisis, a new social emergency. In particular, we attend to a reconfiguration of the purchase baskets and sales channels in favor of electronic commerce, for example, and a tendential transformation, in a value sense, of the same meaning of the act of consumption.

The second part of this paper focuses on the reactions to these crises by businesses, based on the results of the qualitative and quantitative research of the main private and public research institutes, aimed in particular at investigating the factors underlying a rapid economic recovery.

In details, the production sector has had to face not only higher costs to increase the safety and production capacity of basic necessities, but the most innovative companies have decided to pursue production diversification choices so as not to interrupt its business. In this regard, a privileged observatory was the monitoring during 2020 of the activity of Lombard manufacturing companies - both industrial and craft businesses - whose results were periodically published in the InFocus Imprese Reports on the related quarterly field surveys by Unioncamere Lombardia in collaboration with the Department of Economics, Management and Quantitative Methods, University of Milan.[2] The reality of Lombard manufacturing companies is of particular interest for more than one reason. Firstly, Lombard manufacturing production shows the highest production indices at national level and is absolutely competitive compared to the European average. Secondly, no less important, the Lombard production structure has an employment level and a variety of product sectors - from fashion to precision mechanics, from pharmaceuticals to food - which configure it as an extremely explanatory reality for understanding the trend of entire national production.

The third moment is finally dedicated to reflections on the learning processes by companies, following the various lockdowns and the momentary recovery in the summer of 2020, both from the point of view of the ability to react in the short term, and from the strategic point of view. In fact, the pandemic lasted so long that it produced structural effects on a competitive level. In general, what emerges is a tendency towards the reconfiguration of international supply chains and a consequent internal reorganization in favor of new markets and targets; greater attention to access to credit and third-party financing, as well as investments in capital goods and digitalization to improve the quality of production processes and support more effective internationalisation. The quarterly economic surveys of Unioncamere Lombardia have however revealed in particular a great capacity for resilience and entrepreneurial tenacity that will represent the real discriminant for the future, especially in the sectors of activity most in crisis due to the effects of the lockdown and, above all, in those characterised by a structural productivity crisis already in 2019.

## 2 Health Context and Social Economic Background

The pandemic has hit Italy, officially, starting from February 2020, see Figure 2.[3] Since the beginning of the epidemic, in April 2021, there have been 3,667,576 cases of COVID-19 and 110,559 deaths. The epidemic curve shows that the impact of the second wave, in terms of the total number of daily cases, was actually much higher of the first one, thanks to the increased diagnostic capacity.

From the point of view of government measures, the first and most severe lockdown was promulgated on the following 8 March with the total forbidding occasions for social interaction and blocking of all economic activities, not considered essential, until 4 May 2021.

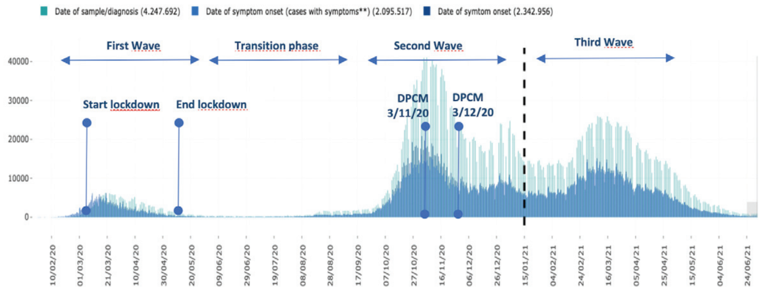


**Figure 2:** Cases of confirmed SARS-CoV-2 infection reported in Italy, by date of sample/diagnosis (green) and by date of symptom onset (blue) *(February 2020 - June 2021)*. Source: Ministry of Health, Italy, Directorate-General for Communication and European and International Relations - http://www.salute.gov.it.

From mid-November, the curve showed a slow but steady decrease until 21 December, and then rose again in the following 2 weeks - despite the latest Prime Ministerial Decree of December 3, which established the return of the entire national territory to an intermittent “red zone" for the Christmas holidays. The different and subsequent waves, however, have unfortunately it continued to affect social interactions and all sectors of activity, directly and indirectly connected. In January the curve stabilized with small daily variations, but from February there was a new increase in cases, which led to a third wave, albeit to a lesser extent than the second.

The first effect was therefore an important and immediate drop in consumption. According to data published by the Confcommercio Research Office,[4] the Confcommercio Consumption Indicator (ICC) for 2020 reports an overall decline of 14.7%, with a reduction of 30.3% for services and 7.9% for goods; the only exceptions are the expenses for domestic power (+ 2.1%) and for communications (+ 8.7%). Beyond the trend of the individual quarters, 2020 signaled a real collapse in demand for many sectors, with reductions well above 50%, in sectors such as tourism in the broad sense, recreational services, clothing, footwear, furniture and furnishings. Focusing on the analysis of the consumption of goods, the trend can be further investigated by resorting to periodic Istat surveys, on overall retail sales by macro-sectors, by product categories and by sales channels.

On a trend basis, in December, retail sales decreased by 3.1% in value and 3.2% in volume. More precisely, there was a strong growth for food goods (+ 6.6% in value and + 5.7% in volume) and a fall for non-food goods (-9.4% in value and -9.5 % by volume).

As regards the individual types of non-food products, there are negative trend variations for almost all product groups, with the exception of equipment for information technology, telecommunications, telephony (+15.3%), household tools and hardware (+2.3%), and furniture, textiles and furnishings (+0.5%). The trend seems to be consistent with the typical recovery of gifts during the Christmas period and the greater attention paid to one's living environment[1]. The most marked downturns concern clothing and fur (-23.4%) and footwear, leather and travel items (-14.6%). Although the data are in line with the previous Confcommercio surveys, the indications on the individual sectors show more marked indications[2].

A second phenomenon determined by the pandemic was that of a redistribution of consumption by sales channels. Compared to 2019, the value of retail sales decreased both for large-scale distribution (-2.8%) and for companies operating on small surfaces (-10.1%). Sales outside the shops (i.e. street vendors) fell by 13.9% while e-commerce confirmed a strong increase (+ 34.6%)[3], as expected also in the same 2021 (+ 37%)[4]. The forms of distribution with a predominantly non-food vocation were the most penalized, as they often do not deal with "essential" product categories. On the other hand, it is equally interesting to note that in the food distribution sector, the sales of supermarkets (5.6%) and especially discount stores (+ 8.2%) have grown, confirming the search for greater convenience and a reduction in purchasing power.

The qualitative analysis of the trend and composition of consumption during 2020 made it possible to highlight the emergence of new needs and purchasing habits, which have had the opportunity to assert and structure themselves, so much so that it is likely to distinguish the post-covid recovery. For example, with reference to food products, the purchase of basic ingredients, for cooking at home, is back in favor of a healthier diet[5]. With regard to non-food sales, the growth of parapharmaceutical and hygiene and cleaning products; consumer electronics and goods and services - that have supported social interactions via the web, entertainment and care for one's psycho-physical well-being - stands out. This has in fact favored a real literacy in favor of any form of digitization (from e-commerce, to new electronic payment methods). The greater propensity towards digitalization has favored significant changes in purchasing behavior and shopping habits. As known, online sales have exploded both of necessary products (ie drugs, health aids, etc.), and non-essential ones (ie furniture, clothing, electronics, fitness, etc.), however also favoring the development of foreign supply chains and actors. In this context, an element of great novelty in 2020 compared to the previous year is given precisely by the explosion of the so-called

[1] Assessments also confirmed by what emerged in.[5]
[2] https://www.istat.it/it/archivio/253286.
[3] https://www.istat.it/it/archivio/2532868.
[4] AJ-Com.Net, November 2020.
[5] Information Resources Inc (IRI), February 2021.

e-grocery, i.e. the online market for the consumption of fresh or packaged food, products for home and personal hygiene, and in general consumer goods that can be found in supermarkets. Online sales of large-scale distribution closed 2020 with a turnover of 1.33 billion euros with a jump of 120% compared to 2019, anticipating the achievement of the objectives set for 2021 (IRI; 2021) [6].

The forced renunciation of goods and services, as well as the inability to carry out daily activities considered normal or taken for granted before the pandemic, has also affected the value system and preferences of individuals. The repercussions were found first of all, as already mentioned, in the composition of the shopping basket, in favor of brands and products considered sustainable (i.e. "at km 0", of local origin and in any case Italian, of lasting quality over time and not simply "fashionable"), avoiding unnecessary purchases or superfluous with respect to new sensitivities, and modifying one's behavior, for example in mobility, limiting waste of money or environmental resources.[6] Another effect was the already mentioned recovery of the family dimension and the attention towards one's home, with a relapse in terms of purchases of goods and services to rebalance private and working lives at home (i.e. smartworking) or in terms of interventions for the redevelopment or renovation of living spaces.

It should also not be forgotten that the pandemic has forced many companies to resort to layoffs for their employees, with a generalized effect of depression of the level of available income of families. Thus, the reduction in per capita income and the growing uncertainty about the future have contributed to the further reduction in consumption and, at the same time, to a significant increase in the household saving rate (including non-interest bearing). In this regard, the indications of the Bank of Italy on the trend of consumer households' propensity to save and the current account balance for the three-year period 2021-2023 may be of help. They show how the household saving rate, which rose to 15 percent in 2020, should slowly decline, remaining above pre-Covid values for the entire three-year period, when it was still around 8 percent, see Figure 3. For the three-year period 2021-23, the macroeconomic scenario seems to foreshadow a significant recovery in consumption, but less marked than that of GDP, with only a gradual reabsorption of the sharp increase in the propensity to save, also attributable to precautionary reasons. In more detail, according to the forecasts of the Bank of Italy, consumption should increase by just over 3 percent on average this year and next, to slow down in 2023.

It is therefore evident that each of these aspects has therefore had an impact on the sales of sectors and companies, benefiting some (i.e. e-Commerce Companies) and disadvantaging others, those entrepreneurial realities most in difficulty in deciphering the change of context.

[6] *Il canale Web della Gdo archivia un 2020 da record*, [The GDO web channel archives a record 2020], La Repubblica 24.01.2021.

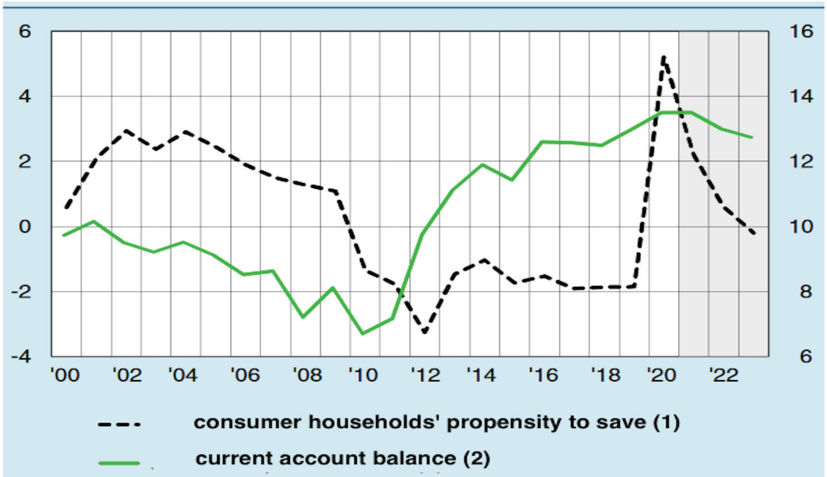


**Figure 3:** Consumer households' propensity to save and current account balance (percentage points) - January 2021. Source: Unioncamere (http://www.unioncamerelombardia.it/images/file/OE%20Analisi%20Congiuntura%202020/Report_4Q_2020_DEF.pdf); 1) right-hand side reference scale: consumer households' propensity to save - 2) left-hand side reference scale: current account balance - relative to GDP.

## 3 The Impact of the Pandemic on the Italian Production System: the Case of Lombard Manufacturing Companies

The impact of the pandemic was deleterious not only for all non-essential activities that had to comply with government regulations, but also for all those that had to cope with a blocked internal demand, both for the reduction of the level of income and due to the degree of uncertainty about the future, which has favored savings where possible.

In terms of demand, furthermore, as already mentioned in the previous paragraph, there have been important changes, in purchasing and consumption behavior, including in terms of values and brand preferences. With respect to the offer, some companies have shown a resilience capacity above expectations, especially in the manufacturing context. In other words, in this context, the survival of businesses was in fact only minimally allowed by government aid, but above all by their ability to react.

### 3.1 The Effect of the Crisis on the Business Structure

To analyze this aspect and the factors underlying this capacity, reference is made here to the results produced in a qualitative-quantitative conjunctural study, conducted in 2020 by the DEMM-Department of Economics, Management & Quantitative Methods of University of Milan in collaboration with the

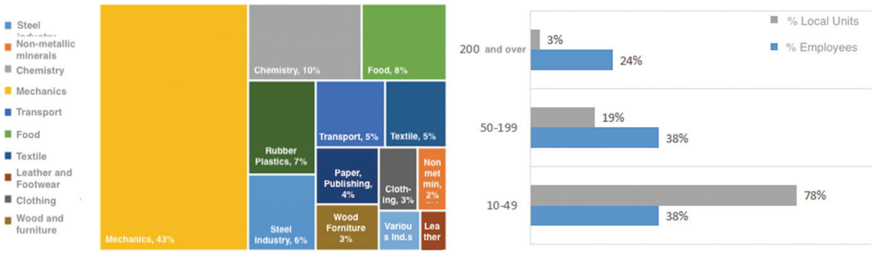


**Figure 4:** Representativeness of the Lombard manufacturing industry: distribution of employees by sector and distribution of employees and local units by size. Source: data processed by Unioncamere Lombardia on ISTAT - ASIA 2017 local unit data (size: 13,596 local units), latest available data.

Research Office of Unioncamere Lombardia, published on a quarterly basis.[2] More specifically, the contents of the study represent the integration between several sources on the recent evolution of demand and the Italian industrial sector, with the results of a quarterly empirical survey, conducted on a significant sample of industrial companies and craft enterprises in the Lombard manufacturing sector (about 3000 in total, each quarter), both in terms of product composition and in terms of revenues and number of employees. The importance of these data is given by the fact that - due to the density of businesses, concentration of employees, as well as the variety of sectors of activity represented - the Lombard manufacturing sector is extremely significant for interpreting the trend of the whole italian industry, see Figure 4, and therefore the state of health of the national economy itself. In this perspective, it is therefore important to point out, first of all, how the Lombard production structure - which includes industry and craftsmanship - at the end of 2020, reached and exceeded national and European levels of competitiveness (see Figure 5 and Figure 6), thus being able to suggest some guidelines for the future, with respect to the strategic choices of investment, diversification and reconfiguration of supply chains. In fact, in each quarter, not only the trend of the main performance indicators (turnover, orders, exports, industrial production by province, sectors and technological content, labor market and forecasts) was monitored, but also how the pandemic had impacted, respectively, corporate strategies, digitization, access to credit and investment trends. By postponing the in-depth analysis of the many data and reflections published in the various economic reports to another time, it is considered useful here to highlight the prospective value of the study, at a general level and at the level of a single sector of activity.

In fact, in a situation in which the macroeconomic indices (euro-dollar exchange rate, oil price and interest rates) were neutral, if not even favorable, Lombard companies were able to recover almost all of their pre-Covid19 production, registering a more pronounced rebound compared to both the Italian

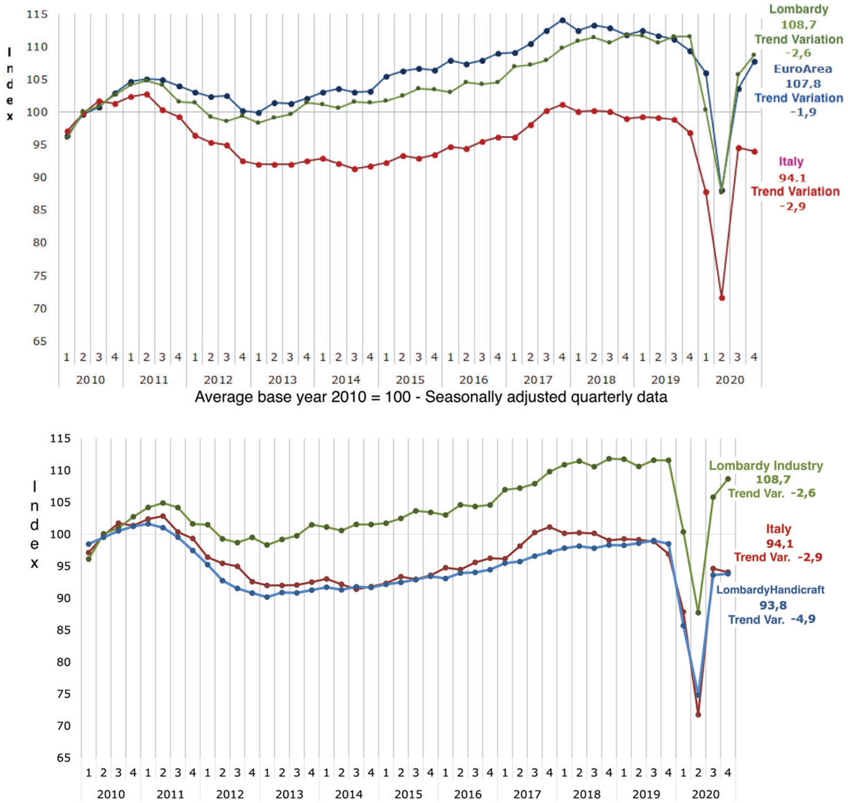


**Figure 5:** Top: Manufacturing Sector Production Index - Lombardy, Italy and Eurozone. Bottom: Production indices of the manufacturing sector - Handicraft and Industry, compared (2010 average basis = 100- seasonally adjusted quarterly data). Source: Unioncamere Lombardia - Eurostat.

and the European average. As can always be observed in Figures 5, in manufacturing there has been a 'V' recovery: so steep was the fall, so fast was the recovery - unlike the Great Crisis, characterized by a very slow restart of activity productive in 2009 and in the following five years. It should also be noted that in the fourth quarter Lombard production continued to grow more than Europe, despite the second wave of the pandemic and despite Italy as a whole recorded a small decline.

This confirms Lombardy as one of the driving forces of the Italian and European economy and bodes well for the future, even if this trend has not been the same in the different areas of activity. The first distinction concerns the size of the companies. In Figure 6 it is possible to see how for industries with 200 and more employees, the industrial production index quickly returned to the same seasonally adjusted level as in 2019. More modest result for companies

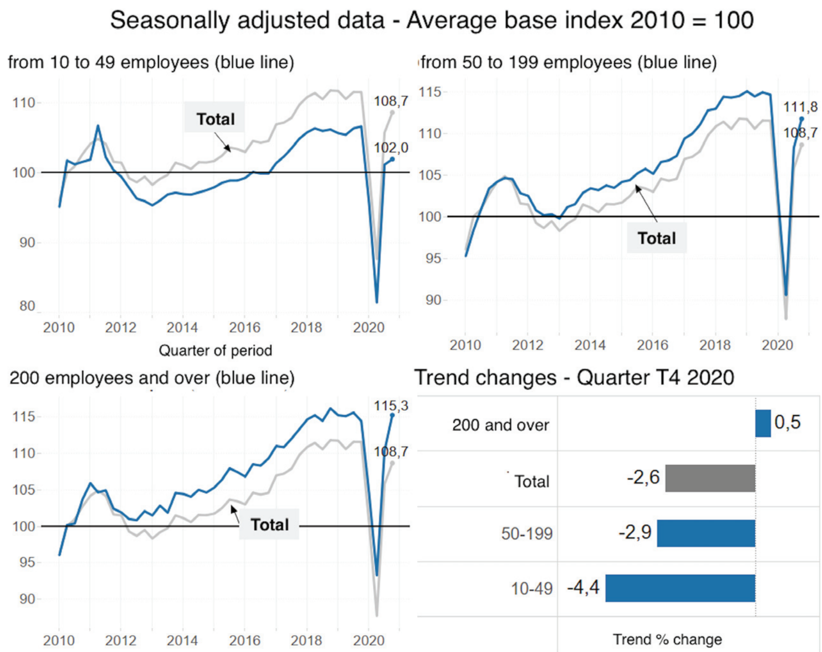


**Figure 6:** Index of industrial production by number of employees. Seasonally adjusted data - 2010 average base index = 100. Source: Unioncamere Lombardia.

with employees between 0 and 199 and decidedly little sustained for companies with fewer than 50 employees, which also recorded a quarterly trend variation of -4.4%, against -2.9% for companies with 50-199 employees and + 0.5% for companies with more than 200 employees. Surely the greater availability of resources, of the larger companies, have favored a faster recovery, while the smaller ones have not been able to fully use their flexibility to be able to get back on top.

The second distinction can be seen in Figure 7 and is related to the industrial production index by type of destination. In particular, the production of “investment goods" and “intermediate goods" already reached almost the same levels as in 2019 at the end of 2020 - rising in terms of trend changes in the last two quarters, respectively from -5.4 / -5 , 5% down to -1.5%, giving hope for growth prospects in the medium to long term. The “final goods", despite the recovery during the last quarter, recorded a further decline (-6.4% in Q4 vs -4% in Q3), affected by the closure of non-essential activities and the opportunities for sociability, positively associated to final consumption.

In both cases - whether we consider the number of employees or the type of destination - there is an increase in the values of the indices, which exceed the threshold 2010 = 100, except in the case of final consumer goods (which even

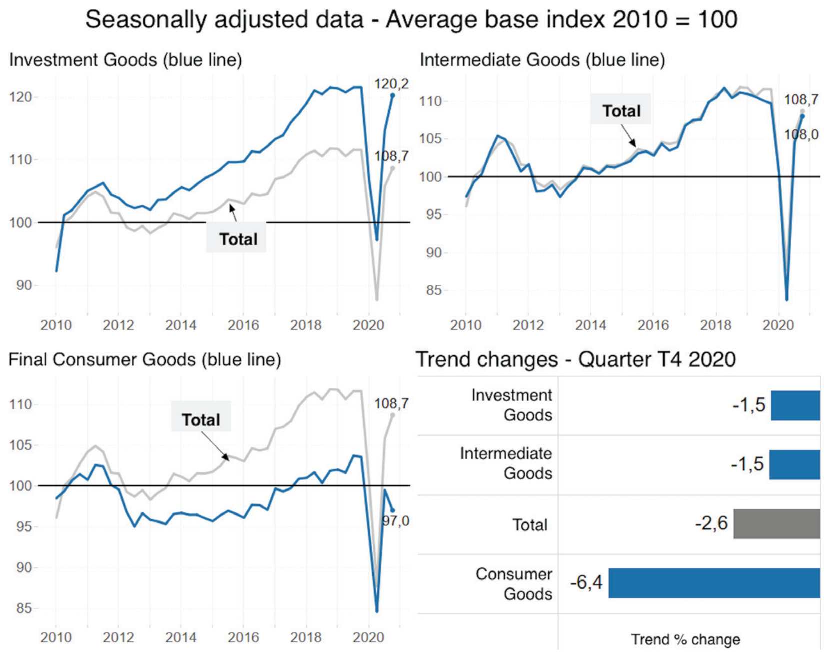


**Figure 7:** Industrial production index by type of destination. Seasonally adjusted data - 2010 average base index = 100. Source: Unioncamere Lombardia.

reach the value 97), showing a net decrease in value - due to the loss of disposable income and the slowdown in domestic demand, already present in 2019.

A further study is offered by the trend of industrial production according to the classification of the PAVITT sectors, based on the technological content, compared to the total (Figure 8). Against an average trend value of -2.6%, it is clear that the sectors with a high technological content (and therefore high R&D) achieve the best results (from + 2% in Q3 to + 5.3% at the end year), demonstrating a competitive capacity far superior to traditional sectors. The latter, in fact, show a trend variation equal to -7.1% (-8.6% in the previous quarter). In the last two quarters of 2020, the situation of sectors with high economies of scale (-0.1% currently, -4% previously) and specialized ones (-2.6%, -4.6% previously) has also improved, because they are able to incorporate more technological innovation, especially of process.

A last relevant aspect is the sectoral analysis (Figure 9). Although the pandemic has affected all sectors, those who have shown the greatest difficulties throughout 2020 were undoubtedly clothing (with a trend of -18.3%; Figure 9a), textiles (-17.7%) and leather-footwear (-10.9%), even if in part an improvement compared to the previous quarter, where they stood at -12.5%, -21.2% and -14.4% respectively. However, these are all sectors with evident bad debts already at the

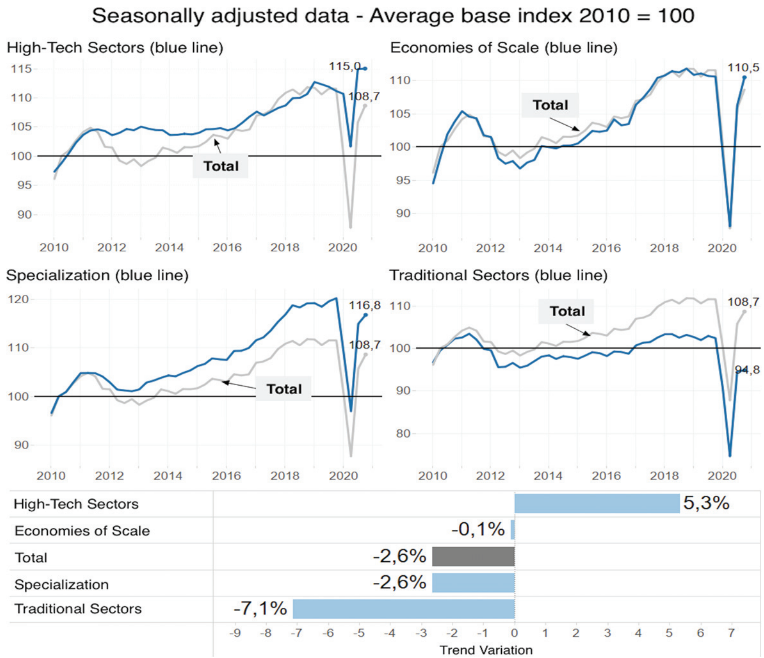


**Figure 8:** Pavitt industrial production index by sector. Seasonally adjusted data - 2010 average base index = 100. Source: Unioncamere Lombardia.

end of 2019 and which failed to seize all the opportunities offered by the new digital sales channels.

The only sector in marked recovery is that of means of transport (+ 6.3%), facilitated in part by incentives for the purchase of hybrid and/or electric cars, but above all driven by the demand for intermediate goods and components coming from abroad, and in particular from Germany, where the automotive sector is in sharp recovery. In addition to means of transport, only plastic rubber (+ 0.6%) and non-metallic minerals (+ 0.4%) recorded positive changes, while all the others showed a negative sign. Among the less penalized sectors with slightly negative variations, especially if compared with previous quarters, there are industrial sectors that have nevertheless shown resilience, such as chemicals (-0.7%), steel (-1.2%), and mechanics (-1.3%). The sectors that recorded particularly negative data in the last quarter are also those that recorded a significant share of annual turnover during the Christmas period (typically food -4.7%) and the fashion and accessories sector (from -10.9% to -18.3%). On the other hand, if we consider the average annual variations by sector of activity (Figure 9b), it is clear what the damages were for the "non-essential" sectors of activity (typically the clothing/textile/footwear recorded reductions in 2020 of between -18.2% in clothing and -23.6% in leather-footwear), compared to companies belonging

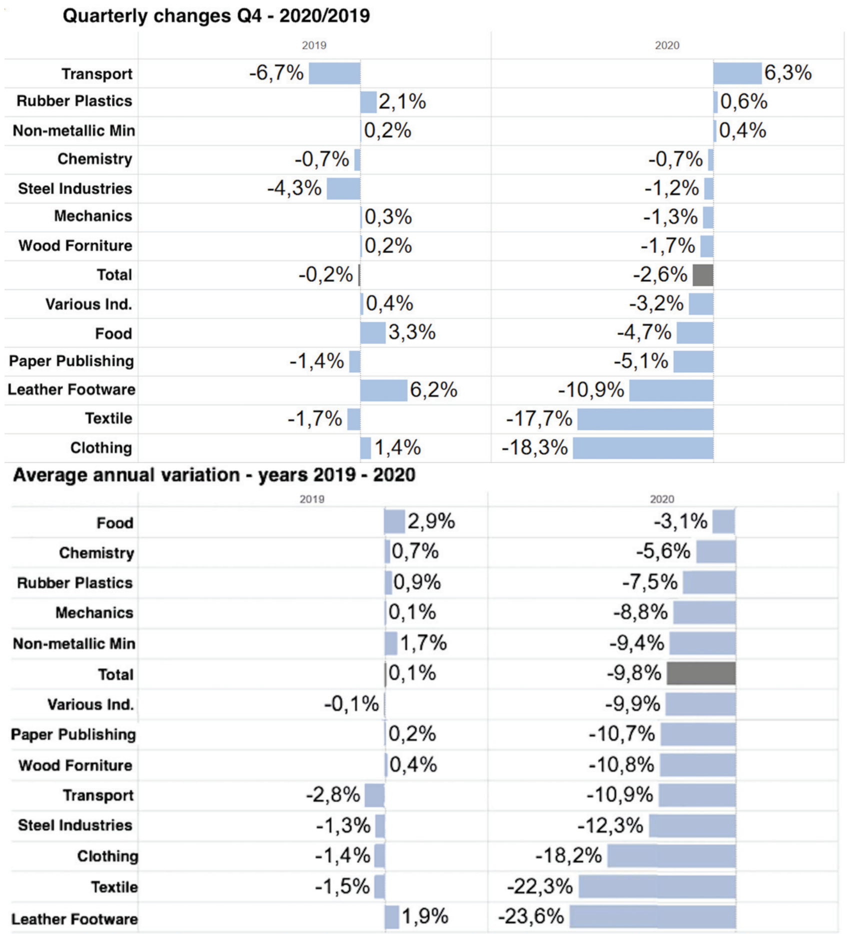


**Figure 9:** Industrial production by industrial sector, trend variations (left) and average annual variation (right). Source: Unioncamere Lombardia.

to the supply chains of primary necessities (i.e. Food, only -3,1%). Those who have contained the most damage are therefore the sectors relating to necessary productions (such as the case of chemicals with -5.6%), or driven by typically foreign production chains in recovery (i.e. electrical automotive) which have had a positive effect on the rubber-plastic sectors (-7.5%), mechanics (-8.8%) and non-metallic minerals (-9.4%), in the case of the resumption of building renovations. In Figure 10, the trend of the industrial production index of each sector over time is highlighted, revealing how critical the situation of certain sectors was already, based on the distance between one's situation and the average of the total industry, as in the case clothing. Within these sectors, however, all those companies that in 2020 managed to pursue courageous production

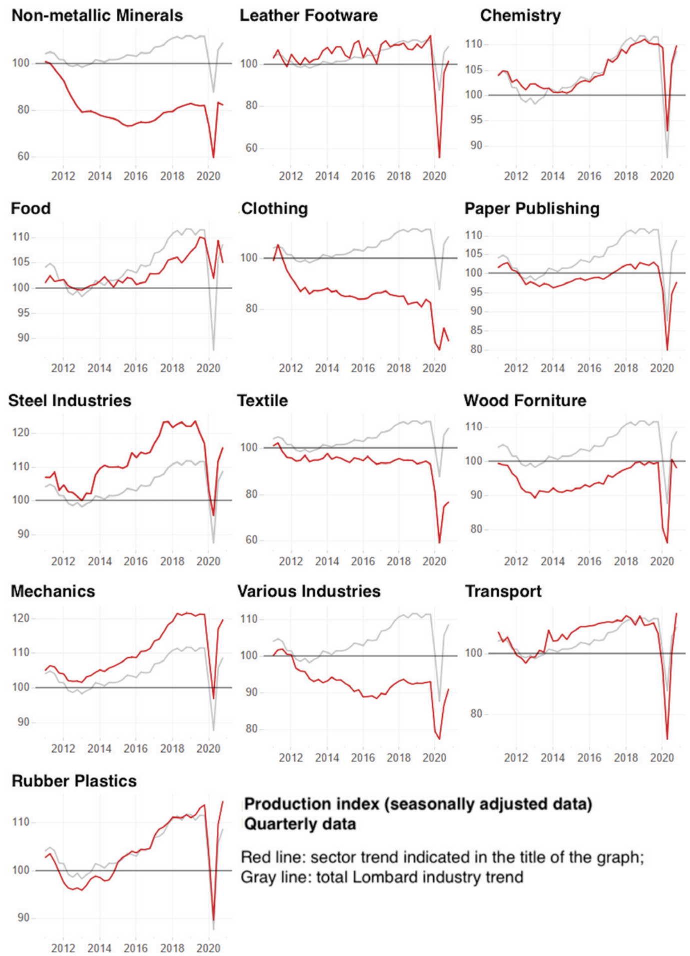


**Figure 10:** Industrial production: trend indices by sector and total industry. Source: Unioncamere Lombardia.

diversifications, reconversion of activities - for example in favor of the production of personal protective equipment (from masks, to gowns for health workers) or disinfectants, essential to deal with the health emergency. Similarly, even in the more traditional sectors (such as the furniture sector with a decline of 10.8% on an annual basis) there are companies that have been able to conquer new markets - national and/or foreign - using e-commerce website or focusing on new emerging needs (depending on the use of smart working).

The analysis of the turnover index of Lombard manufacturing companies (Figure 11) shows how the ability to recover the levels of the last quarter of 2019 and the resilience during the different waves of the pandemic have been supported by orders and foreign turnover, which represents just under 40% of the total.

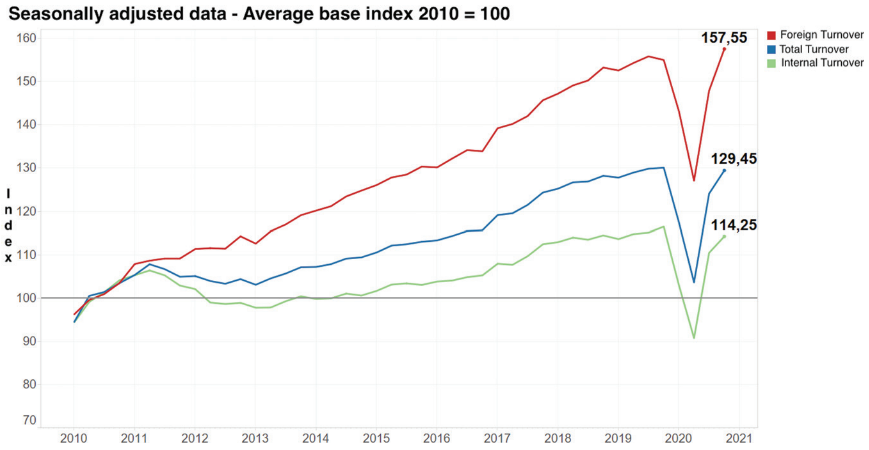


**Figure 11:** Index of total turnover, domestic and foreign - Industry. (Seasonally adjusted data - 2010 average base index = 100). Source: Unioncamere Lombardia. Note: Red Line: Foreign turnover; Blue Line Total Turnover; Green Line: Domestic Turnover.

After three quarters with a negative sign, in fact, the trend change in turnover returns to be positive for abroad (+ 1.6%) and greatly reduces the negative trend internally (-1.9%). The result is a total turnover index substantially identical to the value of the fourth quarter of 2019.

In this context, the labor market has been conditioned by the blocking of lay-offs established at the government level and, therefore, it seems more significant than anything else to consider the use of the redundancy fund "CIG-Cassa Integrazione Guadagni" (used for temporary unemployment benefits in Italy), by sector of activity. First of all, it should still be noted that the seasonally adjusted entry-exit balance for industrial employment in the Lombardy production system at the end of 2020 was negative (-0.3%), although in a lower value than last quarter. After a year of sharp slowdown, the seasonally adjusted index also starts to rise again. As regards the share of hours in CIG on the total number of hours per sector (Figure 12), the clothing sector (18.5% of hours on the total number of hours per sector) and the textile sector (10.8%) are those showing the greatest difficulties, despite the recovery.

All the other sectors have an incidence of less than 10% and a certain number below the average (3.3%, down compared to the previous quarter where it was 4.4%), with a generalized improvement compared to the previous quarter, except for the clothing.

Despite the difficult situation, the confidence index of Italian manufacturing companies in 2020 progressively improved, passing in the last two months, according to ISTAT data, from 90.9 to 95.9; to be evaluated with respect to that of services (which increased from 74.8 to 78.2), construction (from 136.8 to 136.0)

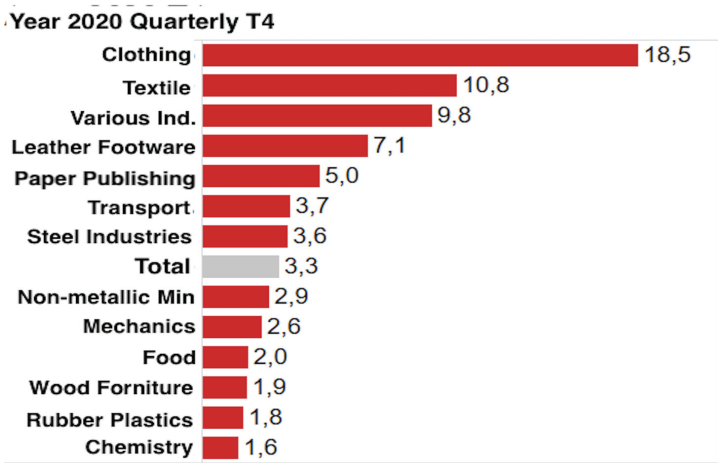


**Figure 12:** CIG: redundancy fund - share of the hours per sector (Year 2020 - Q4). Source: Unioncamere Lombardia.

and, above all, the value referred to retail trade (94.9 to 88, 5).[7] With reference to the components of the confidence index, in the manufacturing industry the improving items are above all those relating to production expectations (from -9.2 to +0.4) which signal a clear change in trend, especially for goods instrumental (from -10 to +4.2) and intermediate (from -5.3 to +2.6).

Concerns remain regarding orders (from -28.6 to -25.7), especially for those operating in the consumer goods sectors (from -29.6 to -31.6). In this context, the assessments of the confidence of Lombard manufacturing companies appear substantially even more encouraging and positive. Figure 13 in fact shows the comparison between the national, supra-regional and regional confidence indices, which show the desire for redemption and recovery, despite the second pandemic wave that hit Lombardy at the end of 2020. Confidence levels are rising, with respect to the recovery in demand - primarily foreign and later domestic - although in the last quarter the distribution of frequencies seems to tend mainly towards a certain stability, as well as towards production and employment levels (Figure 14).

### 3.2 The Ability of Businesses to React to the Pandemic

The impact of the pandemic on the Lombard manufacturing sector, from the point of view of entrepreneurs, was consequently an element of particular study in 2020. In fact, it was not just a question of recording the changes in the performance indicators, but of analyzing how the strategic orientations of companies have changed over time. From this point of view, it is therefore particularly interesting to highlight how in general the pandemic represented a health, social and economic tragedy, but also an accelerator of change and

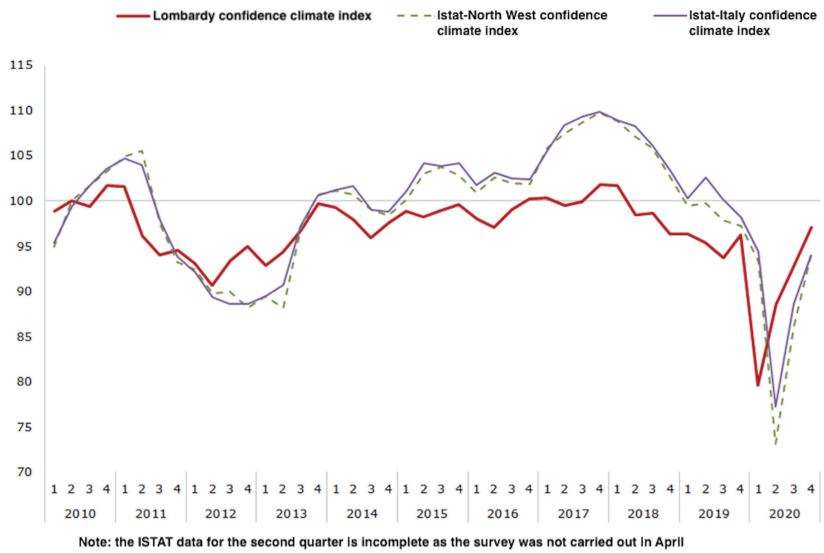


**Figure 13:** Business confidence index Numbers Index Base average 2010 = 100 (seasonally adjusted data). Source: Unioncamere Lombardia. Note: Red line: Lombardy confidence index; Black line: Istat, Italy; Dotted Line: Istat, North West confidence climate.

innovation, demonstrating that everything that seemed established could be questioned.

The damage of the pandemic from the point of view of the economic (in terms of turnover, liquidity, order cancellation, liquidity problems, production interruption, delays in the supply chain, etc.) and the organizational impact (change in the organizational structure and personnel, review of internal processes, restructuring, etc.) was significant and widespread in every type of company and sector of activity. However, the sectors most affected economically in industry were non-metallic minerals (100% of the Unioncamere sample), means of transport (100%), the steel industry (98.7%), clothing (96.4%), and furniture wood (95.7%). The least compromised sectors at an economic level were: paper and printing (84%), chemicals (78.6%) and the food industry (73.9%). From an organizational point of view, it is worth noting the supply problems (interruptions or changes in supplies) which affected 8.5% of the companies that remained active, in particular, in the chemical and mechanical sectors, especially due to the dependence of raw materials from third countries.

Looking into the impact of the first lockdown on the production and organization of companies, it is interesting to note how companies reacted differently from the start. Firstly, compared to an average trend decline in production of 10.1% (up to peaks of -19% for clothing and -23% for leather and footwear), the first effect was to change the organizational and

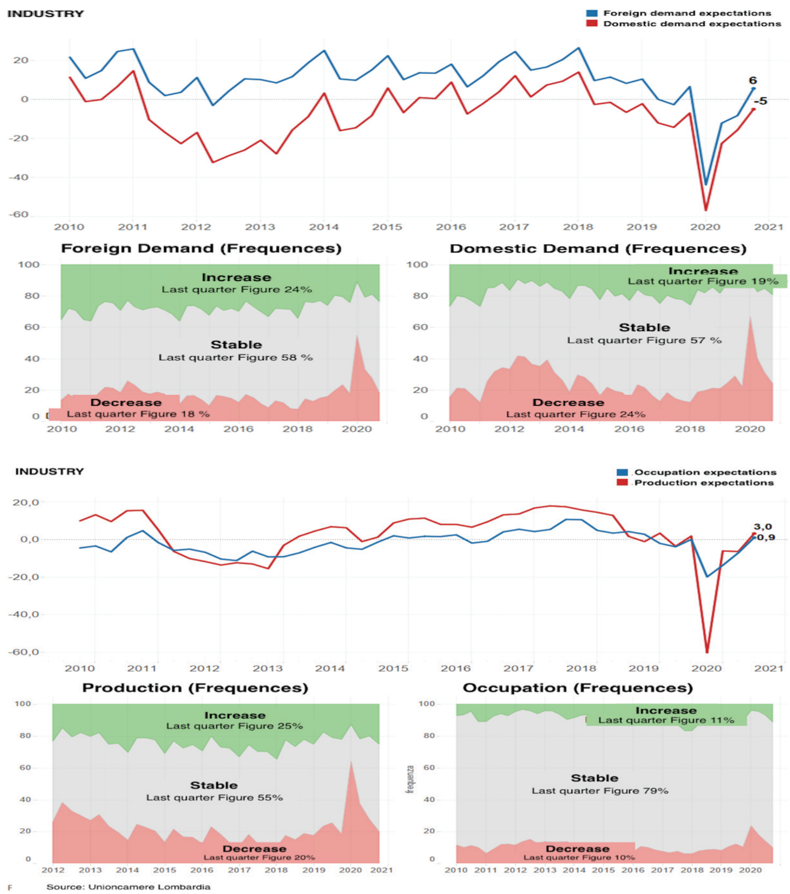


**Figure 14:** Expectations on: (top) foreign and domestic demand and (bottom) Production and Employment - Industry - Balanced assessments of increase and decrease. Source: Unioncamere Lombardia.

personnel structure (65.9% industry and 47.2% crafts, making extensive use of smartworking and redundancy payments), manage procurement-production-distribution difficulties (44.2% and 37.7%), while over 10% had no impact (11.1% and 16.7%). In this regard - in the logic of organizational transformation, as well as of the business models themselves - the ability to oversee new technologies represents an increasingly urgent diktat. The digital transformation underway, already begun with Industry 4.0, has only been accelerated by the pandemic which, in a completely exogenous and unpredictable way, has forced and continues to require a rethinking not only of the industrial scenario, but also of the relationship with the market.

Production trend, however - in terms of reduction, increase or reconversion - was affected not only by the type of business sector, but also if not above all by the creativity, speed of response and courage of entrepreneurs, the so-called *dynamic capabilities*. Dynamic capability is "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments".[8] They can be distinguished from operational capabilities, which pertain to the current operations of an organization. Dynamic capabilities, by contrast, refer to "the capacity of an organization to purposefully create, extend, or modify its resource base"[9] in the search for new paths of development and forms of innovation of their business. Overall, the cases of reconversion and increase in activity account for 7.8% of the companies in the sample in industry and 5% in crafts. However, the decline in production affected all sectors, none excluded, with particularly critical situations in 68.9% of companies.

The industrial sectors that have benefited most from the current situation are obviously the food and chemical-pharmaceutical sectors (respectively 16.5% and 15.6%); the most penalized (all over 70%) were the rubber and plastic sectors (77.3%), leather and footwear (76.2%), mechanics (74.9%), wood and furniture (71.9%), non-metallic minerals (70.5%), means of transport (70.4%). Positive surprises come from companies in highly critical sectors that have been able to significantly reconvert their business by sensing the new demands of the market (such as personal protection devices and food disinfectants), as recorded in the clothing sectors (which stands out with 26, 5% of cases) and, more widely, in textiles (7.3%), chemistry (5.4%) and food (4.3%).

An interesting contribution to the study of the impact of digitization on the various traditional and non-traditional sectors, both at the organizational back-end level and at the front-end level towards the market, is given in.[10] In particular, the organizational learning processes triggered as a result of the pandemic are highlighted, in a national and international comparison between companies operating respectively in the following sectors: food, fashion, sportsware, furniture and manufacturing-industrial equipment - examples that have had the merit to trigger further innovation processes. In the food sector, in the face of the modification of purchasing and consumption processes in favor of raw materials for self-production at home, instead of finished products - some companies have innovated the brand experience by offering consumers "shoppable contents", to enrich the product offer with "branded" digital editorial content, which made it possible to intercept and accompany consumers throughout the quarantine, in different ways than in the past. The fashion sector, heavily affected by the effects of Covid-19, has revolutionized the presentation activities to buyers of its products, with completely new ways of dialogue between suppliers and customers, through the use of the most innovative digital and immersive technologies (from platforms in remote, to virtual reality). In the sector of sports products and equipment (sportware), conditioned by seasonal activities and by the restrictions of social distancing, there was a boom in the online sale of products and clothing for fitness at home, destined to stabilize also in the future, so such as the relative collapse in sales of outdoor sports equipment. Here the competitive advantage was the speed of reaction from the companies that were able to innovate their product portfolio and the brands themselves, and communicate them effectively on the web, where users-customers were easier to intercept. The ability to review its supply chain and the ability to distribute content and products has made the difference and has allowed us to conquer new market segments. In the furniture sector, strongly conditioned by a traditional production and distribution chain, mediated by sales channels and with a low rate of digitization, the innovation that has materialized by the most advanced brands and dealers is that of offering completely online furnishing and design consultancy services, up to the sale itself, transforming the relationship between producers and distributors into an even more collaborative perspective. A final indication concerns precisely the management of the procurement processes of the manufacturing industry, in the face of the disappearance of the sales force of the supplier companies, gradually replaced by b2b e-commerce sites / marketplaces, able to disintermediate traditional distribution with solutions agile and more efficient.

In this perspective, it is therefore interesting to investigate the four prevailing forms of innovation pursued. The introduction of *new products and services* was a strategy that mainly involved chemicals, textiles and clothing in industry and food in crafts. The ability to conquer new markets, on the other hand, was the prevailing response in the more traditional sectors (mechanics, textile-clothing, furniture, steel and rubber-plastic, paper and printing), in a rather homogeneous way both in terms of industry and craftsmanship. Another interesting strategy was the *redefinition of sources and supply chains*, often excessively dependent on the Far East. In fact, the pandemic seems to favor a new globalization more centered on Europe, guaranteeing the continuity and quality of production, especially for all those supply chains considered strategic at the country level, with evident positive effects for the already active and well-known Italian supplier companies. The sectors most interested in this case are mechanics, means of transport / automotive, chemicals, wood, furniture and various (which includes a large part of electro-medical and other specialized productions) which incorporate different raw materials, technologies, components. In the sectors with productions characterized by a greater impact and complexity of the technology based on plant engineering (means of transport, chemistry, mechanics, steel, rubber-plastic), the *reorganization and rethinking of the way of working* is also important, without excluding *smartworking* in structural way for the future where possible.

However, the capacity for innovation of companies in any sector has often been accompanied by the ability to obtain access to credit and the propensity to invest, with particular regard to digitization projects and the renewal of equipment.

As regards the first aspect, the financial situation of companies was severely tested by the drop in turnover due to the blocking of activities, as well as for having anticipated the redundancy fund for employees. The Unioncamere Lombardia research, therefore, made it possible to investigate the degree of indebtedness, the use of the various sources of financing and the assessments on access to credit by the Lombard industry and crafts, where the capacity and response times of the system credit are as critical as the effects of the economic crisis.

The companies that have not had financial difficulties (and/or that have continued to invest) are mostly, but not exclusively, those that have continued to operate on the market, because they belong to the authorized supply chains (chemical, mechanical and food in industry and plastic rubber in crafts).

In any case, the situation was worse for small and medium-sized enterprises (both industrial and artisan) with a weaker financial structure or which had to close without being able to reconvert production. The companies that said they were most in distress, mostly belong to the automotive and traditional "non-essential" sectors - as leather, footwear, textile-clothing, wood, furniture in industry and clothing; as well as in crafts, in which the largest share of possible business terminations is found, unable to overcome the effects of the total closure of retail distribution.

The pandemic has also represented an excellent opportunity for growth from a credit and financial point of view and, for some, an opportunity for real financial literacy, as it has pushed companies to inform themselves, even if only to be able to take advantage of aid and government credit facilities with respect to innovative instruments or instruments different from own funds and bank credit, which have always prevailed above all in smaller companies.

In fact, it is no longer just a matter of choosing the most agile and least expensive tool for the company, but from time to time the combination of the most appropriate tools with respect to the specific business strategy.

In general, the picture appears quite positive with regard to the solidity of companies, even if there has been a slight increase in indebtedness to third parties, if we look at the index between third parties and own means, historically, even at a national level, less than 1, both in industry and in crafts.[11] This report indicates the ability of companies to repay their debt capital to third parties through their own resources and, in the last five years, the use of internal resources compared to external ones for financing the business has grown very significantly. In the five-year period 2014-2019, the percentage of those declaring a ratio of third parties / own means greater than 5 fell from 6% to approximately 2% and those declaring a ratio between 2 and 5 fell from 14% to 12% industry, and from 14% to 10% for crafts, while the percentage of those with an index lower than 1 has risen.In industry, on the other hand, 4% of companies have slightly increased financing through third parties, while maintaining an index below 2.[2] In 2020, this trend has slowed down slightly, especially in the craft sector, which sees an increase in the percentage of companies with a third-party / equity ratio greater than 2 compared to a reduction of 7 points in the percentage of those with an index lower than 1. In other words, the economic literature considers companies that have a debt / EBITDA index lower than 2 (ie similar to that highlighted in the Unioncamere Lombardia survey) as particularly secure on a financial level and, therefore, it is possible to affirm that Lombard companies maintain in 2020 there is still a high potential for investment financing. In general, in fact, the accumulation of own capital compared to third-party capital in 2019 served to not reach unsustainable levels of debt during the Covid-19 crisis. More precisely, if companies with a third-party / equity ratio lower than 1 slightly increase their debt, they could finance key investments, to effectively overcome the structural shock caused by the Covid-19 pandemic, without compromising financial stability. This financial security is less pronounced in artisan businesses which, in 2020, all see an upward shift in the index.

As regards the forms of financing used - in addition to self-financing as the main source for industrial enterprises (57.6%) and the second source for artisan enterprises with 44.6% - it is highlighted as the second most important source in industry (and first in crafts) is bank credit (52.1% for industry and 48% for crafts). The third prevailing source of financing in industry is leasing (15.1%) while in the case of crafts, similar importance is given to public financing and incentives (12.3%). Compared to 2019, in 2020 there is also a progressive and generalized reduction of traditional sources, against an increase in: trade receivables, public financing, subsidized finance and factoring. This trend would appear to increase in the future, also favoring other instruments, such as venture capital and / or private equity and online financing operations. These data are perfectly in line with what was observed in.[12]

As for the tools most used to support liquidity, it emerges that the industry uses a broader and more diversified portfolio. During the pandemic, craftsmanship benefited more extensively from non-repayable public grants made available by the central and local administration, compared to industry (34.5% compared to 14.9%). The most widely used instruments in both categories were: moratoriums (30.4% for industry and 23.6% for crafts) and guaranteed bank credit (28.1% for industry and 32 , 3% for crafts); add to this the cancellation of IRAP (26.5% and 19.8%) and the tax credit (23.3% and 13.5%). Finally, just over 24% of businesses, both in crafts and in industry, did not use any of the liquidity support tools listed - a factor that may deserve further investigation. The reasons behind the use of credit at the end of 2019 were productive investments in industry and the need to finance liquidity and cash in crafts. In the midst of the 2020 pandemic, however, the priority reason is to finance liquidity and cash (65.8% of craft enterprises and 62.5% of industrial enterprises), particularly urgent for smaller companies. Industrial companies (in particular the larger ones) are those that, however, take advantage of the increase in funding to also support productive investments, which the craft industry sees reduced. Finally, in both categories, the resources allocated to debt consolidation and restructuring increased.

The judgments on access to credit tend in general to be positive: a good percentage of Lombard manufacturing companies declared that they did not encounter any critical issues in accessing credit during the first half of 2020 (for industry, 42% of companies did not detect any criticality, while the percentage drops to 31% for crafts), however showing a sharp decrease compared to 2019, both in crafts and in industry. The craft has more difficulties than industry also because they are usually less structured internally, to follow complex procedures; they mainly concern:

"the increase in ancillary costs", "the increase in guarantees required" and "the reduction in the amount of credit required". The more the size of the company increases, the more the companies are structured and can manage these problems, relieving the organization and the entrepreneur.

Anyhow, it should be emphasized that despite the measures ordered by the Government to mitigate the corporate liquidity crisis, both in crafts and in industry, all the companies have nevertheless encountered difficulties in finding liquidity in a short time, probably due to an inadequate response from the sector. to the "Liquidity" decree and the "Cura Italia" decree and for the ancillary costs linked to the practices handled by the individual bank branches.

The second aspect, relating to the ability to make investments, is equally important for understanding the level of resilience of the Lombard manufacturing sector. More in detail, thanks to past Unioncamere Lombardia surveys, it was found that in the Lombardy Region of Italy, total investments show a slowdown over time, after a continuous recovery in the five-year period 2015-2019, falling to values lower than those of the 2010, both for industry (52% of companies compared to 65% in 2019), and for crafts (23% compared to 34% in 2019).

The 2020 in fact - marked by uncertainty about the actual economic and financial resources due to the various waves of the pandemic - showed a collapse in investments in the Lombard manufacturing sector, particularly significant for craftsmanship compared to the industrial sector, due to the known structural and dimensional limits - as well as being more dependent on the trend of domestic demand, already depressed in the pre-pandemic phase. Nonetheless, if we consider that the investment growth gap compared to 2019 is completely similar to that of 2012 (at the end of the 2008 financial crisis, 51% of industry and 24% of craft enterprises invested), 2020 can be considered less negative than expected.

However, among those who invested, the share of industrial companies that decided to increase investments compared to the previous year also decreased (50% compared to 67% in 2019), while crafts show a decline in the propensity to invest compared to the previous year less worrying (72% vs 81%), balanced in all probability by the increase in digitization projects. On the other hand, the share of those who reduce the share of investments doubles, both in industry (43% vs 23% in 2019) and in crafts (17% vs 9% in 2019). In both sectors the propensity to invest prevails the more the company size increases (84% of enterprises with over 200 employees and 33% of artisan enterprises with or more than 10 employees), risking to widen the distance, compared to companies weaker from a structural point of view.

The analysis of investments by sector of activity shows how the decline was generalized. As regards industry, the four sectors in which the most investments are made are Chemicals (66.7% vs 76.9% in 2019), Steel (63.3% vs 73.3%), Food (62,0% vs 73.8%) and Plastic Rubber (60.3% vs 70.9%). If Chemicals and Food are the sectors least affected by the pandemic at an industrial level, the most significant drop is in Textiles (-23%, from 65.1% to 49.1%). Leather and Footwear (35.7 vs 47.1%) and Clothing (35.5% vs 44.2%), on the other hand, are the sectors that stand out for maintaining the lowest level of investments, often due to inertial behavior in the the structural and competitive weakness of these sectors is determined. As for crafts, the sectors that show the highest percentages of investment are food (28.3% vs 40% in 2019), plastic rubber (26.4% vs 36.4%), non-metallic minerals and mechanics (25% vs 29.1%), however down compared to 2019.

Given the critical issues encountered by companies, it was therefore interesting to understand what the main forms of investment - tangible and/or intangible - were and with what strategic objective. As regards material investments, investments in instrumental machinery prevail (with a share of 64% of companies in industry and 68.9% in crafts, both essentially stable over the years). On the other hand, investments in information technology have grown in the last year, both in Industry (12.3% vs 10.2% in 2019) and in Crafts (11.7% vs 8.8%), even if only following the strengthening of smart working, for all various types of businesses. Another item is that of buildings, which is also fairly stable over time (8.1% vs 9.3% in 2019, for Industry; 6.5% vs 6.2% for Crafts). A last item “other" includes various goods, often “refuge" (eg investments in art), which do not seem to have great fluctuations (15.5% vs 15.4% in 2019 for industrial companies; 12.9% vs 14.9% in Crafts).

Further interesting observations derive from the analysis of intangible investments, among which the item consultancy and R&D emerges, with a percentage decrease for industrial enterprises (from 46% to 35% of the total) and increasing in artisan enterprises (from 43% to 49%), probably following the stimulus offered by calls for support for the search for new markets and sales channels, as well as the spread of digitization projects. In both types of companies, investments in ICT closely related to the precedents and to the spread of remote smartworking are growing (from 32% to 38% in industry and from 33% to 36% in crafts). Another relevant item, but unfortunately much more limited, is that relating to patents and licenses (from 13% to 15% in industry; from 14% to 12% in crafts), as an indicator of the innovation capacity of businesses.

The propensity to invest could be favored by subsidized instruments, but they are not always easy to access, so much so that 34.6% of industrial enterprises and as many as 59% of artisan ones declare that they have never used any instrument. Among those who find the most success, in order, for both types of enterprises, the Super-depreciation measures (39% for industry and 19.5% for crafts), Hyper-depreciation (34.6% and 16%), Nuova Sabatini (Innovation credit; 14.0% and 12.9%), Research and Development Tax Credit (22.2% and 10.6%) and innovative start-ups (0.6 % only for industry) - also by the ease of using certain solutions compared to others, by the size of the investments themselves and in relation to procedures and consultancy assistance, often necessary. It follows that these instruments tend to be used more by more structured companies capable of efficiently managing the necessary activities: the example of industry alone applies, where super depreciation and hyper depreciation - regulated in the tax credit instrument in favor of investments in capital goods (tangible, intangible and functional to the technological transformation "Transition 4.0") - they are widespread in companies with over 200 employees (60.3% and 50% respectively), while the same are halved in the size class between 10 and 49 employees (24.5% and 24.8%).

A proof is given by the fact that as the size of the company decreases, the share of industrial companies that did not use any tool increases (25.3% in companies with over 200 employees, 30.2% between 50-199 employees and 43 , 3% in the class between 10-49 employees). The same phenomenon is found in crafts, with even more significant shares: 48.8% of companies with over 10 employees, 60% of those with 6 to 9 employees and 74.7% of companies with 3 to 5 employees employees do not use any tools. Also in the artisan sector, Super depreciation, Hyper depreciation, Nuova Sabatini and tax credit in R&D are the most used. In particular, the largest companies (with at least 10 employees) use the measures of hyper-depreciation (24.8%) and super-depreciation (22.3%), more than the new Sabatini (17.4%) and the Tax credit (14.0%).

It was also important to deepen the analysis of Lombard entrepreneurs' perceptions of how the pandemic has actually affected their investment decisions (Figure 15). In this sense, what emerges in both types of companies is a certain polarization: on the one hand, companies that have absolutely not changed their plans - 41.0% in industry and 39.5% in

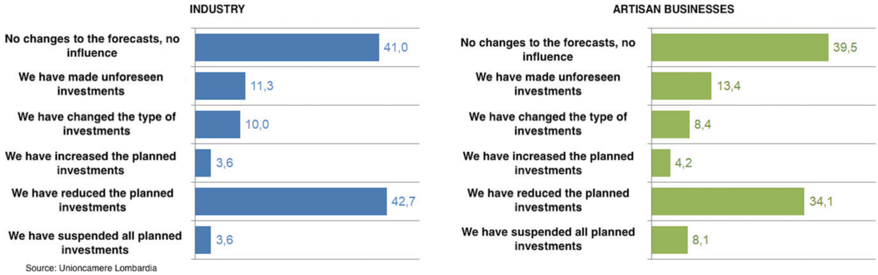


**Figure 15:** How was the decision to invest in 2020 affected by the pandemic? Industry and crafts, in comparison. *(Multiple question - multiple answers possible).* Source: Unioncamere Lombardia.

crafts - and on the other hand, the companies that necessarily had to reduce the planned investments (42.7% and 34.1%, respectively). It is probable that the first item could therefore include the strongest companies in sectors not particularly damaged by the pandemic, as well as those unwilling to invest. The ability to react and adapt the production system is also undoubtedly interesting, detectable by the ability to cope with “unexpected investments" (11.3% in industry and 13.4% in crafts) or to have changed the investment (10.0% and 8.4% respectively). Not to be overlooked are those who, on the other hand, had to completely suspend these decisions while waiting for better times, with a much higher incidence in crafts (3.6% vs 8.1%).

Particular attention within the Unioncamere Lombardia research was also reserved for investments abroad, an extremely interesting topic for assessing the degree of internationalization of companies and the direction of development of the same. The share in 2020 is generally very low and similar for both crafts and industry (3% of tangible investments and 1% for intangible ones), but increasing compared to 2019. In particular, while the industry has seen an increase in tangible investments abroad by 15% and intangible ones by 11%, craftsmanship - despite having favored investments in Italy - recorded a significant increase above all in material ones (11%) compared to intangible ones (2%).

It is therefore interesting to analyze the product sectors where it is possible to find the greatest propensity for investment abroad (Figure 16), by type. In industry, 18.6% of the clothing sector emerges, which reflects the choices of production relocation, in search of new market opportunities and / or cost containment; much more spaced non-metallic minerals (5.2%) and paper and printing (4.0%). The sectors that have seen a higher percentage of intangible investments abroad are: chemicals (4.6%,

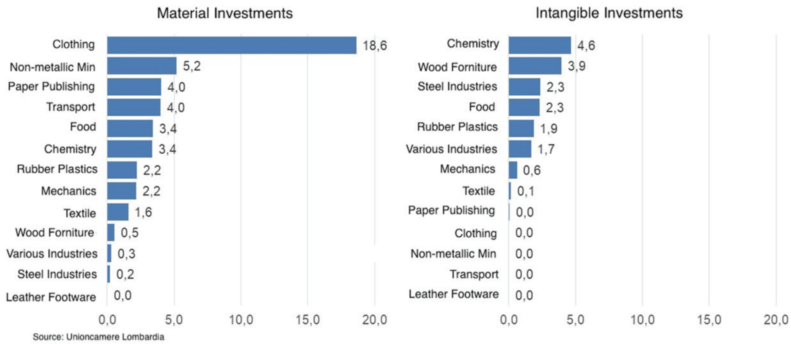


**Figure 16:** Manufacturing industry - Tangible and intangible investments abroad by type and sector (2020). Source: Unioncamere Lombardia.

basically in patents and licenses), one of the sectors in which Italy is more competitive; followed by wood and furniture (3.9%), a sector that in the crisis held its own for the reorganization of public, private and entrepreneurial spaces to adapt to the intensive use of smart working and which may be affected by positioning choices for its business in other markets; finally, the steel sector extremely exposed to international competition (2.3%), which in Italy will have to undertake the path towards the ecological transition for a clean steel.

The situation at the level of craftsmanship is less complex. Material investments abroad are found only in the paper-print (7.7%), mechanical (4.8%) and plastic rubber (2.1%) sectors, with clothing in last position and with minimum values (1.2%). Intangible investments are limited to the wood and furniture sector with 9.5% (which could be motivated by the digitalization projects of the sales channels) and to mechanics (0.3%).

In any case, the choice of investments abroad seems to be mainly motivated - both at the level of industry and crafts - by the need to renovate obsolete production plants (45% and 46.7%), as well as to increase the same capacity. productive (31.3% and 25.7% respectively). This is followed by the objective of diversifying the production activity (5.7% and 10.7%), the launch of new businesses (3.5% and 3.8%) and, less importantly, the internationalization of the company (1.8% and 0.8%). In general, there is therefore a good response from the productive sector in the search for higher levels of productivity or growth (diversification, new business, internationalization), rather than in a purely defensive logic.

By comparing the findings obtained on the reasons behind the investments - renovation of obsolete production plants; increase in production capacity; diversification of production activities; activation of a new business; internationalization of companies - with the individual sectors of activity, some interesting indications emerge on the criticalities not only of the manufacturing sector, but also of the country itself. Only in six sectors - such as chemicals, mechanics, steel, food, paper and printing and wood-furniture - are companies able to pursue all the strategies. Internationalization, on the other hand, is currently completely absent in sectors such as textiles, clothing, non-metallic minerals, various productions (including electromedicals), means of transport and leather-footwear - a phenomenon often directly related to the reduced company size, typical of the Italian production system, in a mutual cause-effect relationship. Furthermore, all sectors, except Wood and Furniture, have made investments for the renovation of obsolete production plants, a widespread defensive strategy essential for the recovery of competitiveness.

Nonetheless, the forecasts of Lombard entrepreneurs regarding investments in the future tend to be positive, both for crafts (24% of companies) and for industry (58%), although still far from the levels reached in 2018 (28% and 63% respectively). The analysis of investment forecasts by sector (Figure 17) shows that the greatest investments are expected in the industrial sectors that emerged more painlessly from the crisis - such as steel (71.9%), affected by the ecological transition foreseen in the Recovery Plan; chemical (70.3%) and food (68.7%). To these, the means of transport (68.2%) has to be added, a sector that must completely rebuild itself after the pandemic, thanks to investments that allow it to return to growth, to face the huge losses of the lockdown. The sectors that, on the other hand, foresee lower investments in 2021, are still those that emerged with great difficulty from the pandemic, in particular: Textiles (44.3%), Leather and footwear (28.6%) and Clothing (19.4%). As for crafts, the sector that plans to make the most investments in 2021 is that of non-metallic minerals (36.5%), followed by paper-printing (30.8%), miscellaneous (29.9%) and rubber-plastic (28.6%), mechanical (25.9%). Sectors in which lower investments are expected to be made are, once again, clothing (19.4%), leather and footwear (12.0%) and textiles (11.6%) - the sectors most affected by the crisis.

However, the risk is that a vicious circle could be created: the sectors that most need investments to redevelop products and processes - also by virtue of the ecological and technological transition - do not actually have the resources and skills to do so, because too much marked by the effects of the crisis. The uncertainty of market prospects (the most important factor

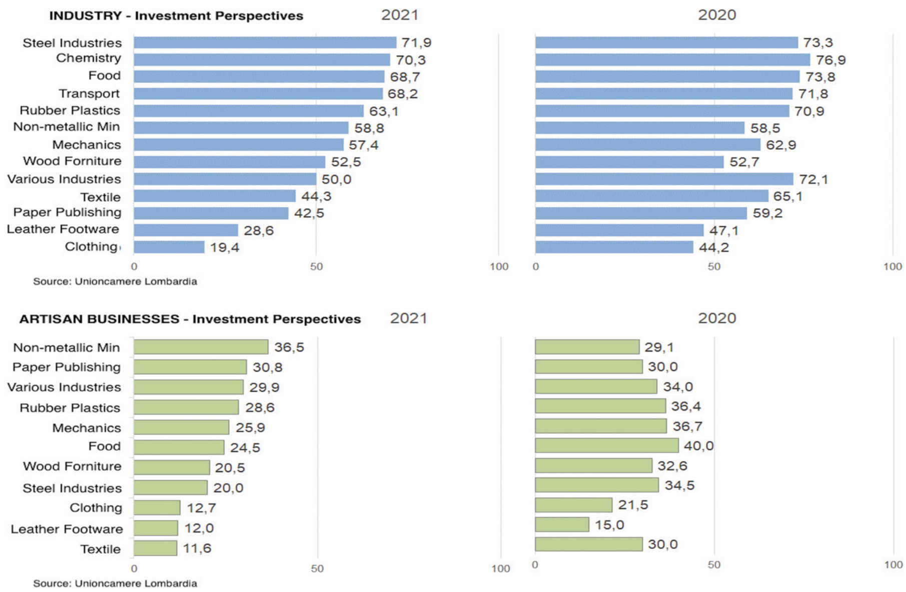


**Figure 17:** Manufacturing firms - industry and crafts - planning to make investments in 2021, by sector. Source: Unioncamere Lombardia.

holding back investments in 2021, for 44.6% of industry and 43.6% of crafts) also contributes to further delaying decisions. It is therefore believed that most companies will keep the situation unchanged in 2020 (42.3% in industry and 46.6% in crafts), but an equally significant share of companies intends to increase them (33.4% industry and 16.4% of crafts), from which it can be deduced a greater difficulty of artisan enterprises, since the remaining 37% will have to reduce them (against only 24.3% of industrial enterprises).

Among the most important investments, those relating to digitization should be mentioned, as the so-called *digital transformation 4.0* has become not only an essential choice, but the way of "doing business" is changing. If in recent years it could have been a simple option, first, and then a real source of competitive advantage, today it could represent a real *condicio sine qua non*, to achieve the minimum conditions of effectiveness and efficiency to compete in the most diverse sectors. , both nationally and internationally. However, this is a real cultural evolution, because it is not a question of making simple investments in hardware and software, but more and more often in the acquisition of specific data science skills to extract value from the information flows generated, increasingly strategically relevant.

It is therefore more and more appropriate that any financial facilitation tools to support investments in this sense (especially for artisan businesses, facilitating, for example, access to e-commerce or the web where relevant) also consider interventions in training/consultancy (indiscriminately for industrial and artisan companies) aimed at accompanying the change in organizational processes and the activities that they determine and require.

Within the Unioncamere Lombardia firm, therefore, it was in particular possible to investigate the role currently attributed to investments in digitization in the context of the business decisions of Lombard manufacturing companies. Faced with the extreme speed of diffusion of digital technologies in final demand, recorded since the pandemic, entrepreneurs seem to be much slower to take action and make a decision in this regard. Only 35% of industrial enterprises and 18% of artisan ones, in fact, were informed about the potential of digital and business 4.0 technologies; just over half of the former will invest in the future (56%) and only 35% of the latter will move in the same direction. The data is surprising if we consider what, during the pandemic, was one of the first urgencies for companies, namely the organization for its employees of a smart working system with the related technological equipment (hardware, software and VPN), that allowed to continue the activity.

However, the impact of digital technologies is transversal within and outside organizations, investing on the one hand every company function (think of the automation of production, testing and assistance processes) and the relationships between the same company functions; on the other hand, they concern the processes along the supply chain as well as towards the market. In fact, there are many variations of digital technologies, such as the family of 4.0 solutions that integrate IoT, AI and ICT in order to make an entire production plant more “intelligent" and autonomous in decisions, but despite the maturity of certain solutions, not the whole sector manufacturing seems aware of the real potential. At the industry level, in 18% of cases (24% in 2019) the knowledge of these technologies is completely lacking (since it increases to 37% for crafts); a general, if not even superficial, curiosity prevails, which consists mostly of reading articles on the internet (40% at the industry level and 45% in crafts).

On the other hand, 44% of industrial companies declare that they have done “something about it" or “plan to do it" (compared to only 18% in crafts); a quite alarming situation considering the competitors and the current international competition, based on visibility and an ability to relate to the market without interruption.

The level of knowledge and implementation of digitization projects is positively correlated with the growth of the company size: the greatest incidence is in fact found in industrial companies with over 200 employees (46.4%) and in artisan companies with at least 10 employees (22,0%). Also in this case, in fact, the companies with the greatest economic and financial resources are facilitated, which nevertheless represent a minority of companies; hence the great interest in the different subsidized finance instruments.

The extent of the investments made is also a variable to estimate their relevance and, therefore, their transformative scope within organizations: for example, a simple e-commerce site built in economy, in fact, not integrated with a CRM evolved, nor accompanied by a process of reconfiguration of internal processes could remain a spot intervention, without bringing any organizational learning or any structural innovation to the company. Within the sample, it was found in particular that - despite a digital literacy problem in a large part of the national businesses - those who actually carry out business 4.0 and or digitization projects tend to make strategic choices. 80.9% of industrial enterprises (and as many as 66.1% of craft enterprises) that made an investment in technologies have in fact spent a total of over 100,000 euros. Nor the share of companies that made investments from 60 to 100 thousand euros is irrelevant (7.9% of businesses and 10.5% of artisan businesses). The simplest activities - with an investment of less than 20 thousand euros - are among the respondents in the sample a minority component (4.1% of industry and 9.7% of artisan enterprises), but prudence suggests, in this case, not to generalize with respect to the universe of small and medium-sized enterprises in the area.

Within these investment choices, first of all, the new technologies supporting infrastructural choices, such as mostly solutions for advanced manufacturing (in 50.8% of cases at industry level and 45,2% in crafts), which include interconnected and rapidly programmable collaborative robots to make production activities more efficient. Other new technologies follow in importance, respectively attributable to vertical/horizontal integration along the value chain (29,4% and 27,7%), Industrial Internet and IoT solutions (18.1% and 16.1%), which allow multidirectional communication between production processes and products; additive manufacturing, with the use of 3D printers connected to digital development software (11.6% in industry and 14.8% in crafts); simulation between interconnected machines to optimize processes (19.8% and 27.7%); access to the cloud (18.1% and 11.6%); CyberSecurity and business continuity (16.6% and 7.1%).

Investments in frontier technologies, such as the management of big data and analytics (in third last place in both sectors, with values of 15.9% and 7.7% respectively) or virtual and augmented reality applied both in contexts of production, training and marketing, in the last place (respectively 8.5% and 5.8%) do not yet receive sufficient attention.

In addition to infrastructure solutions, other technological applications are often considered complementary or synergistic with respect to the previous ones (e.g. artificial intelligence, digital technological solutions for supply chain management; e-commerce systems, also via app), which generate and process the 'set of information flows, which help to extract knowledge and create value for companies.

This is the case of software, platforms and digital applications (Figure 18) for the management and coordination of business processes (ERP, MES, PLM, SCM, CRM; RFID, barcode, etc.), now indispensable in the most diverse production contexts. (78.2% in industry and 59.0% in crafts). Other examples are given by System integration solutions applied to process automation (respectively equal to 29.9% and 25.2%) and for those digital technological solutions for the optimization of supply chain management (Drop Shipping, of "inventory zeroing "and" just in time") (17.3% and 11.5%).

On the other hand, the feedback from artisan businesses towards the activation of mobile and / or internet payment systems, electronic invoicing and fintech (22.3%) and e-commerce systems (15.8%), with values higher than industry (which reaches, respectively, 16.7% and 12.9%). The most advanced technologies, such as artificial intelligence, blockchain and technologies for the in-store customer experience, are too underdeveloped.

In general, there is a different sensitivity towards these applications: the industry seems to favor efficiency optimizing vertical / horizontal integration along the value chain and safety, in terms of business continuity; craftsmanship is more sensitive to solutions that can increase production flexibility, compatibly with a smaller company size and investment capacity.

An extremely relevant issue, with regard to investments and the implementation of digital transformation projects, is the awareness of companies about the strategic importance of the skills necessary to enable and enhance these solutions within organizations and the identification of the type of necessary supports in this regard. With regard to the latter, there is

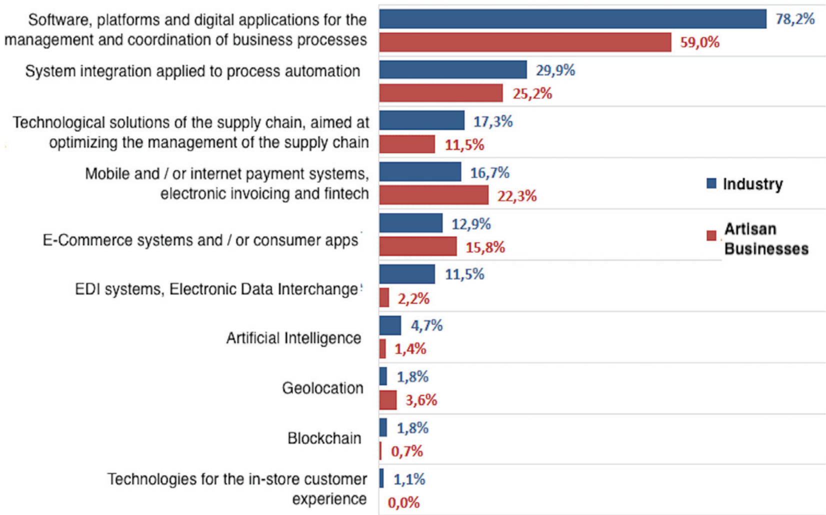


**Figure 18:** Compared to the following list of technological solutions, in which of these has already invested or intends to invest in the short term (multiple choice)? Source: Unioncamere Lombardia.

a certain widespread sensitivity, although support services are considered different priorities based on the type of enterprise - industry and crafts - and size class. More specifically, in industrial enterprises, in general, financial support (58.2%) and staff training (54.2%) are favored, but the latter is a priority for companies from 50 employees upwards. (reaching values of 61.4% and 66.2%, respectively, in companies with more than 200 employees), as a guarantee to obtain significant effects and create value for the company. Companies with fewer than 50 employees, on the other hand, show greater relative attention to financial support (61.9%) and, subsequently, to training (46.7%) and specialist consultancy (32.7%). It is easy to see how crafts, similarly, privilege financial support (68.6%), in a substantially homogeneous way in all size classes and particularly distant from the other items. Training reaches 36.7%, but only in larger companies (with 10 employees or more), which are more sensitive to qualitative aspects.

With regard instead to the presence or absence of specialist skills within the organizations, an indirect evaluation was opted for, verifying how the data generated by the use of the implemented technologies are processed, distributed and used.

The resulting picture is quite dramatic, since 53% of industrial enterprises and 47% of craft enterprises distribute “hand-prepared" data. This means that not only a certain degree of backwardness prevails with respect to the enormous potential of current technologies, but also a waste of resources and / or the presence of important organizational inertia, especially if this happens in companies where significant investments have been made. If we also add to these percentages those relating to the total absence of the use of some tools for preparing and disseminating data (16% in industry and 45% in crafts), it is clear that the problem of staff training and adaptation of some organizational mechanisms within organizations is an absolutely critical and crucial aspect, for the majority of the companies in the sample (69% of the industry and 92% of the craft enterprises). Only 48% of industrial enterprises and 42.1% of craft enterprises use structured reports generated by business intelligence analytics tools, while big data solutions that also integrate external data sources, as well as artificial intelligence algorithms are essentially exceptions. (4% and 1% in industry and 3.8% and 1.1,% in crafts, respectively).

Cultural growth at the level of digitization is also based on the awareness of the effects of the latter in organizations and, therefore, of the return on investment, from a qualitative and quantitative point of view. In general, companies perceive positive results in terms of greater effectiveness and internal efficiency (57.8% of cases in industry and 23.1% in crafts), which however clashes with the possibility of measuring them. Added to this is the finding of a higher overall quality of production (25.5% and 12.8% respectively), which translates into an increase in efficiency) and the reduction of scraps and waste (22.1% and 13, 1%), with further effects on internal efficiency. Finally, the issue of profit (4.6% in industry and 3.0% in crafts), as a further indicator of the return on investment in a systemic business logic.

## 4 Conclusions: Managerial and Political Implications

The results of the analysis of the Lombard manufacturing sector during the different quarters of 2020 are very interesting because:

1. they are *signs of the health of the manufacturing sector* as a whole and, therefore, of the entire Italian economy;
2. *highlighted the different criticalities between sectors and between companies* in the same sectors of activity, with respect to different dimensions (i.e. revenues, markets, cost structure, resources and skills);

3. revealed the *critical success factors, often transversal between sectors and companies,* which are decisive not only in the face of the crisis, but above all for growth, that can exceed pre-Covid levels.

With reference to the first point, the sector has shown a clear reaction, confirmed by the trend of the industrial production and turnover indices, by virtue of the ability respectively to reconfigure production chains and individual supply chains in favor of European suppliers instead of those from the Far East, in search of a higher quality of product and service; to diversify production and to conquer new foreign markets, in the face of the collapse of domestic demand, thanks to new investments in digitization and more.

The second point is, however, equally relevant: the sectors with the most critical issues are in fact the traditional “made in Italy" ones which, even before the pandemic (end of 2019), showed levels of low productivity, inefficiencies and low propensity for production and processes innovation. However, it does not seem to be a question of resources, but rather of skills and competences portfolio. Although the apparel sector suffered from the closure of physical stores, consumers continued to buy but different products and turning to digital channels. At the same time, companies that have invested in digitalization by combining e-commerce with their traditional business have had to change - in as few months - their internal organization, information processes, marketing perspective and communication methods, customer service and logistics.

At the same time, the analysis of the economic trend of the manufacturing sector makes it possible to highlight the characteristics of the sectors and companies best able to face the crisis situation due to the pandemic, net of the fact that they belong to the sectors defined as essential, who were able to continue their business despite government restrictions. In particular, it is possible to refer, on the one hand, to the monitoring of real critical success factors; on the other, to the specificities that seem to characterize companies that are able not only to survive the crisis, but to lead the economic recovery. Among the main critical success factors, “technological & market innovation" and “research and development" undoubtedly stand out, both in terms of process innovation within traditional sectors (which is revolutionizing both production and sales both production and sales channels and management relationships with the customer), and typically in high-tech sectors, where there are strong investments in R&D and as many significant economies of scale at the production level. Moreover, these are the same sectors that stand out for the high share of exports and competitiveness at an international level, with companies included in supranational chains characterized by high global growth trends (for example, the automotive sector in Germany, which is having positive effects on the mechanical, components and advanced electronics industry). In some cases, the ability to blend technological innovation and specific sectorial know-how (as in highly specialized sectors) also allows small and medium-sized companies to operate successfully on national and international markets. Ultimately, it could be argued that the basis of the resilience demonstrated by the manufacturing sector is the visionary capacity of companies that have been able to make counter-cyclical investments (tangible and intangible, in Italy and abroad) and activate more or less structured partnership agreements to “create a system", in cases where it was necessary cope with market or procurement difficulties.

The sectors most in difficulty are therefore those where the majority of companies before the pandemic had already given up investing in innovation - of every order and degree - exploiting with inertia the income advantage that the market position seemed to guarantee, even if it had already been verified significant changes in demand and sales channels. It is therefore possible that many small and medium-sized enterprises (from 15 employees upwards), both manufacturers and /or suppliers and at the retail level - with the disappearance of the restrictions, they will not be able to recover the previous levels of revenue and profit, because not more able to intercept what was their original market, nor to be able to cover the costs of previous inefficiency with government support, in addition to the higher costs due to the necessary health safety conditions in the workplace.

Moreover, during the pandemic the various public tenders intended to mainly support digitization projects for the conquest of new markets, in favor of micro and small-medium enterprises, have certainly had the advantage of accelerating a phenomenon of basic literacy by most of crafts and small manufacturing (in furniture, jewelry, clothing and accessories), but often these investments were alongside traditional management (e.g. opening of an e-commerce by external consultants), without new knowledge and skills have been effectively metabolized and internalized within the organizations. It is therefore desirable that the effectiveness of these transfers could be assessed not only in terms of the amount of expenditure, but also in terms of qualitative impact on local businesses, facilitating, for example, the acquisition of new resources and skills, to implement structural changes in the approach to the market. In other words, if in the short term it is essential that the public actor be able to insert liquidity into the system, in the medium term it is strategically important to address the structural criticalities of the production structure, so that the harmful effects of the end of the layoffs can be avoided.

From the perspective of industrial policy at the national level, it is therefore possible that it is necessary to consider new dimensions of sectoral analysis and competitive transformation.

The first consideration concerns the transformation of supply chains, aimed at bringing suppliers closer to end markets, reducing risk factors. In this regard, resistance to globalization is emerging, as understood up to now, limiting it to the continental macro-region, especially for the strategic supply chains for the Italian economy.

A second consideration concerns the resilience and efficiency of the system - in terms of its ability to absorb a shock and to come out of it even better than its competitors - and not only of individual companies. If we compare the current situation with the financial crisis of 2008, the recovery of companies (and sectors) has been much faster, not only for the availability of resources and liquidity in the economic system, but for having quickly reduced costs in non-strategic activities and directed energies on rethinking the entire business model. This in order to neutralize avoidable risk factors (e.g. basing supply on global just-in-time) and digitizing processes, both at the back end and front end level, for the management of relations with the market, maximizing the value of the return of information (ROI). Thanks to Covid19, digitization itself has undergone a strong acceleration, leading to the birth of new business models (the so-called contactless economy), especially at the level of e-commerce, automation and digital health, in the face of an increasingly receptive demand in this sense.

It is also possible to observe how the pandemic has led to accepting, if not even requiring, a much more incisive role of the government in the economy. During times of great crisis or emergency, citizens are in fact willing to accept and support greater government control over the economy, in order to preserve jobs, support companies in difficulty and help the population in difficulty. It is already noted that the Italian government is already intervening by nationalizing companies, acquiring shares, providing loans or regulating more carefully the import of goods or activities that could be penalized due to competition (eg. job security). It is also desirable that the government can support the same digital transformation underway, already begun with Industry 4.0, not only through funding to support digitization, but also by defining tools to feed research and development activities in small and medium-sized enterprises (through the external outsourcing of research or the creation of multi-company research centers), often extremely specialized.

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# Citizen Behavior & Health Indicators in Israel During COVID-19: A Systematic Analysis of Data Over Time

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The management of the COVID-19 pandemic involves the interaction and collaboration of three key players: the citizens, policy and decision makers and the healthcare system. The main goal is to find the fragile balance between keeping an open society, a working economy and saving lives. SARS-COV-2 is known to be highly contagious, with a potential for severe health complications, especially in the elderly. In this paper we analyze changes in Israel, in health outcomes and citizen behavior, from the initial stages of the pandemic (March 2020) until the beginning of mass vaccination (December 2021). This perspective includes the impact of government's policies (lockdowns and re-openings) on levels of morbidity. We used official national health data and Google Mobility data to examine these changes. Several models are used to analyze their mutual effects. Results show that public behavior changed over time to a lesser degree than health related data. The implications to policy formulation are also discussed. The main point in the paper is that data driven policy is much needed in conditions of pandemics.

## 1 Introduction

COVID-19 has led to unprecedented changes in various domains including economic, social, labor, education, air travel, political and technological sectors. Given that the SARS-COV-2, or COVID-19, is highly contagious, a critical goal in this pandemic management has been minimizing the burden on healthcare systems. A related universal goal has been to prevent hospital surge in numbers of critical and ventilated patients.

The data we consider here are preceding the start of vaccination in Israel. The early indications are that vaccinations are effective and match the vaccination efficiency estimates from the clinical trials. However, many uncertainties remain regarding resilience to mutations and contagion effects of vaccinated populations.

Pandemic management policies in Israel included national and local lockdowns, with frequent closures of air traffic, education institutions, and economic

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sectors. Citizens were called to adhere to protection measures, such as keeping physical distance, practicing hygiene measures and using face masks. Government applied policies such as lockdowns and re-openings according to the perceived “acceptable loss" derived from a balance between running the economy and minimizing economic and social damage versus the need to save lives.[1] As expected, easing of lockdowns led to an increase in morbidity. At the same time, lockdowns and quarantines caused severe damage in terms of social and economic factors as reflected by increasing rates of domestic violence, unemployment, depression, non-normative behavior (alcohol drinking and drugs) among others.[2–4]

Research has shown that citizen compliance with stay-at-home policies[5] is predicted by perceived risks and trust in science and scientists,[4] trust in the authorities[6] and social capital.[7] Moreover, restricted mobility options (such as closures of air traffic, shopping malls, sport events and education institutions), were found to effectively prevent outbreaks and reduce the number of death.[8–10] Furthermore, research has also found that citizens voluntarily decreased their mobility, without official instructions to stay at home.[11,12]

In the current analysis, we examine both health and behavior, or activity related data of Israeli citizens, over time. Israel experienced national lockdowns in March, September and December 2020. Referring to official national health data and to Google Mobility data we trace patterns in citizens behavior, in response to lockdowns and re-opening, as well as changes in different behavior domains such as attendance at workplace, public places and staying at home behavior, in response to changing reported health indicators and government policies.

## 2 Methodology

We used Israeli official Ministry of Health daily data from March 1$^{st}$, 2020 until Dec. 28$^{th}$, 2020. Variables included in the study are: number of tests, number of hospitalized patients, number of people ventilated, number of reported positive cases, number of severe condition patients, and number of COVID19 attributed death, per day. We also use Google Mobility data (https://www.google.com/covid19/mobility/) for Israel for the same time frame. Variables included mobility indicators for retail and recreation, grocery and pharmacy, parks, transit stations, workplaces, and residential places. Mobility variables show the percent change from pre-pandemic baseline.

The analysis included multivariate $T^2$ control charts, cluster analysis, decision trees and structural equation models (SEM). To account for the nonstationary in the data, ARIMA models were used first and the multivariate control charts were applied to the residuals. The analysis was performed using the JMP 15.2 software (http://www.jmp.comwww.jmp.com).

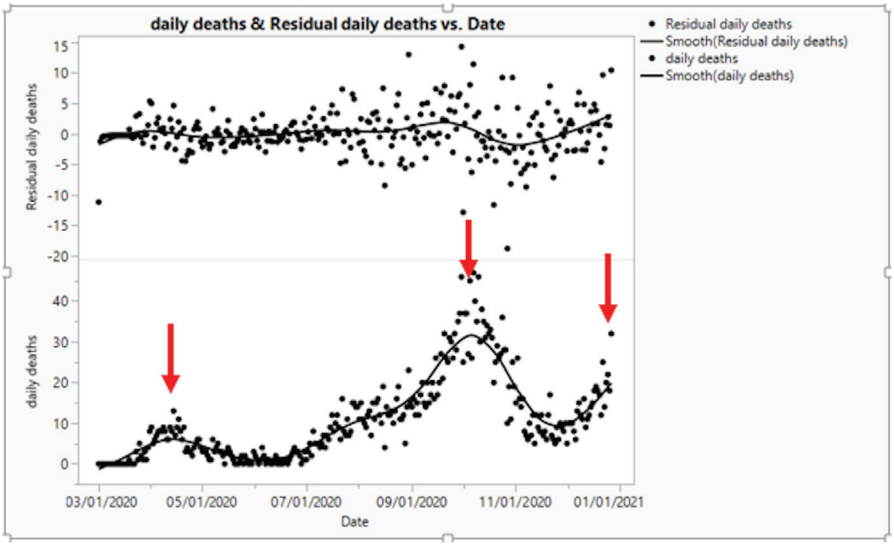



**Figure 1:** Number of daily deaths and residuals from AR(8), over time.

# 3 Findings

## 3.1 Health data during COVID-19

The lower panel in Figure 1 is the number of daily deaths in Israel, over time. The first, second and third pandemic waves are clearly visible when adding a smoother to the raw data. The data is non stationary and, in order to apply control charts which assume independence between observations, we fit an autoregressive model of type AR(8) to all the health and activity data. The AR(8) model was found to best fit the 12 time series. The upper panel in Figure 1 shows the residuals of daily deaths, after fitting the AR(8). Some heteroscedasticity is apparent towards the end of the series but this does not affect the analysis we conducted with non parametric methods such as K-means clustering and decision trees. In order to handle the combined 6 health related indicators we apply a multivariate $T^2$ control chart to the 6 series of AR(8) residuals.[13] In that chart, the Mahalanobis $T^2$ distance is used to indicate deviations from the 6-dimensional vector of averages of residuals over the 303 observations. The distance is calibrated to account for the correlation structure of these variables. The $T^2$ control chart on these 6 dimensions is presented in Figure 2 .

In order to identify clusters in the health data patterns, a K-means clustering of the health data was conducted with K=4. This was an optimal clustering using the cubic clustering criterion (CCC) as shown in Figure 3. The CCC is used to estimate the number of clusters using Ward's minimum variance method, K-means, or other methods based on minimizing the within-cluster sum of squares.

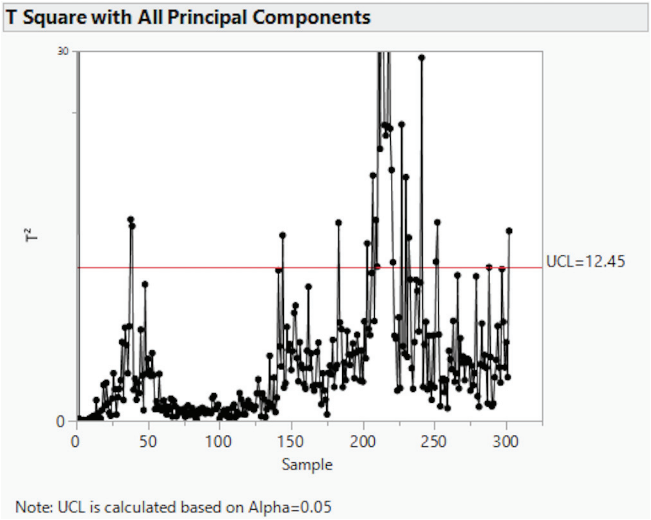
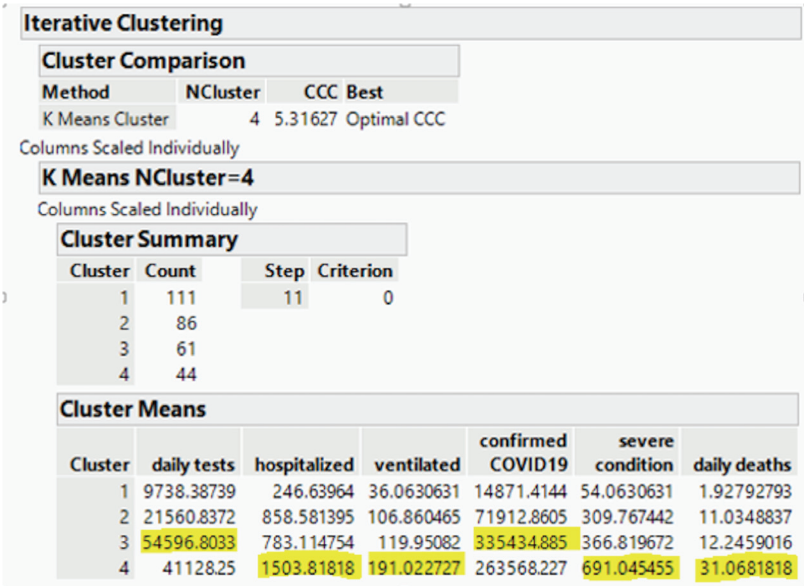



**Figure 2:** $T^2$ chart on six health related variables.



**Iterative Clustering**

**Cluster Comparison**

| Method | NCluster | CCC | Best |
|---|---|---|---|
| K Means Cluster | 4 | 5.31627 | Optimal CCC |

Columns Scaled Individually

**K Means NCluster=4**

Columns Scaled Individually

**Cluster Summary**

| Cluster | Count |
|---|---|
| 1 | 111 |
| 2 | 86 |
| 3 | 61 |
| 4 | 44 |

| Step | Criterion |
|---|---|
| 11 | 0 |

**Cluster Means**

| Cluster | daily tests | hospitalized | ventilated | confirmed COVID19 | severe condition | daily deaths |
|---|---|---|---|---|---|---|
| 1 | 9738.38739 | 246.63964 | 36.0630631 | 14871.4144 | 54.0630631 | 1.92792793 |
| 2 | 21560.8372 | 858.581395 | 106.860465 | 71912.8605 | 309.767442 | 11.0348837 |
| 3 | 54596.8033 | 783.114754 | 119.95082 | 335434.885 | 366.819672 | 12.2459016 |
| 4 | 41128.25 | 1503.81818 | 191.022727 | 263568.227 | 691.045455 | 31.0681818 |

**Figure 3:** K-means analysis of six health related variables, with K= 4.

The performance of the CCC is evaluated by Monte Carlo methods. The results show that clusters vary in the volume of the health components in each cluster and its type, see Figure 3. For example, Cluster 1 includes lower levels in all health indicators in comparison with the other clusters. Cluster 3, represents

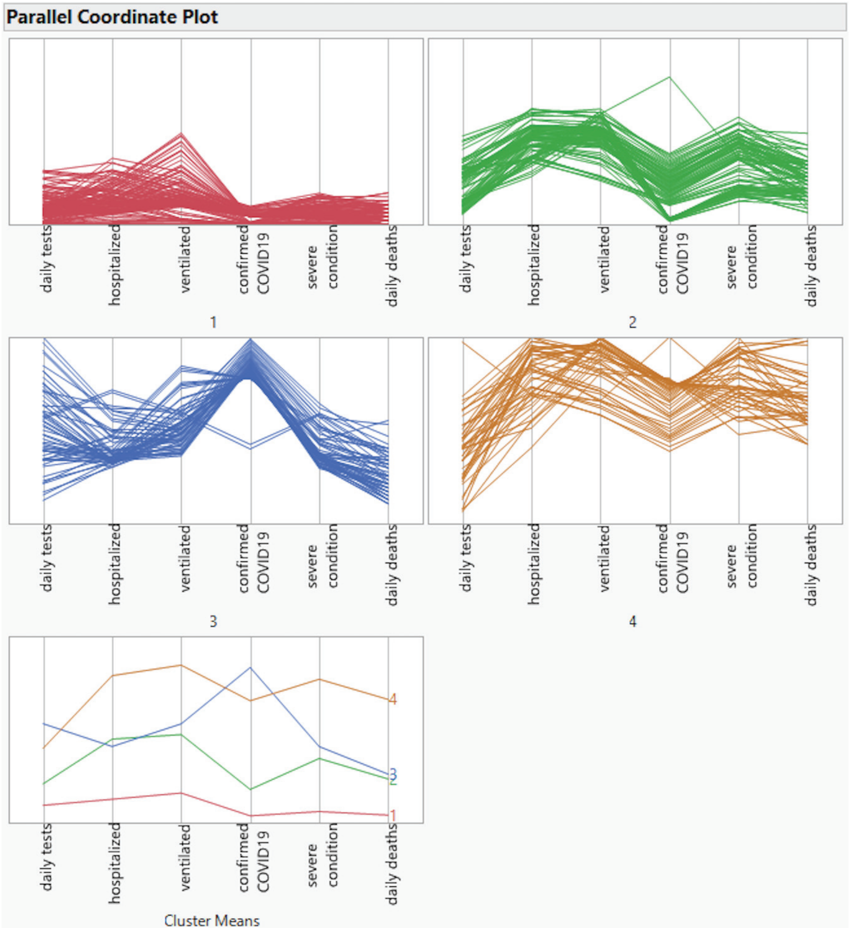



**Figure 4:** Parallel plots of the 4 clusters of the health-related data.

extreme levels of daily tests and confirmed (positive) cases, with non severe data in other health indicators, as in Cluster 4.

A parallel plot display of the 4 clusters is shown in Figure 4. The increase in confirmed cases is characteristic of Cluster 3. This was low in Clusters 1 and 2. Higher levels of morbidity were found in Cluster 4. These results indicate different patterns of the pandemic over time.

The derived 4 clusters are consistent with time ordering, see Figure 5. Cluster 1 is the initial phase with cluster 2 indicating the first pandemic wave. Cluster 4 is the second wave and Cluster 3 is the third wave.

A complementary analysis was conducted by replacing the health raw data with three ratios representing the effect of exposure. The indicators we calculated are *'pandemic outbreak'* measured as the number of positive cases divided by number

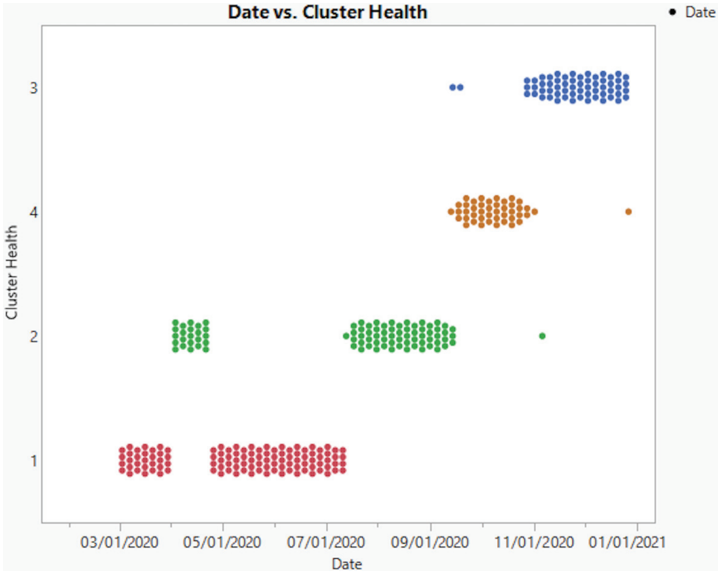



**Figure 5:** The 4 clusters of the health-related data (note reordering of clusters 3 and 4 to match the time dimension).

of testes, *'healthcare system's capacity'* measured by number of severe conditioned patients divided by the number of hospitalized, and *'pandemic severity'* which is measured by the number of deaths per number of patients hospitalized. Figure 6 present these three indicators over time.

From Figure 6 we see in Cluster 3 a stable ratio of confirmed/tested with an increased level of severe/hospitalized and deaths/hospitalized in Clusters 4 and 3 relative to Clusters 1 and 2.

Control charts of severe/hospitalized and deaths/hospitalized are presented in Figure 7. They show that the patients with severe conditions, as a proportion of hospitalized patients, has increased significantly from Clusters 1 and 2 to Clusters 2 and 4 and that the proportion of COVID related deaths as a proportion of hospitalized patients is reduced in Cluster 3 relative to Cluster 4. For an application of control charts to survey data analysis, see.[14] For general applications see.[13]

The results shed light on the changes in the pandemic over time. However, these changes vary across indicators. In other words, the pandemic does show increases in all parameters at once, but rather, is reflected in the combination of several indicators.

### 3.2 Public behavior and activity during COVID-19

We proceed to analyze the activity related data. Figure 6 is the $T^2$ chart for the activity data residuals after fitting an AR(8). Comparing Figure 8 to Figure 2

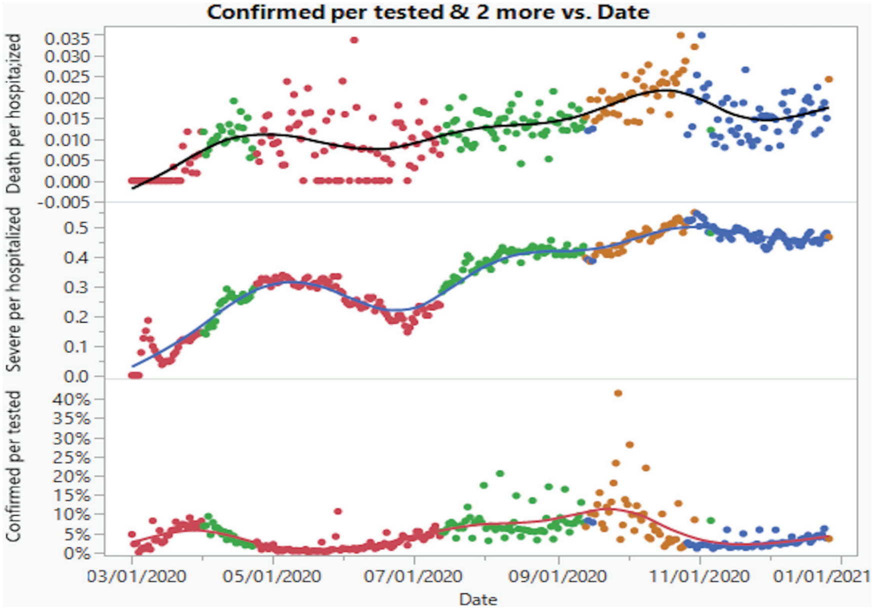



**Figure 6:** Trends of confirmed/tested, severe/hospitalized and deaths/hospitalized.

we observe different patterns. Clusters 2 and 4 corresponding to the second and third pandemic waves, did not show parallel behavior in the activity chart. In other words, the behavior of citizens in the period of clusters 2 and 4 apparently ignored the trends in health-related data. Moreover, government policy - of national stay-at-home orders in this time period proved less effective.

A classification predictive analysis, with a random forest analysis of the activity related data as predictor of the health clusters, produces a 19% misclassification rate in the confusion matrix. The ROC curves are shown in Figure 9 with AUC ranging from 93% to 97%. The "column contributions" shows that the clusters are mostly determined by the decrease in transportation and retail activity. Less so by the other 4 activity related variables (Figure 10). Closure of public transportation and retail activity are included in the government's policy, and therefore forced the public to avoid it. However, grocery and pharmacy and visiting parks were less effected - as the decrease in these activities were minor.

As the decision tree in Figure 11 indicates, the decrease in transit stations is the significant reaction of all health-indicators clusters. Furthermore, as the left leaf in the figure shows, for Cluster 1, (the first pandemic-wave characterized by lower levels of morbidity, but the beginning of the pandemic), the decrease was also in retail, then grocery and pharmacy and workplaces. However, in the 2$^{nd}$ and 4$^{th}$ cluster, which represent the second and third waves of the pandemic when morbidity was very high, we see a different behavioural pattern: transportation

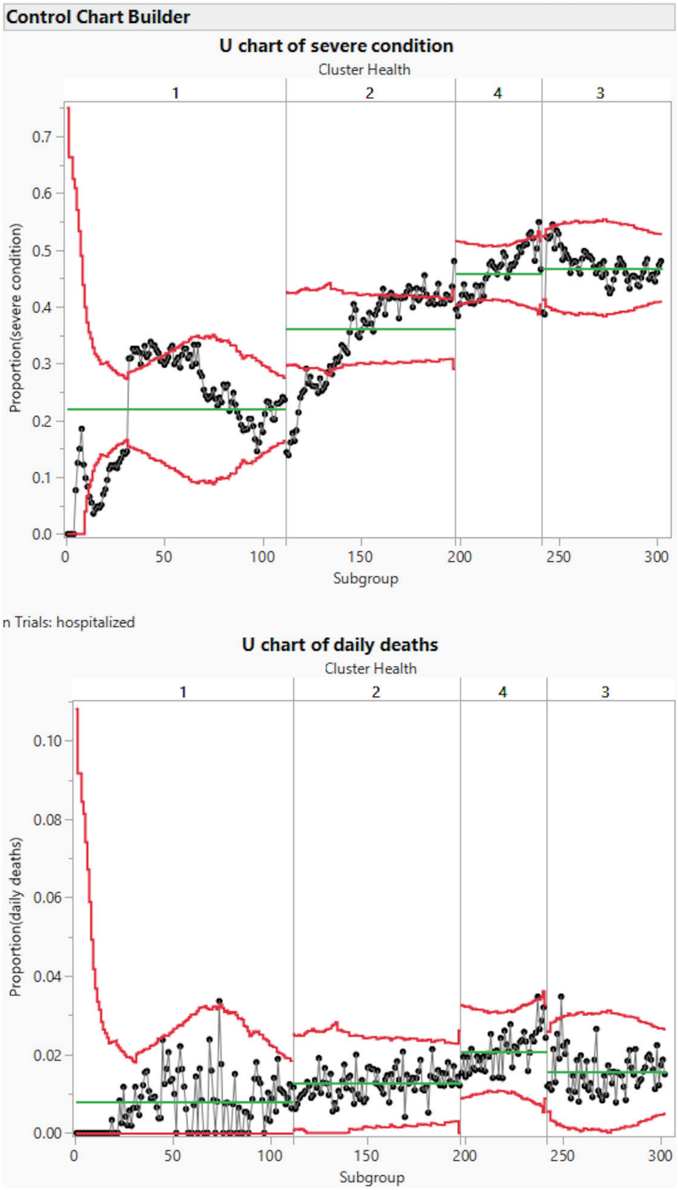



**Figure 7:** U charts of severe/hospitalized and deaths/hospitalized by cluster.

and retail are decreased by the force of the national lockdown, however the grocery and pharmacies are increasing as well as workplace attendance. This means that although the morbidity was high, with increasing numbers of cases of deaths people hospitalized in severe condition, the public's behaviour was not compliant with lockdown orders.

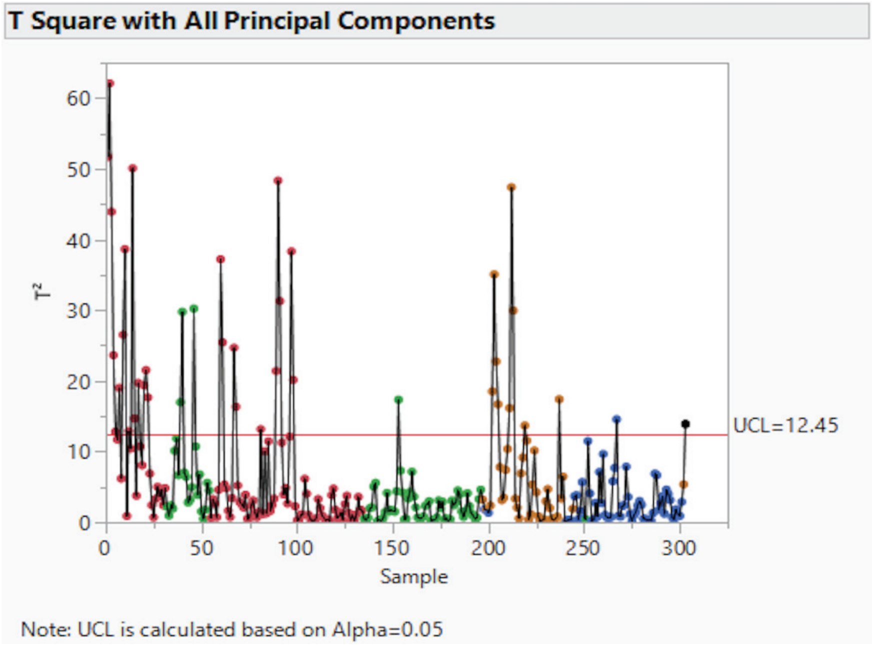



**Figure 8:** $T^2$ chart on six activity related variables.

The tree with 10 splits is presented in Figure 11 followed by a listing of its leaves Figure 12

Yet another analysis aiming at identifying latent variables affecting the health and activity data was conducted using confirmatory structural equation models (SEM) applied to the standardized health residuals and the activity residuals, see Figure 13.

The SEM comparative fit index (CFI) was marginal (0.79) and only the loadings on the citizen activity latent variables turned out significant with a nonsignificant covariance of the health and behavior latent variables of -0.017. CFI represents the model fit by examining the discrepancy between the data and the hypothesized model while adjusting for sample size inherent in the chi-squared test of model fit. CFI values range from 0 to 1, with larger values indicating better fit. This reflects the findings in Figure 5, 6 and 7 which indicated that the health variable change over time, but separately - not all health indicators increased at the same time. Furthermore, we run another analysis where we added to the model regressions between the health indicators and each of the behavior variables. Results showed an improved fit (CFI=0.91).

The loadings (Figure 14) show that increased number of hospitalized patients increases visits to grocery stores and pharmacy and decreases attendance at workplaces. Also, confirmed cases had the strongest effect on decreased attendance at

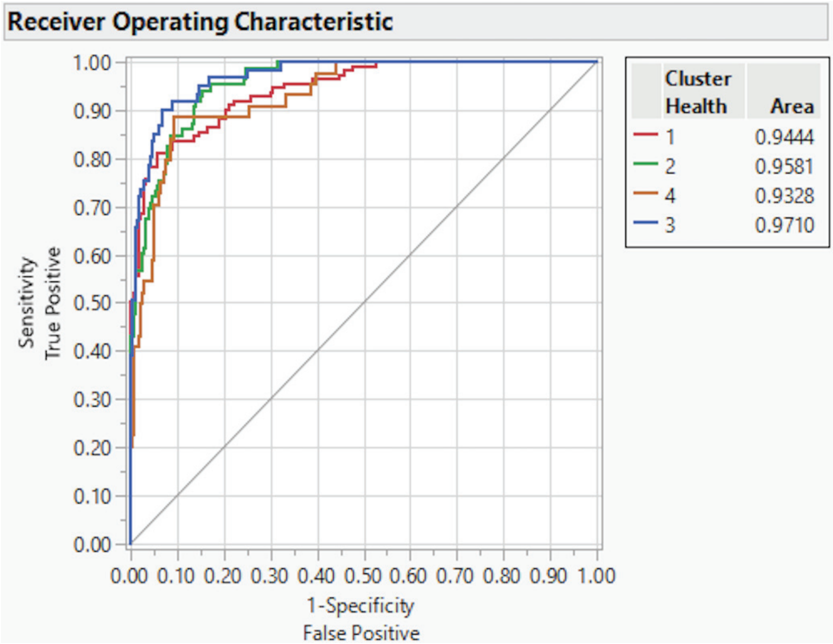



**Figure 9:** ROC curves from random forest predictive model of the activity data as predictors of the health related clusters.

**Column Contributions**

| Term | Number of Splits | G^2 | Portion |
|---|---|---|---|
| transit_stations_percent_change_from_baseline | 547 | 40.1151085 | 0.2788 |
| retail_and_recreation_percent_change_from_baseline | 608 | 31.0928002 | 0.2161 |
| workplaces_percent_change_from_baseline | 567 | 24.6520721 | 0.1713 |
| residential_percent_change_from_baseline | 580 | 16.3495367 | 0.1136 |
| grocery_and_pharmacy_percent_change_from_baseline | 555 | 16.159777 | 0.1123 |
| parks_percent_change_from_baseline | 559 | 15.5218915 | 0.1079 |

**Figure 10:** Column contributions in random forest predictive model of the activity data as predictors of the health related clusters.

workplaces. The number of daily deaths did not affect the behavior. The findings show that the number of hospitalized and ventilated patients were predictors of behavioral change.

# 4 Discussion

The paper provides an analysis of daily health data and citizens' activity related data (March - December 2020) in Israel during the COVID-19 pandemic.

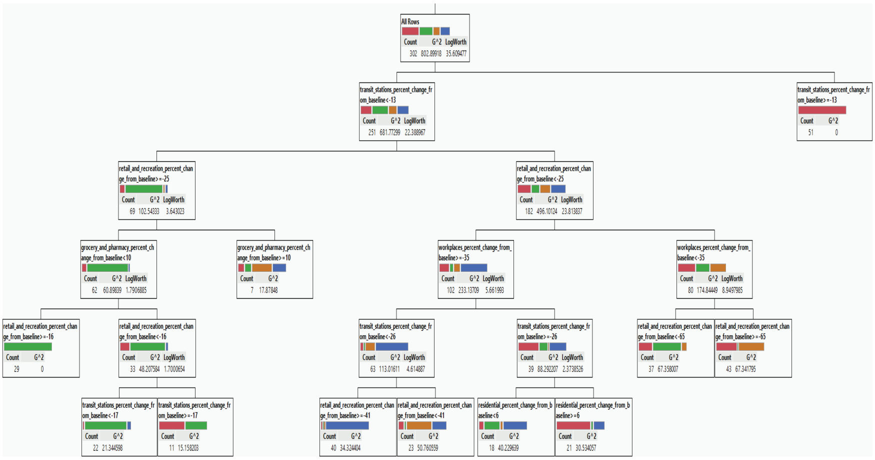



**Figure 11:** Decision tree predictive model with 10 splits of the activity data.

Multivariate control charts were used to monitor changes over time and three pandemic waves are visually apparent. A K-means clustering analysis identifies 4 health-indicators clusters that are consistent with the three pandemic waves over time. The clusters are characterized by lower levels of morbidity at the beginning of the pandemic (March 2020), then moderate levels of morbidity with relatively low number of tests and confirmed cases (September 2020). Two clusters (3+4) representing higher levels of morbidity with relatively low numbers of tests and positive cases (Cluster 3). This indicates a variability in the term "morbidity". This is an important aspect for pandemic management and policy. The question posed, in that context, is not how high are the different indicators, but rather, who are the important indicators, or combination of indicators, which represent an extreme situation that demands extreme actions.

The changes in health-related indicators over time and the cluster which were found in this study, are followed by changes in public activity, such as adherence to the stay at home instructions. Governmental policies such as national lockdowns were very effective in the first wave. The results show lower morbidity rates and significant decrease in public activity, with an increase in grocery and pharmacy visits. However, over time, in the second and third waves of the pandemic, the same policies did not achieve the expected results. The public did not change its behavior in accordance with the high morbidity and vice versa - the increased activity increased the morbidity rates. The change in public activity which were officially supposed to be locked, such as retail and recreation, was less significant in the second and third waves than in the first wave. This represents an adaptive behavior pattern of the public to the unfolding situation. A closer examination of the results found that as the health indicators varied across the pandemic

| Leaf label | Cluster 1 (red) | Cluster 2 (green) | Cluster 4 (brown) | Cluster 3 (blue) |
|---|---|---|---|---|
| Transit stations<-13, retail and recreation>=-25, grocery and pharmacy<10, retail and recreation>=-16 | 0.0103 | 0.9797 | 0.0042 | 0.0059 |
| Transit stations<-13, retail and recreation>=-25, grocery and pharmacy<10, retail and recreation<-16, transit stations<-17 | 0.0565 | 0.8445 | 0.0049 | 0.0941 |
| Transit stations<-13, retail and recreation>=-25, grocery and pharmacy<10, retail and recreation<-16, transit stations>=-17 | 0.5250 | 0.4519 | 0.0094 | 0.0137 |
| Transit stations<-13, retail and recreation>=-25, grocery and pharmacy>=10 | 0.1664 | 0.1674 | 0.3923 | 0.2739 |
| Transit stations<-13, retail and recreation<-25, workplaces>=-35, transit stations<-26, retail and recreation>=-41 | 0.0563 | 0.0302 | 0.0283 | 0.8852 |
| Transit stations<-13, retail and recreation<-25, workplaces>=-35, transit stations<-26, retail and recreation<-41 | 0.1379 | 0.0516 | 0.5066 | 0.3039 |
| Transit stations<-13, retail and recreation<-25, workplaces>=-35, transit stations>=-26, residential<6 | 0.1234 | 0.3291 | 0.0601 | 0.4874 |
| Transit stations<-13, retail and recreation<-25, workplaces>=-35, transit stations=-26, residential>=6 | 0.6975 | 0.0569 | 0.0064 | 0.2391 |
| Transit stations<-13, retail and recreation<-25, workplaces<-35, retail and recreation<-65 | 0.2987 | 0.5863 | 0.1098 | 0.0051 |
| Transit stations<-13, retail and recreation<-25, workplaces<-35, retail and recreation>=-65 | 0.4398 | 0.0291 | 0.5267 | 0.0044 |
| Transit stations>=-13 | 0.9878 | 0.0055 | 0.0028 | 0.0039 |

**Figure 12:** Leaves of the decision tree of the activity data.

waves, the public tended to decrease its activity as a reaction to increasing levels of positive cases and the number of hospitalized. This represents the way the public perceives the severity of the pandemic and how it acts accordingly.

Lockdowns and stay-at-home instructions in Israel had an impact on citizen activity. However, at the beginning of the events (March 2020), public compliance was much more significant than in the next two waves and lockdowns. These results provide policy makers a method and insights for tracking public compliance with stay-at-home instructions, when facing various levels of morbidity.

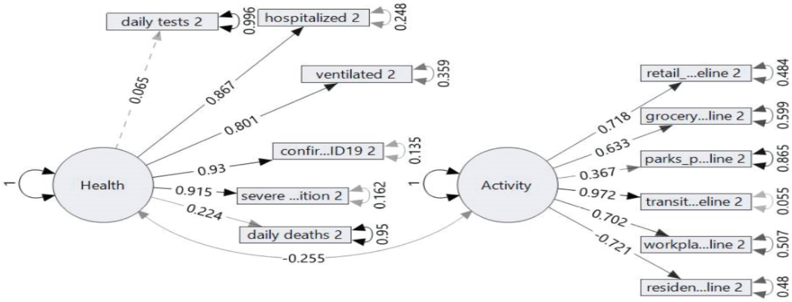



**Figure 13:** Structural equation model analysis of the health and activity variables with latent variables behind the health and activity data.

| Regressions | Estimate | Std error | Wald Z | Prob >Z |
|---|---|---|---|---|
| daily tests 2 → retail and recreation | 0.100314 | 0.056932 | 1.761994 | 0.0781 |
| daily tests 2 → grocery and pharmacy | 0.040184 | 0.058529 | 0.686561 | 0.4924 |
| daily tests 2 → parks | -0.04888 | 0.059814 | -0.81726 | 0.4138 |
| daily tests 2 → transit stations | 0.157795 | 0.057094 | 2.763801 | 0.0057 |
| daily tests 2 → workplaces | 0.108495 | 0.05643 | 1.922643 | 0.0545 |
| daily tests 2 → residential | -0.12688 | 0.058122 | -2.18301 | 0.029 |
| hospitalized 2 → retail and recreation | 0.355041 | 0.207605 | 1.710177 | 0.0872 |
| hospitalized 2 → grocery and pharmacy | 0.409025 | 0.200172 | 2.043363 | 0.041 |
| hospitalized 2 → parks | 0.063684 | 0.153197 | 0.4157 | 0.6776 |
| hospitalized 2 → transit stations | 0.231329 | 0.207474 | 1.114976 | 0.2649 |
| hospitalized 2 → workplaces | -0.59716 | 0.216911 | -2.753 | 0.0059 |
| hospitalized 2 → residential | -0.03614 | 0.165549 | -0.2183 | 0.8272 |
| ventilated 2 → retail and recreation | 0.051492 | 0.142212 | 0.362082 | 0.7173 |
| ventilated 2 → grocery and pharmacy | -0.01365 | 0.13915 | -0.0981 | 0.9219 |
| ventilated 2 → parks | 0.092759 | 0.114601 | 0.809403 | 0.4183 |
| ventilated 2 → transit stations | -0.04009 | 0.142314 | -0.2817 | 0.7782 |
| ventilated 2 → workplaces | -0.46903 | 0.147282 | -3.18456 | 0.0014 |
| ventilated 2 → residential | 0.023281 | 0.120022 | 0.193976 | 0.8462 |
| confirmed COVID19 2 → retail and recreation | -0.4175 | 0.359958 | -1.15986 | 0.2461 |
| confirmed COVID19 2 → grocery and pharmacy | -0.12312 | 0.342118 | -0.35988 | 0.7189 |
| confirmed COVID19 2 → parks | -0.18703 | 0.239873 | -0.77971 | 0.4356 |
| confirmed COVID19 2 → transit stations | -0.22 | 0.359224 | -0.61244 | 0.5402 |
| confirmed COVID19 2 → workplaces | -1.33665 | 0.387411 | -3.45022 | 0.0006 |
| confirmed COVID19 2 → residential | 0.164108 | 0.269891 | 0.608053 | 0.5432 |
| severe condition 2 → retail and recreation | -0.1152 | 0.308709 | -0.37318 | 0.709 |
| severe condition 2 → grocery and pharmacy | -0.1654 | 0.294237 | -0.56214 | 0.574 |
| severe condition 2 → parks | 0.032263 | 0.21 | 0.153631 | 0.8779 |
| severe condition 2 → transit stations | -0.08664 | 0.308175 | -0.28114 | 0.7786 |
| severe condition 2 → workplaces | -1.08946 | 0.330702 | -3.29438 | 0.001 |
| severe condition 2 → residential | -0.13512 | 0.234305 | -0.57667 | 0.5642 |
| daily deaths 2 → retail and recreation | -0.09566 | 0.057844 | -1.65369 | 0.0982 |
| daily deaths 2 → grocery and pharmacy | -0.08587 | 0.059343 | -1.44698 | 0.1479 |
| daily deaths 2 → parks | -0.10376 | 0.060163 | -1.7247 | 0.0846 |
| daily deaths 2 → transit stations | -0.07211 | 0.058004 | -1.24313 | 0.2138 |
| daily deaths 2 → workplaces | -0.10003 | 0.056088 | -1.78347 | 0.0745 |
| daily deaths 2 → residential | 0.096292 | 0.058589 | 1.643518 | 0.1003 |

**Figure 14:** Regressions of SEM model.

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# Italian Regional Healthcare Services Put to the Test by Covid-19: Strategic and Managerial Issues from the First Wave

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The Italian Regional Healthcare Services (RHSs) have the responsibility for the provision of health services in their territory, for the organizational design and strategic direction of public providers, and for contracts with private accredited providers. RHSs have had to rapidly adapt their strategies for the purpose of facing the Covid-19 health crisis. There is scarcity of research on the influence of RHSs over the organisational capacity and managerial autonomy of the healthcare organizations (HCOs) in responding to an emergency. This paper aims to investigate the role of the Italian RHSs in the governance of Covid-19 emergency and to analyse the influence on the response of HCOs in managing the first wave. Findings show the prevalence of two models (centralized vs decentralized) in pandemic crisis management that have achieved different outcomes in the RHSs; oftentimes the weakness of regional strategies was compensated for by bottom up initiatives from individual HCOs.

## 1 Introduction and Background

The coronavirus pandemic has proven to be the highest level of natural variability healthcare systems have ever experienced: a phenomenon which has undermined the ability to predict Covid-19's impact on patient flows and thus the ability to implement consistent approaches for service delivery. Since this disease is new, in fact wholly unknown, there has been complete lack of information about:[1] i) its spread through the population; ii) expected inpatient flow to hospitals; iii) consequences on patients' health and subsequent level of care assistance requirements.

Moreover, this outbreak has exacerbated the negative side effects of the austere health policies of the last ten years,[2] especially the cuts in resources (professionals, physical assets such as beds, equipment, technologies for non-invasive and invasive ventilation, etc.) available to face this emergency. Thus, Health Care Organisations (HCOs) have had to adapt their processes rapidly so as to deal with the public health crisis and deliver services by converting production assets

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(beds, operating rooms, Intensive Care units, physical pathways, etc.) and taking advantage of the few elements of predictability that have gradually emerged from the crisis.

The Italian National Healthcare Service (INHS) follows the principles of the Beveridge System, in which resources are collected by general taxation at central level and then devolved to the 21 Regions and Autonomous Provinces (Regional Healthcare Services - RHSs).[3] Therefore, the responsibility for the provision of care, for governance, for the design of the organizational model of public Local Health Authorities (LHAs) and hospitals, and typically for the contracts with accredited private hospitals, is decentralised to Regional level.[4]

Thus, RHSs differ from each other in governance arrangements, financial mechanisms, organisational design, number and relevance of private providers and in the quality of the service provided.[5] As a consequence of these governance mechanisms, RHS policies can exert great influence on how HCOs (e.g. Local Health Authorities and Departments of Public Health and Prevention, LHAs' hospitals and Hospital Trusts, community and primary care practices, long-term care facilities, local public health departments) manage their service provision. Cross-field scientific literature has studied the role of national governance in the management of healthcare systems during periods of epidemics such as SARS, MERS[6–8] and recently, Covid-19.[9,10] There is no agreement amongst scholars about whether centralised governance structures and mechanisms have a more positive effect on pandemic responses than decentralised ones. However, one of the latest studies on Covid-19 highlights that a centralised governance structure may not facilitate a proactive strategy in dealing with a pandemic but rather may foster a less effective response.[9] On the other hand, there is scarcity of literature which examines the role and influence of RHSs on the organisational capacity and managerial autonomy of the single HCOs in responding to an emergency.

## 2 Aims and Methodology

The main aims of this research are:

- to investigate the role of the Italian RHSs in facing the Covid-19 emergency;
- to analyse to what extent the RHSs' strategies could have affected the response of HCOs in managing the first wave of the Covid-19 pandemic in their territory because of the Regional level centralisation of decisions regarding the emergency.

RHSs were selected from the first, worst-affected Italian regions to face the Covid-19 emergency in terms of number of infected people. Their healthcare systems in particular experienced huge stress because of the pandemic (Italian

Department of Civil Protection, open data). Six RHSs were analysed: Piedmont, Lombardy, Veneto, Emilia-Romagna, Tuscany and Lazio.

Research was conducted using the following methodological approach:

- desk analysis of the policies and regulations that the RHSs implemented during the first wave of the pandemic (from February to mid-July 2020);
- interviews with 15 key informants (CEOs and/or Clinical directors and/or Administrative directors and/or Social directors) of public and private healthcare providers, using a semi-structured questionnaire in order to gather insights on COVID-19-related governance and strategies in their RHS and to investigate how they influenced organisational and managerial efforts.

The desk analysis and semi-structured questionnaire to key informants was undertaken focusing on three main items: (i) characteristics of regional crisis teams and governance mechanisms, (ii) the strategies for facing the Coronavirus emergency in the following healthcare management areas: acute care services and hospital networks, health and prevention services, community and primary care practices, laboratory services and networks, iii) digital innovation and telemedicine.

These items were identified from the strategies and operational tactics that HCOs adopted in the first wave in response to the crisis[1] and are the managerial levers likely to be most influenced by the RHS policies used to tackle the pandemic.

# 3 Findings

### 3.1 RHSs Crisis Teams and Governance Mechanisms

The role of the specific RHS crisis team and the governance mechanisms can have a huge influence on the responses by the HCOs.

In the Piedmont region there were two distinct phases in the organisation of the Regional Crisis Team (RCT). The first coincided with the period between the end of February and the first half of March. It was characterised by centralised management and was focused on a prevalently medical issues and hospital-centric response. The RCT took responsibility for decisions relating to: number of Intensive Care beds, patient distribution by ambulance to Emergency Departments, patient transfers between hospitals, swab testing authorisations. Clinical Directors participated in the RCT as representatives of their HCOs, then took responsibility for implementing RCT directives. In this chain of command, the role of the CEOs was to ratify the decisions brought back by the Clinical Directors. Even administrative activities such as hiring extra staff and purchasing PPE (Personal Protection Equipment), swab tests and medical equipment for the whole RHS was centralised in the RCT. In the second phase, a new Covid Emergency Commission was nominated which involved CEOs more actively despite maintaining the line of command and control between the RCT and clinical directors.

This centralisation of decision-making was also characteristic of the Veneto region, but with more management sharing and participation. The composition of the RCT comprised the CEOs of the various HCOs and Authorities (i.e. regional Departments, Administrative Authorities) as well as professional and medical staff (i.e. infectious disease specialists, laboratory directors, etc.) who were fundamental in handling the Coronavirus emergency, both for clinical and organisational responses. The RCT guaranteed a uniform response across the region, while allowing flexibility for individual businesses to apply policies based on their particular contexts.

In the Lombardy region, the governance of the crisis had three distinct levels of RCT which involved an extremely high number of professionals, encompassing regional, HCOs and Administrative Authorities positions. In general, a strong centralisation of decision-making and of pandemic management (e.g. patients transfers between Intensive Care Units, the regional discharge management team) was observed.

In the Tuscany region, the RCT was presided over by the President of the Region, with a lot of involvement from CEOs. The RCT centralised decisions regarding the emergency by creating directives focused on the many crisis management areas, clearly outlining how they were to be implemented. HCOs were, however, able to develop bottom up projects which were taken as a reference model at regional level.

The Lazio region was also characterised by deeply centralised decision-making at regional RCT level, intervening promptly in the definition of the role of public and private LHAs in the network managing the emergency, albeit working closely with the various CEOs.

On the contrary, in the Emilia-Romagna region the role of the RCT was prevalently that of co-ordination and direction, guaranteeing the possibility of implementing responses at local level in a flexible manner, coherent with the characteristics and the organisational capabilities of the context. The RCT coordinator had a wealth of experience in healthcare management, having been the regional health minister and CEO of several healthcare organisations. The RCT favoured sharing emergent best practices which could be spread across the whole region.

### 3.2 Regional Strategies in Facing the Crisis

Regional strategies during the first wave of the pandemic were concentrated on the areas of acute care services and hospital networks, health prevention services and primary care practices, laboratory services and networks.

### *3.2.1 Acute Care Services and Hospital Networks*

Regions paid the most attention to the management of the public and accredited private hospital networks. Hospital plans were defined, identifying:

- hospital hubs to manage time-dependent pathologies and urgent interventions;
- the number of intensive care and acute care beds to dedicate to Covid patients in the various hub and spoke hospitals;
- Covid hospitals and Covid-free hospitals (actually, only very few hospitals were Covid-free due to the evolution of the epidemic and its increasing impact on the beds necessary for treating Covid patients);
- Covid focused hospitals (e.g. a public Intensive Care focused hospital at the Milan Exhibition Centre and a private accredited focused hospital in Rome, following an agreement between "Gemelli" hospital and the RCT of the Lazio region).

### *3.2.2 Prevention Management*

Only the Veneto region instantly recognised the key role of prevention strategies to identify the main breeding grounds of the epidemic in the region immediately. In the first wave of the pandemic, the massive screening plan implemented by HCOs was one of the most efficient for containing the spread of Coronavirus because of its speed and coverage.

Regional focus on screening and prevention strategies in the Emilia-Romagna region came later, despite the region having a deeply-rooted prevention and public health culture. Consequently, HCOs developed bottom up strategies for epidemic tracing and testing management even during the first phase of the emergency.

For the other regional health systems, there was a delay in attention paid to these policies. Specifically:

- in the Piedmont region, a unique regional platform was established to monitor swabs and results from the end of March as first step for implementing prevention policies;
- in the Lombardy region the first screening campaign guidelines including the involvement of general practitioners, were only introduced at the beginning of May, when the evolution of the epidemic showed a decrease in positive cases of Covid-19;
- in the Tuscany region the first guidelines regarding prevention coincided with the reduction in the use of intensive care beds, however, some screening plans had been initiated by individual HCOs.

#### *3.2.3 Community Services and Primary Care Practices*

The regions' set-up Community Integrated Care Teams - CICT (called USCA - Unitá Speciali di Continuitá Assistenziale), active seven days a week from 8am to 8pm, in accordance with the national regulations. CICT are tasked with managing patients who do not require hospital treatment to be treated at home through telephone and/or video consultations and home visits. The Lombardy, Veneto and Lazio regions also activated a telemedicine support system to monitor Covid patients at home.

#### *3.2.4 Laboratory Networks*

Initially, the majority of regions opted for concentrating swab tests in a restricted number of specialised laboratories which were reference hubs. Later, other laboratories were accredited and added to the network given the exponential spread of the virus and the impossibility of returning test results promptly to avoid overcrowding in emergency departments and to identify the best patient flows for patients (those to be hospitalised and those to be sent home).

Only the Veneto region established a network of target-selective swab testing centres across the territory from mid-March (e.g. positive contact tracing, categories of essential service workers), co-ordinated by the Academic Medical Hospital of Padua. This promptness, combined with massive production capacity, allowed for rapid screening and meant that patients could be cared for quickly.

### 3.3 Digital Innovation and Telemedicine

Telemedicine was one of the most relevant basics for clinical check-ups during the Covid-19 pandemic (as regional directives had halted in-person service, with the exception of urgencies). Concentrating on tele-consults, the various regions show differing directions.

The Veneto region was one of the first to standardise the tariffs for telemedicine outpatient visits, thus guaranteeing the LHAs the certainty of reporting and obtaining fees commensurate to in-person visits.

The Emilia-Romagna region too guaranteed funding for telemedicine visits, based on the reporting of the LHAs, albeit with a reduction in comparison to the usual tariff for in-person visits.

Tele-consults in the Tuscany region were additional to, rather than substituting traditional, in-person consultations so as to guarantee an uninterrupted service to patients who were already undergoing treatment. In this case, the tariffs were the same as those of an outpatient visit.

The Lombardy region defined neither operational guidelines nor tariffs for telemedicine services. In June, HCOs were asked to define protocols for each specific specialisation as a pre-requisite for approving tele-consultations. These requirements, although imposed with the intention of ensuring better service security and delivery, actually slowed their adoption and pushed back pending cases. During the first phase, the Piedmont and Lazio regions did not formalise directives.

## 4 Discussion and Conclusion

The analysis of the evidence relative to the examined RHSs indicates the prevalence of two models in pandemic crisis management:

- The centralised model in the experience of Piedmont, Lombardy, Veneto, Tuscany and Lazio, albeit with differences in the RCTs' choice of governance and in the methods of intervention.
- The decentralised model in the case of Emilia-Romagna which left the implementation of operating methods to the individual HCO crisis units.

As far as the regional policy range is concerned, the RCTs' decisions were prevalently concentrated on hospital assistance, generally dedicating less space to policies relative to the areas of prevention and of public health.

During the peak phase of the epidemic, the main range of the regions' co-ordination in the area of hospitals was that of intensive care beds; in some cases, using a central prescriptive method, in others, through co-ordinated management.

Historically, public health policies at national and regional level have only marginally involved the development of prevention departments in HCOs[5] opting for other intervention areas (primarily hospitals), with the partial exception of the Veneto and Emilia-Romagna regions. This has meant that over time there has been a decrease in the number of staff dedicated to prevention. The crisis has intensified this criticality, highlighting a notable shortage of staff in these functions, jeopardising the likelihood of reaching adequate levels of efficiency.

Regions have shown weakness in directing HSOs towards adopting telemedicine: the technical aspects of acquiring and managing platforms, the issues relative to privacy and to sharing health data between organisations compromised the speed at which telemedicine was adopted. Embraced earlier, it may have had a positive impact on waiting times for healthcare services and on pending healthcare visits.

In the first wave of the epidemic, a wider centralisation of strategies regarding response to the emergency at a regional level, aimed at guaranteeing co-ordination and knowledge sharing between the various healthcare organizations, had different outcomes in the various regions. In some cases, the weakness of, or the extreme focus on regional policy was compensated for by bottom up initiatives from individual HCOs. Future developments in research must investigate how, on the basis of the problems encountered in the first wave, regional governance and pandemic response strategies evolved during successive waves.

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# FENStatS COVID-19 Working Group: Goals, Initiatives and Perspectives

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The FENStatS Covid19 WR is a free spontaneous association of statistical experts from 14 European countries, united by concerns related to the current pan-infodemic and statistical challenges revealed by the Covid-19 havoc. The present short paper tracks when, how and why the WG has formed, illustrates our mission, aims and scope, describes the steps taken so far and outlines perspectives for future work.

## 1 Introduction

The Italian Statistical Society (SIS) is a member of the Federation of European National Statistical Societies (FENStatS) since its foundation in 2011. Under the umbrella of the FENStatS, the Covid-19 working group (Covid19 WG) was born and I have been appointed to while serving my 4-years mandate in the board of the SIS. The FENStatS Covid19 WR is a free spontaneous association of around 30 statistical experts (at the moment of the writing of this short paper) from scientific statistical associations and institutions, from 14 European countries (Figure 1).

## 2 When, How and Why

At the onset of the pandemic emergency, late winter 2020, several Covid-19 related initiatives were launched within the statistical European community, both with scientific and disseminating purposes. The SIS, for instance, promptly responded with its own dedicated webpage, where a large amount of material was gathered during the long Italian lockdown. In the same period, SIS was also coordinating an intense community discussion through its email-Forum and online meetings. Differently, the FENStatS Covid19 WG has formally formed later, in June 2020. That was the time when, in Europe, we started figuring a possible 'back to normality'. Yet, we were already becoming more and more aware that exactly that sort of 'normality' was, in fact, under discussion.

We have heard it over and over, indeed: this is not only a crisis, it is an opportunity. We have all wondered whether we will be able to subdue the crisis

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**Figure 1:** 14 EU countries represented in the FENStatS Covid19 Working Group.

and make us better citizens of a better world. Surely it has been a planetary storm of numbers, models, epi-curves and predictions. A pan-info-demic. And it has shown us with unprecedented clarity how important high-quality data and statistics are for the preparation, implementation, assessment and adaptation of difficult political decisions. Particularly for the statistical community at large, it has been a true call for action, to do our part and contribute as statisticians. Looking at how data and quantitative information were collected, communicated and spread for use as decision-drivers, discomfort has been growing parallel to the worry about the threat to our health and daily life as we knew it. We, at the FENStatS Covid19 WG, are united by the concern to counter the current lack of statistical competence in society as revealed by this coronavirus havoc.

The FENStatS Covid19 WG pursues the mission to raise public awareness of the current and potential need for standardized, reliable statistics to support news media and the planning, implementation and evaluation of political decisions, during the Covid-19 global calamity and beyond. The WG sees itself as a supplement and support for activities at the national level and among its members. The WG does not conduct independent research. Rather, it is committed to connect initiatives and expertise, to provide information for general use, to prioritize the international comparability of statistics, to promote standards guidelines and data sharing. These are the crucial goals we are most concerned with. We are interested to work on topics that relate to all aspects of the pandemic. In a first phase the focus has necessary been on the health angle. Successively we shall focus on social, educational, economic and ecological consequences of the pandemic global experience. In a forward looking perspective and inspired by the United Nation 2030 agenda of Sustainable Developing Goals (SDGs) the FENStatS Covid19 WG will aim at building statistical capacity while leaving no one behind.

## 3 Steps along the Path

In a first step, the WG has engaged in collecting material about basic data and indicators - e.g. mortality, health, diseases, health care, tests, etc. - to create an overview of how data is currently recorded in different countries, how data is evaluated and indicators are released. This activity has supplied an abundance of information, both within and beyond the European countries represented in the WG. As a result, starting on fall 2020 and based on such information, the implementation of the FENStatS Covid19 WG own Wikipedia project has initiated. It will be soon accessible at.[1]

During the summer 2020, the WG has been actively involved in supporting a Swiss project for a data literacy campaign.[2] The project was actually rooted in an initiative dating back more than three years ago, and yet made compelling by the current crisis. As a matter of fact, the Covid-19 has exposed how all sections of the population, as well as many disciplines, are lagging behind in our individual and collective data literacy. Particularly in the age of digitization, data literacy and statistical reasoning appear as key competences, that are indispensable if we as citizens are to be able to play an informed and responsible role in all areas of life, along the path toward an accomplished democracy. The joint draft of the 'Appeal for an urgent national data literacy campaign' has been released late July 2020 and it is accessible at.[3] It invites all interested organisations and associations, but especially the general public, to support this appeal. Each signature or support will help to anchor and implement the vital topic of promoting social data literacy in the political agenda in a lasting manner. Data literacy, and the apparent lack of, is a main concern for the FENStatS Covid19 WG, not limited to this particular initiative and certainly in need of further attention and action, as it will be discussed more in the concluding part of this short paper.

It makes conceivable part of the mission of the FENStatS Covid19 WG to respond and contribute to public requests related to its own priorities. As a third step, in late August 2020, the WG committed to two open requests for expert consultation. One of those was launched by the US National Academies of Sciences, Engineering, and Medicine as a 'rapid expert consultation' seeking inputs and advice to compose a guidelines book for decision makers to understand the extent and spread of Covid-19 based on an improved use of data.[4] Building upon the fact that decision making related to the pandemic often requires the use of

| | Representativeness | Bias | Uncertainty, Measurement & Sampling Error | Time | Space |
|---|---|---|---|---|---|
| **Number of confirmed cases** | ⚠ | ⚠ | ☑ | ⚠ | ⚠ |
| **Hospitalizations** | ⚠ | ⚠ | ☑ | ⚠ | ⚠ |
| **Emergency department visits** | ⚠ | ⚠ | ☑ | ⚠ | ⚠ |
| **Reported deaths** | ⚠ | ⚠ | ⚠ | ⚠ | ⚠ |
| **Fraction of viral tests that are positive** | ⚠ | ⚠ | ⚠ | ⚠ | ⚠ |
| **Excess deaths** | ☑ | ⚠ | ☑ | ☑ | ☑ |
| **Prevalence surveys (representative)** | ☑ | ☑ | ☑ | ⚠ | ☑ |

☑ Data source usually meets this criterion.

⚠ Data source may or may not meet the criterion, and questions related to that criterion should be asked.

**Figure 2:** 7 Covid-19 types of data (rows) and 5 assessment criteria (columns).[4]

data not designed for the specific task at hand, e.g. collected in an emergency, the guide aims at enabling leaders to gain insight into the strengths and weaknesses of available Covid-19 data, to understand the data type best-suited to the question at hand and to inform decisions most effectively. The guide focuses on 7 types of data, available both in US and EU, to support decision making and on 5 criteria against which the reliability and validity of these data types can be assessed. Key implications for decisors are discussed and ready-to-implement tools, such as for instance Figure 2, are provided.

Among the conclusions of the guide, it is remarked how continued investment in public health and its data surveillance structures is needed to meet the nation's current and future public health challenges.

The second open public consultation to which the FENStatS Covid19 WG contributed late summer 2020, was launched by the United Nation Statistical Division to make a commitment to support and implement the 'Global community's response to Covid-19'. The initiative has then been announced during the closing session of the 2020 virtual UN World Data Forum,[5] on the occasion of the third World Statistics Day the 20th of October. A draft version of the consultation is accessible at.[6]

In the last few months the focus of the FENStatS Covid19 WG appears to have shifted toward more practical interests and outputs. A shared desire has emerged within the WG to work on a project to be implemented and actually applied in the near future for the benefit of the general public. The challenge constituted by the lack of social data literacy has arose, during meetings and discussions, as the most urgent. At this end, the FENStatS Covid19 WG and the pre-existent FENStatS Statistical Literacy Group are joining efforts to develop a framework for data literacy campaigns to promote and disseminate across EU. The starting point from which to build upon, will be the Data Literacy Charta, which has been just launched in Germany[7] and is already receiving an unexpectedly wide media response. More specifically, two groups are currently working jointly on the idea of creating a web-based course on the topic of 'Data-informed decision making in a pandemic'. The digital course is to be hosted on a professional educational platform and the necessary contacts and actions are being taken.

I would like to conclude by reminding that, as mentioned in the introduction, the FENStatS Covid19 WG is a free spontaneous group of statisticians. Anyone with an interest to engage and contribute to the mission, aims and scope of the group as illustrated in this short paper, is much welcome to join. All it is needed is to email me or directly the WG's coordinator katharina.schueller@stat-up.com.

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# The Severity of Covid-19 in Italy Seen from Its Epicenter

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The onset, the spread, and the outcome of COVID-19 at the beginning of 2020 in Italy has been characterized by multiple socio-territorial factors that can help to read the pandemic evolution from different points of views. This paper has a special focus on statistical significative aspects emerged in a multidisciplinary research of the University of Bergamo that has the aims to identify some factors of contemporary urban and mobile living, which favored the spread and propagation of COVID-19 in Italy. We describe the methods used and the results obtained to describe the severity of the impact of COVID-19 epidemic in the first months of its spread in Italy, and in particular in its epicenter, the Bergamo province. We aim also, on the one hand, to integrate and validate different information from various sources of territorial data, and, on the other hand, to provide a measure of the severity of the impact of COVID-19 epidemic on the territories of the area of Bergamo, Italy.

## 1 Introduction

The onset, the spread, and the outcome of COVID-19 at the beginning of 2020 in Italy has been characterized by multiple socio-territorial factors that can help to read the pandemic evolution from different points of views. This paper has a special focus on statistical significative aspects emerged in a multidisciplinary research of the University of Bergamo that has the aims to identify some factors of contemporary urban and mobile living, which favored the spread and propagation of COVID-19 in Italy. The project engaged geographers, urbanists, cartographers, jurists as well as statisticians, to outline the different roles of the disciplines involved and to highlight different point of view starting from the idea that pandemic is not only a biomedical problem, but also a socio-territorial problem. In this direction, the social, economic, geographical, and political aspects are considered and compared with the population of the territories, the spread of the contagion and the severity of the pandemic. The contribution as statisticians to the project was related, on one hand, to integrate and validate different information from various sources of territorial data, on the other hand, to provide a measure of the severity of the impact of COVID-19 epidemic on our

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territories. The number of deaths classified by age group were estimated for each Italian region keeping as a constraint the data provided by the Italian Higher Health Institute (ISS). In[1] the results are highlighted by a reflexive cartography that shows the relationships between the intensity of the contagion and socio-territorial aspects as well as it can identify the correlations between intensity, severity, and outcome of the COVID-19 on the Italian population. In the next sections, we describe the methods used and the results obtained to describe the severity of the impact of COVID-19 epidemic in the first months of its spread in Italy, and in particular in its epicenter, Bergamo province.

Starting from the first case recorded, information on the spread of COVID-19 in Italy is communicated daily by the institutions. The number of deaths related to COVID-19 is provided by the ISS but only at the regional level and by age at national level. At present, information on the age of deceased persons at regional level has not yet been given. Also, during the most critical phase of contagion, several people died without a swab test that would have established whether they had contracted the virus.

For these reasons, we decided to analyze deaths rates using ISTAT (Italian Office of Statistics) mortality tables. From these data emerges that mortality rates in March in Lombardy arose from 9 (mean of the previous 5 years) to 25 for 10,000 inhabitants in 2020. The same rate for the Bergamo province arose from 8 to 55 in the same period. Induced from these astonished numbers we decide to go further in the investigation and to provide a method to estimate the number of deaths from causes attributable to COVID-19.

## 2 Methods

The ISS data included subjects who tested positive to a swab by region and by age group at national level. However, it did not provide information relating to deaths by age group in each region. The number of deaths from all causes attributable to COVID-19 is estimated by comparing the number of deaths recorded in March 2020 with the number of deaths recorded in the same month over the previous five years, from 2015 to 2019, and keeping as a constraint the data provided by the ISS. This number is defined: "number of deaths due to COVID+" where + stands for deaths due to COVID-19, but also for the other three causes related to the presence of the virus on the Italian territory, as described in.[2] We denote this number with $C_{re}^{+}$, where $r$ stands for the geographic area and $e$ denotes the age group. Let $D_{re}$ denote denote the number of deaths in area $r$ and in the age group $e$ and $G_{re}$ the number of deaths due to other causes not attributable to COVID-19 in area $r$ and in the age group $e$, which is estimated by the mean of deaths in the previous years in the area $r$ and for the age class $e$. We have the following equality: $D_{re} = G_{re} + C_{re}^{+}$. Moreover, $C_{r.}^{ISS}$ and $C_{.e}^{ISS}$, respectively the total deaths for COVID-19 in the area $r$ and in the age class $e$, are known and provided by ISS but, unfortunately, they underestimate the deaths for COVID-19 in some areas and for some age classes.

Starting from the marginal, the deaths due to COVID+ for each age $e$, $C^{+}_{\cdot e}$ is defined as:

$$C^{+}_{\cdot e} = \begin{cases} D_{\cdot e} - G_{\cdot e}, & \text{if } D_{\cdot e} - G_{\cdot e} > C^{ISS}_{\cdot e} \\ C^{ISS}_{\cdot e}, & \text{otherwise.} \end{cases}$$

where $D_{\cdot e} = \sum_{r=1}^{R} D_{re}$ and $G_{\cdot e} = \sum_{r=1}^{R} G_{re}$.

Moreover, the total deaths for COVID+ for each area $r$, $C^{+}_{r\cdot}$, is defined as:

$$C^{+}_{r\cdot} = \begin{cases} D_{r\cdot} - G_{r\cdot}, & \text{if } D_{r\cdot} - G_{r\cdot} > C^{ISS}_{r\cdot} \\ C^{ISS}_{r\cdot}, & \text{otherwise.} \end{cases}$$

where $D_{r\cdot} = \sum_{e=1}^{E} D_{re}$ and $G_{r\cdot} = \sum_{e=1}^{E} G_{re}$.

Once the marginals have been estimated it is possible, at a first stage, to estimate $C^{+}_{re}$ , such as:

$$C^{+}_{re} = \begin{cases} D_{re} - G_{re}, & \text{if } D_{re} - G_{re} > 0 \\ 0, & \text{otherwise.} \end{cases}$$

$C^{+}_{re}$ must be adjusted according to the estimated marginal. If, for an age class $e$, $\sum_{r=1}^{R} C^{+}_{re} < C^{+}_{\cdot e}$ or, for a geographical area $r$, $\sum_{e=1}^{E} C^{+}_{re} < C^{+}_{r\cdot}$, then the deaths due to COVID-19 are underestimated. Therefore, the estimate for that age class and for that area must be updated using the method proposed in [2]. Our method is an alternative to the one proposed in.[3]

## 3 Results

Detailed results are available in[4] e.[5] According to ISTAT mortality tables,[2] in March 2020, in Italy, 85,786 people died against an average of 58,265 over the previous five years. The region where the death toll was the highest is Lombardy, indeed one third of the people who died in Italy in March 2020 were in Lombardy. After obtaining the estimates for COVID+, the death rate for COVID+ is calculated in each region. Analysing the ratio of the estimated mortality rate for COVID+ and the death rate due only to COVID-19, according to data released by the ISS, emerges that this value is always higher than 1, except for few regions, and in Lombardy this value is almost double, which indicates that for every COVID-19 death certified by a swab test there is another death attributable to COVID-19 for direct or indirect reasons. In[4] reflexive cartography model - which presents localized and cross-referenced data - allows us to interpret mortality in its impact on population and on its regional distribution in a detailed and, at the same time, comparable vision. This recovers the social impact of epidemic mortality and promotes a search for the possible causes of these differences in other socio-territorial data such as type of settlement, mobility, pollution or other. The analysis of reflective mapping outlines a partition of Italy into three geographical areas, in accordance with different mortality rates and COVID-19 contagion severity. Results confirm that the COVID-19 epidemic had a major impact on Italy, and an even more significant impact on Lombardy, both in terms of absolute number of deaths and mortality rate. In this early stage of the epidemic, the spread of COVID-19 had a different impact on different age groups. To analyse this disparity, we estimated the mortality rate for each age group in each region as the institutions in Italy do not provide information on the age of deceased at regional level. COVID-19 impact on people under the age of 60 is virtually negligible compared to impact in older age groups. It may be observed that the oldest class (aged 90 or over) is the most affected. In fact, each region for this class presents the highest mortality rate. An analysis on the impact by age in each region, indicates once again that Lombardy is the region most severely affected by the disease. Lombardy shows, indeed, the highest number of deaths and the highest mortality rate in each age group. It should be emphasized that in the case of people over 70 years of age, COVID-19 is responsible for approximately one in three deaths. Focusing on the Lombardy region, the results show that in some provinces mortality impact was much higher than suggested in official reports. A comprehensive mapping of research estimates confirms that the Bergamo province experienced the highest mortality rates in March, even if the Cremona province had the highest death toll in April. Analysing the ratio of death rates for COVID+ and COVID-19 in March and April, in each Lombard province this value is much above 1, with a maximum of 2.07 in Bergamo, meaning that for every 100 official deaths from COVID-19 there are an estimated 207 deaths from COVID+. Analysing the maps in [3] concerning the data on the mortality for each province and the estimates for COVID+, it is possible to partition the Lombardy in three areas. The provinces of Bergamo, Brescia, and Milan make up a first sub-region, in which COVID-19 impact was more severe and mortality rates were high both in absolute terms and by population. These are the three Lombard provinces characterized by dense urbanization and intense productivity. Then there are the provinces of Pavia, Lodi, Cremona, and Mantua, where the impact of COVID-19 was lower than in the first group while still higher than in the rest of Italy. This is an area of Lombardy with a strong agriculture-driven productive network, made up of smaller urban areas. Finally, the other provinces of Lombardy are the ones less affected by the first COVID-19 outbreak. Contagion impact for these provinces is like the rest of Italy. Regarding age groups in Lombard provinces, COVID-19 affected age groups differently and the mortality was seen to be highest among the oldest age groups with a significant impact on mortality in the provinces of Bergamo, Cremona, and Lodi, but also in the provinces of Pavia and Brescia. Impact was more attenuated, but still comparatively high, in the other provinces. As expected, throughout all the provinces, oldest age groups recorded the highest mortality rates, which confirms that the disease strongly affects the elderly. In addition, excess mortality recorded in the oldest age groups is almost exclusively to be ascribed to COVID-19 or related causes, since differences between provinces in mortality rate from other causes are negligible.

## 4 Conclusions

The impact of the COVID-19 disease in March, in Italy was severe, but Lombardy was the region that, in addition to the highest absolute numbers of deaths, revealed the highest rates of variation and the greatest mortality rate. Our estimates confirm that COVID-19 impact in Italy was significant. A meta-analysis of mortality data in the region of Lombardy suggests that, for the purposes of data interpretation, the region may be divided into three macro-areas. The first macro-area is made up of the provinces of Bergamo, Milan, and Brescia, where both the absolute numbers of deaths and mortality rates were very high, between three and four times those of previous years. The second macro-area consists of their south neighbouring provinces: Pavia, Lodi, Cremona, and Mantua. Here the impact of mortality was greater than in other regions of Italy, but lower than the first three provinces. The third group comprises the other provinces, where the incidence of mortality was lower and generally comparable to the Italian average.

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# Crisis and Resilience in the Post Pandemic Between Trust and Commons in the Emergent European "Green New Deal"

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In the last years a long strain of crises has triggered a continue search for a better management of common goods and public means. New emerging alliances between State, market and people could answer many of the question raised by these crises, included the Covid-19 pandemic. Stakeholderships and common goods should be considered for long-term growth with sustainability and responsibility together with European multilateralism, sustainability and resilience.

## 1 Introduction: a Long Chain of Multidimensional Crises and Commons as an Answer

Crises are expression of the fragility of societies and communities or entire states, but today we should say - in the face of the outcome of the Covid-19 pandemic - of the entire global *polis* organization, pushing us to improve in development cooperation, medical sciences, tangible and intangible infrastructures, regulatory institutions. However, crises are also evidence of societies' resilience and require radical changes due to a widespread global discontent in the face of radical shocks, such as the healthcare crisis in 2020-21.[1,2] Also because the incremental adaptations activated by markets are no longer sufficient when crises take on systemic value over time and space in a risk-increasing society.[3,6] An example of this type of crises was the one that took place from the fall of the Berlin wall to the defeat of communist systems by launching a global capitalism, seemingly without competitors and limits: this crisis later on triggered the first internet crisis of 2001, the invasion of Afghanistan and Iraq and the tragic political-terrorist trail of 9/11. This was be followed by the 2008 subprime economic crisis that "accompanied" a chain of interconnected short- and medium-long-term crises in a political-economic-technological-climate-health cycle from which we have never emerged (Table 1).

This has been a long and constant process, albeit at irregular intervals, that has injected both growing distrust into democratic systems and distrust for globalisation that was supposed to better redistribute planetary resources and

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**Table 1:** Crises triggered by the fall of the Berlin wall and communist systems in the last 30 years.

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| - Terrorist crisis (1995) |
| - Crisis of confidence in technology (2001) |
| - Eurozone debt crisis (2006) |
| - Refugee crisis, (2010) |
| - Climate change crisis (2011) |
| - Political and institutional crisis in democracy (2016) |
| - Covid-19 health crisis |

reinvigorated confidence in democratic systems with the benefits of "a growth for all" policy, resulting from open and transparent societies, while it has widened inequalities and increased environmental pressures. This has not been the case and much could have been better foreseen if the dynamics among the different "factors and actors" would not have been kept well separated, the politician from the terrorist and energy sources, the economic from technology, the climate from health. Three interconnected and welded links from the 2020 Covid-19 global health crisis that have weakened the U.S. imperial role and strengthened China to which the West has dumped much of the environmental pressure on manufacturing over the past 50 years. In particular, China is now exploiting the low wage regimes but also fewer environmental constraints. This trajectory has succeeded in reducing some absolute poverty - especially in eastern and coastal China - but it has been widening the relative poverty at the expense of the planetary middle classes, especially in the West.

All these factors lead to searching for a more balanced development horizon beyond emergencies and in the effort to rebuild a post-covid-19 trajectory, by investing in the resilience capabilities of our societies by recomposing financial, health, environmental and social objectives also with a "relational", over dispensing and authoritative state.

## 2 Response to World Pandemic as a New Emergent Alliance between State, Markets and People

A "more balanced development horizon" means - in our view - relying, as in wartime, much more on centralizing decisions on the key issues of modern development, because markets (as a form of decision-making decentralization) are not able to inject self-regulation and balance with a medium-to-long-term look interweaving transparency, rigour governance and decision-making rules. Where the public will have to gain as a support to institutions, businesses and families both financially and from the bureaucratic side to restore that trust in democratic institutions and markets that has been lost in the last 30 years.

Demonstrating that they know how to spend the necessary resources that will come from Europe by facilitating the healthiest and most active actors towards that line of transformation along the joint digital and environmental transition by investing appropriately on material and intangible infrastructure (from education to safety to health). A critical phase of exit from the crisis that will also require the transitional strengthening of the state's presence through appropriate investments in equity to foster the great convergence between strategic activities considered essential for the future and that go hand in hand with those activated throughout Europe. Continental system investments (from universities, aeronautics, medicine, telecommunications, shipbuilding, etc.) to broaden the scope of these sectors on a European scale. An opportunity to balance and regulate the overcapacity in some of these sectors from a single market perspective.

Four interconnected pillars of a resilient and more equal society can be as follows:

- (i) the development of an infrastructure network for health protection looking at the resurgence of future health crises or the emergence of new ones;
- (ii) the distribution of incentives for an accelerated conversion of the economic sectors to a *green new deal*;
- (iii) widespread investments in education and research to overcome educational and class inequalities for a more open access to knowledge towards a society of equals, to be stronger and faster in adapting to external shocks, to increase the widespread embezzlement of innovations and to restore a resumption of competitiveness in the country, especially in cognitive productivity that allows wages to rise even for greater dynamic stability of the labour markets;
- (iv) reforming a slow and cumbersome public administration that knows how to operate by project and promotes merit, intelligent bureaucracy, aligned with the European trajectories.

Therefore, this is about a "relational state" resuming its regulations, stimulus and incentive centrality around an appropriate industrial policy strategy starting from support to citizenship and for those services that are part (in a bottom-up direction) of the common goods of an inclusive-democratic country such as: school, health, infrastructure, research, justice, with an overview of public participation between the listed companies and coordination that could foster an industrial strategy that produces a real system, also involving the unlisted companies.

These inclusive activities (health, school, research, infrastructure, justice) are the backbone of a country but also the "bottom-up" source of a larger protection in the face of shocks, dynamically protecting families and businesses from the whippings of current and emerging crises. As we will be more indebted from this pandemic crisis and we will be exposed for decades to the risk of financing, we will have to use it to become more efficient and flexible, even relying on refinancing rates below our potential growth rate. Building better trading capacity in Europe and making the best use of the tools it offers us, with long-term loans and secured by the EU umbrella as even in the Covid-19 crisis. Two of the key points are on the one hand our considered private savings as well as - on the other - the primary current account surplus that has been gradually improving since 1992 that do not make us "identify with cicadas" - as the Germans say - but "with ants". In fact, it is the German newspaper Spiegel itself that reminds Germans that for 30 years the Italian state has been spending less in favor of its citizens than it takes from them, if we exclude the *annus horribilis* of 2009, with public investments cut by 1/3 from 2010 to 2015 and a 40% drop.

We must therefore ensure that the enormous private savings are gradually geared towards productive investments even with less use of home ownership where possible and useful as fuelling a recovery in investment and growth that will then allow debt to be "normalised". This is why it is necessary to inject confidence, preventing the legacy of the pandemic crisis from being increased risk aversion as a preference for "inactive" savings due to uncertainty weighing on future returns, further slowing the recovery in productivity that has been declining for more than 25 years. We therefore need to start an industrial strategy that puts the transformation of the production system at the centre of the system by rebuilding the foundations and conditions for a new social and political development. With a "relational state" that cannot be reduced to acting as an "urban vigilante" by lighting yellow and red lights or what you can or cannot do, but also using green for what you can do actively by not just treating the damage that the epidemic and health crisis are creating accompanied by the financial crisis. Therefore, this is a state that stimulates markets, organizations and institutions to reform themselves by co-creating shared value and innovation for an emerging economic, social and environmental resilience by pairing green and digital transformation able to reduce inequality (material and immaterial). This could be achieved by;

- (i) using a "golden power", i.e. a special power to "defend" national state-controlled companies (and not only) from any external threat that might undermine their control;
- (ii) offering directional guidance and promotion of more coordinated investments and production chains defined as strategic (from manufacturing to services);
- (iii) outlining a body of medium to long-term planning tools, avoiding dispersion of actions and interventions at different local-regional levels, especially in the energy, infrastructure and training fields;

- (iv) introducing conditionality related to green and environmental and/or infrastructure innovation policies in a systemic key crossed with the two pillars/actions of circular/sustainable and digital economy.

A “selective" trajectory is able to lift a country like Italy in the post-Covid-19 era from its historical delays, i.e.:

- (i) north-south inequalities;
- (ii) digital divide;
- (iii) access to SME innovation;
- (iv) eco-systemic reinforcement of key supply chains along the physical geographic barriers (in Italy, the Adriatic Sea, the Tyrrhenian Sea, the Alps and the Apennine).

This action should work around the integration between technological and green innovation in close connection with Europe to produce, consume and plan differently with appropriate local “endogenous" industrial policies, well welded with macroeconomic policies by acting on “exogenous" factors.[4,5] For this reason it is obvious that we need in Italy a different mission of the public administration (local, regional and national) focused on greater skills and flexible enough to exercise the address capacity necessary to integrate and monitor the different intervention actions both on the side of regional agencies and on the technocracies side of strategic companies like Eni, Enel, Leonardo, Fincantieri and the state railways company Trenitalia (for a list of the main strategic companies in Italy controlled by the state see Table 2). This should be accomplished within an “alignment" exercised by the Italian main financial state company, Cassa Depositi e Prestiti (CDP), and with address and stimulus by triangulating publicly controlled companies, shares on the private capital of medium-sized enterprises and medium- to long-term financing instruments. We cannot forget that we remain a “mixed economy" that needs coordination that in itself the markets are not able to realize (for economic, social and moral limits,[6,7]) that it must be no longer the support of private initiative (as happened in the 1920s to overcome banking crises and the Great Depression). We need to act together to deal with global hyper-competition with financial and structural instruments to “overcome" those historical typological limits not adequate for an increasingly integrated and interdependent way for company sizes, technology, innovative vocation, low capitalization, family management. Therefore we need an active state prone to innovation[8] that acts in concert with private companies mobilising all its industrial, research and financial potential for eco-system actions. suitable to push the double transition in green and digital and to evolve our companies into networks of networks, along supply chains and platforms increasingly

**Table 2:** Italian major listed and unlisted state-controlled companies (2020 - percentage share in brackets). Source: Italian Secretariat of Economics and Develompent

| |
|---|
| - A. Listed companies |
| Banca Monte Paschi di Siena S.p.A.(68,25%) |
| Enav spa (53,28%) |
| Enel spa (23,59%) |
| Eni spa (4,34%) [with CDP having a share of 25,76%] |
| Leonardo spa (30,20%) |
| Poste italiane spa (29,26%) [with CDP having a share of 35%] |
| - B. Companies with listed financial instruments |
| Amco spa (100%) |
| INVITALIA (100%) |
| CDP(82,77%) |
| Ferrovie dello Stato spa (100%) |
| RAI (99,56%) |
| - C. Unlisted companies |
| Arexpo spa (39,28%) |
| Consap spa (100%) |
| Consip spa (100%) |
| Equitalia giustizia spa(100%) |
| Eur spa (90%) |
| Gse spa (100%) |
| Invimit Sgr spa (100%) |
| Ipzs spa (100%) |
| Istituto luce srl (100%) |
| Mefop spa (59.05%) |
| Ram spa (100%) |
| Sogei spa (100%) |
| Sogesid spa (100%) |
| Sogin spa (100%) |
| Sose spa (88.8%) |
| Sport e salute spa (100%) |
| STMicroelectronics holding N.V. (50%) |
| Studiare sviluppo srl (100%) |

integrated for a generative complex value, with asymmetric impact on distribution of richness and global growth.[9]

## 3 Stakeholderships and Common Goods for a Long Run Growth with Sustainability and Responsibility

For the reasons outlined above it will be necessary to reconsider the growth opportunities for stakeholdership and a common goods approach in emergent European corporations, oriented to mature CSR strategies, in particular after the Covid-19 crisis.

The implications of a concise analysis of the legal structure of the company on both the corporate law and corporate governance side are evident, and simultaneously a review is needed on the temporal indeterminacy of employment relationships and contracts on the one hand and, on the other, of the notion of responsibility that property right approaches are able to deal with strictly. The reasons are quite obvious, because the legal system of enterprise recognizes:

- (i) managers not as mere agents depending on the exclusive interests of shareholders having a broader responsibility towards workers and the working environment or the community as a whole;
- (ii) shareholders not as exclusive owners of the company, having a responsibility towards the company but, also, towards all internal/external stakeholders and towards the environment and the community of reference;
- (iii) the corporation, in its legal personality, not as directly dependent on the exclusive will of the representatives of the ownership, even in the pro-rata form of participation fee, for responsibility towards the environment and the work benefits of its contractors;
- (iv) the corporation, as an institution with "autonomy" with respect to responsibility to all stakeholders and to the environment in a direct way and, indirectly, towards the community.

So, the question is:[10] are we in presence of an ownerless company?

The answer is no. Simply because the assets of the corporation involved cannot be fully identified as exclusive assets of individual specific subjects, but only as common goods or commons: goods that can be treated by the legal system as not excludable in an absolute sense, but that we could also say unrivalled, as an expression of a high specificity, that is historical and cultural rather than economic and technological. Owners exist - as is well known - and act on the boards of listed companies to condition the formation of the values of the securities, as in the boards of the unlisted ones to choose managers, remuneration and investment trajectories.

In fact, it can well be said that the economic theory of common goods or commons is a theory capable of exploring the fundamental and basic conditions within which collective action can preserve, sustain, and maintain efficient valuable resources useful to society, reproducing those factors within which contextual conditions of value appropriation can be regenerated. A theory that can develop a coherent perimeter of emerging ecologies of values and finds its foundation in the preservation of natural and environmental resources and services to these municipalities in the form of common-pool resources as we find them represented and collectively organized:

- in irrigation;
- in fishing;

- in the condition of marine and aquatic life;
- in forest and wood products;
- in aquifer systems;
- in the basics of available raw materials such as in complex and articulated biodiversity systems at multiple cellular levels;
- in life contained and sustained in the air;
- or, in the systematic reduction of the territory with deforestation and land use useful to agriculture and the hydro-geological balance.

The aim is to configure an integrated system of common-pool resources, treated in a differentiated way and parcelled in often residual forms, that led to the well-known paradox due to "the tragedy of the commons". Systems that in recent decades have been subjected to systematic expropriation and/or pollution without any care or attention from politicians to actions for the care of these fundamental primary resources and without which no enhancement (or appropriation), neither public nor private, is possible. Nobel Prize winner Elinor Ostrom explores precisely this dimension of commons evolution, as an expression of shared collective action.

The success of resource use regimes depends on two key state elements. The first level of status refers to the known content of the property rights (PR), while the second level relates to the institutional conditions that are able to produce those property rights. A double level that permeates the effectiveness of property rights (PR). PR that act in contexts of common pool resource is contingent, contested, not self-enforcing according to Deakin's analytical scheme. Therefore, it is critical to consider a broad governance framework to assess how PR can be able to address the collective action issues associated with managing shared resources, in order to be stabilized and used effectively.

Then, the first level of analysis brings us back to the complexity of PR with common resource pools that are defined neither as "open access" nor as the absence of exclusive rights, but on the contrary are identified "by the presence of collectively held rights of access, withdrawal, management and exclusion, and sometimes (but with less salience) the presence of alienation". This is because the right to alienation is not the right to identify the responsibilities for adapting common PR systems in a specific area of application, so that many users of common-pool resources have actual PR without including the right of alienation, as well analyzed by Elinor Ostrom in his studies of the last 30 years.

The second level of analysis looks at the effectiveness of the common-pool resources regimen as being capable of profane standards and systems of regulation in a long-term process. The smooth functioning of the common-pool resources regimen was tested, precisely in this wide time frame, on the basis of specific conditions illustrated by Ostrom (Table 3). On the other hand, in several studies, the question of non-sustainability has been raised in the case of free riding issues

**Table 3:** Principles for commons-pool resources.

| |
|---|
| - Well-defined boundaries |
| - Proportionality between benefits and costs |
| - Collective choice arrangements |
| - Monitoring |
| - Graduated sanctions |
| - Conflict resolution mechanisms |
| - Minimal recognition of rights |
| - Nested enterprises |

in conflict with the management of common-pool resources. The proposed solutions are: (a) a state control over the use of common resources and, (b) the reinforcement of PR with powers arising from alienation rights in open market contexts. The “convergence" of these two solutions between public and private, according to some experts, would allow both an adequate return on private investment and reducing emerging negative externalities. Others say market pressure and government intervention “converge" viciously in raising threats to common property institutions.

Then, three major evaluation problems emerge for the discussion:

- (i) Is there compatibility between the proposed commons model and the modern business structure?
- (ii) Which structures and dynamics of the commons are suitable for empirical evaluation and testing in relation to forms of corporate governance?
- (iii) What are the regulatory implications of a corporation perspective such as commons?

The Covid-19 crisis has pushed forward these main problems for the future of new and emergent European corporations.

## 4 European Multilateralism, Sustainability and Resilience to Overcome the Global Crisis

A design to overcome triple global crisis (health-environment, economic and social) that requires an enormous capacity of institutional reform, by crossing financial instruments into an injection of confidence that through a national and European project leverages a participation of civil society, has happened in the post-war period. But it took place with different political and economic ruling class and with different institutional sensitivities in a situation where the European umbrella was missing, if we exclude the ECSC - European Coal and Steel Community of 18 April 1951 and in force since 1952 by Jean Monnet and Robert Schuman. In particular it happened in a society oriented to produce more risk and not less.[3, 11]

Without forgetting the past, therefore, today's global dimension, from the crisis of 2008 to that of Covid-19 of 2020, has taught us that we are "condemned" to be interdependent because environmental sustainability, migration and refugee flows and financial instability are part of a deep global imbalance and require global responses with more multilateral cooperation. This focus makes Europe even more fundamental than 10 years ago, even if many autocrats today think differently, from Trump's US to post-Brexit UK, from Erdogan's Turkey to Bolsonaro's Brazil, via Modi's India. Finance and Covid-19, as well as the environmental and climate change crisis, have tragically clearly shown us that we need a national but also a global policy coordination and that we cannot get out of these interdependent and interconnected crises alone. But for this we need to regain the trust of people all over the world deeply affected by the effects of an asymmetric and unjust globalization. Globalization was supposed to solve all our illnesses in one fell swoop, while it has increased them by growing inequalities, increasing relative poverty and emphasizing the threats of global warming for which the sovereigns-nationalists who have emerged in the last 20 years have failed to respond adequately, coming out weakened precisely by the global health crisis. The mediation power played by the US so far is coming down and China's global role is growing, while Europe must find its own space, hopefully as soon as possible, perhaps as a positive side effect of the Covid-19.

It is now necessary a vision of Europe as a global player in a strategy of possible and sustainable resilience in planetary balances that first can rethink the way we produce and consume, work and learn, connect and team up, becoming a community capable of reducing the now unsustainable pressure on the use of natural resources. That is why, despite Covid-19 and indeed even more precisely for this pandemic and its nature, the green transition remains the cornerstone of European policies of the next 30-50 years through the leverage of economic sustainability as much as products and services, as well as ways of producing and consuming.

The fight against climate change is in the hands of this generation of young people from all over the planet who better appreciate its wealth and knows how to adapt conditions to reverse the unsustainable trajectory of climate change triggered by global warming caused by a reckless use of the finite resources of the planet. Fighting climate change means also listening to the voice of science and pushing politicians to act now or it will be too late, starting with the Paris Agreement and the Sustainable Development Goals contained in the UN-2030 Agenda.

With Ursula von Der Leyen's European Green New Deal, we are deeply changing our approach to resource management from a global perspective towards a sustainable medium-long (m-l) term economic and productive model realizing circularity. It takes into account the interdependence between resource scarcity, climate change and biodiversity loss. We need the programming capacity of m-l term that the markets or the individual states are able to give themselves for the scale of the changes in progress. That is, this scale should no longer be regional, nor national, nor continental, as Covid-19 taught to all those who thought they could close themselves in isolationist and autarchic strategies. The 2030 environmental targets and the aim of climate neutrality by 2050 require alliances and collaborations in supranational organisms to take a m-l term development trajectory, having exhausted the positive momentum that had brought us out of the tragic 1900s. So we look at green policies as leverages of new employment creation and of a different quality of growth with development, by taking the path of circular and sustainable models in the responsibility of production models that demand increasing socialization of risks. We need an increasing involvement of science that calls for long and not short-term actions,[12, 13] such as the discovery of a drug or a vaccine against the pandemics of today and yesterday.

We have known for some time that pollution comes from industry, transport, agriculture and an excessive consumerist and waste-oriented model, because it is immersed in linear logics. Now we have to trigger circular logics that reduce waste and transform residues into energy and environmental opportunities, in the knowledge that the human well-being (without adjectives) is also a the planet well-being. But we should be aware that the well-being and prosperity we enjoy has been achieved through irresponsible use of natural resources, triggering the climate crisis and in 2020 the health crisis. For this reason, we will also have to reduce the environmental footprint, firstly, (i) by reducing Europe's dependence on resources extracted, used or processed in other parts of the world, resulting in external effects (to Europe) due to the way we produce and consume, and (ii) by reducing inequalities from developing countries with which we trade goods, services and human resources. Then, by supporting these countries with "equal exchanges" and transferring knowledge, investment and infrastructure (materials and intangibles) to them, and, in so doing, reducing the gaps (poverty, education, access to health care and infrastructure) by also reducing the exit of the best resources from these countries to other continents, involving them in green and circular growth. Thirdly, because green and circular growth is global or not global, because there can be no exchange between environmental protection and economic growth that has been the vicious refrain of these last 70 years.

New *circular economy and green new deals* must converge towards inclusive citizenships reducing the pressure on the irresponsible use of natural resources, but we need structural reforms (burocracy, justice, labour markets, property rights, ecc.). In this way we must put our hands on the overall product cycles, starting from a design that is sustainable from the first phase to the last one, and planning sustainable production and technological models. We need to work on the long life cycles of products and their reuse and regeneration so that they remain as long as possible in European territories without "unloading" inefficiencies and diseconomies outside. In fact, too little is the 12% of second raw materials that return to the economy. Too many products become obsolete quickly and many cannot be repaired or reused or recycled (PCs, smartphones, televisions, cars, but also houses or furniture products, etc.), or they can only be used once. While we must offer users the choice of whether to keep old products - repairing or regenerating them - before moving on to new ones, by opting for sustainability choices and thus offering them opportunities to re-emphasize a planned obsolescence of many products, as for most electronic devices.

This represents a trajectory that will result in less resource extraction and less emissions, hence less global warming with all the virtuous consequences that can result.

In conclusion, we are "condemned" to be interdependent - as in the battle against pandemic - because environmental sustainability, migration and refugee flows and financial instability are parts of a deep global imbalance, that require global responses.[14,15] This should be done against the emerging populism-nationalism, and reforms of large global institutions (UN, OMS, IMF, NATO, BEI and UE) with more multilateral cooperation, in order to reduce the risk of turning a trade war into a class war[16] or in the old conflict between the poor and the rich, but on a global scale.

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# The Effect of Case Detection on the Global Dynamics of Covid-19 Mortality: A Cross-Country Analysis

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This study analyzes the dynamics of Covid-19 lethality using a global sample of 137 countries for the period that ranges from January 2020 to December 2020. Using $\beta$-convergence and $\sigma$-convergence tests we find that there has been a convergence process in lethality rates and case detection rates across the globe. In a second step, we investigate if cross-country disparities growth rates of Covid-19 lethality can be explained by country differences in the rate of case detection and its evolution during the pandemic. Our results show the existence of a negative statistically significant relationship among these variables, such that the speed of approximation towards lower long-run equilibrium mortality rates appears to be driven by increasing case-detection rates.

## 1 Introduction

The Covid-19 pandemic has been the greatest global public health emergency since the influenza pandemic of 1918, and by February 2021 there have been 2.3 million deaths and 106 million infections worldwide. However, the effects of the pandemic have been highly asymmetric across countries and numerous studies have attempted to explain the determinants of lethality differentials by analyzing the role played by exogenous factors like climate and culture,[1] the national health-system characteristics and other social and demographic features.[2]

However, as seen in Figure (1), a remarkable feature of the cross-country distribution of Covid-19 mortality, measured by the Case Fatality Rate (CFR), is that after reaching its peak (which usually occurred 50 days after the first death record in each country) not only its average level but also its dispersion has decreased rapidly over time. In fact, by December 2020, the probability of any country experiencing CFRs in the upper extremes of the distribution decreased substantially and the estimation of the ergodic distribution reveals that the long run probability of the CFR being centered around the 1.4% threshold, in the future will be higher to that observed at the beginning of the epidemic outbreak.

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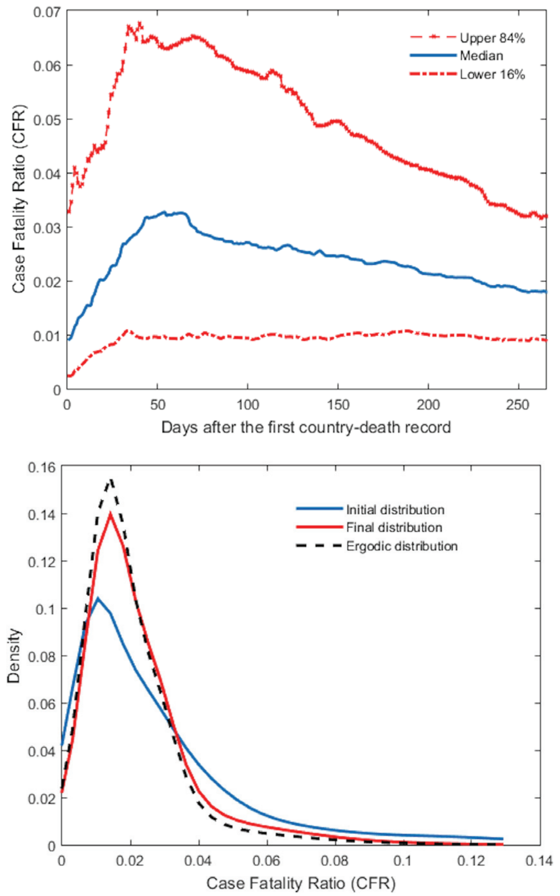



**Figure 1:** The dynamics of Covid-19 lethality.

These stylized facts suggest the existence of a fast convergence process in lethality rates.

Therefore, a satisfactory explanation of the evolution of global lethality dynamics cannot rely solely on socio-demographic factors or cultural traits, which are well known to be slowly varying over time. Against this background, in this study we show that the evolution of Covid-19's lethality is strongly influenced by the share of detected cases and its growth rate. The main argument for a link between case detection and convergence in lethality rates, is that countries that experienced initially high rates of lethality did so, precisely because they did not detect a large share of their cases, which artificially increased their mortality rates relative to the rest of the world.

In this regard, it should be noted that a problematic issue when analyzing early Covid-19 lethality is that CFRs may have provided an imperfect and unreliable measure of the true lethality. There are two reasons to explain this. First, epidemic surveillance initially focused on symptomatic patients whereas milder and asymptomatic cases were unlikely to be detected leading to an overestimation of the CFR. Second, during an ongoing epidemic some of the cases already detected at time $t$ die subsequently (i.e, at $t + h$), which bias downwards the estimate of $CFR_t$.[3]

Nevertheless, given that the under-ascertainment bias is likely to be the dominant because of the high share of asymptomatic carriers of the virus (the best available estimates from[4] and[5] range between the 33-40%), lethality overestimation should tend to vanish with higher detection rates. For this reason, a catch-up process in the detection of cases between countries that initially were not detecting with those that were detecting many of them, could help to explain both, (i) the decrease in the average lethality and (ii) the decrease in the dispersion of the CFR. The rest of this note is devoted to analyze this issue.

## 2 Data

Our research requires information about the CFR and the degree of case reporting in the various countries.

The CFR indicator used to capture the dynamics of Covid-19 lethality is calculated as $CFR_{it} = \frac{D_{it}}{C_{it}}$, where $C_{it}$ and and $D_{it}$ are the total cases and deaths of country $i$ at time $t$, respectively. Data on these metrics were collected from the European Center of Disease Control (ECDC) website for a global sample of 137 countries between January, 2020 to December 14, 2020[1].

On the other hand, to estimate the share of reported of cases we follow Nishura et al.[3] and Russel et al.[6] who show that by combining a *best estimate* of the infection to lethality ratio (bCFR) and a delay-adjusted case fatality distribution of cases with known outcomes (dCFR), it is possible to obtain daily estimates of the under-ascertainment of cases in the official statistics. Specifically, we calculate the share of detected cases with respect the true total epidemic size as:

$$R_t = \frac{bCFR}{dCFR_t} \tag{1}$$

where *(i)* $bCFR$ denotes the best available estimates of lethality taken from large randomized sero-prevalence studies in China, Spain and South Korea, which are in the 1% - 1.7% range (we assume a Gaussian process for the $bCFR \sim N(1.25, 0.3)$ after adjusting or controlling for under-reporting) and

[1]For more detailed information on the sample composition see the Appendix.

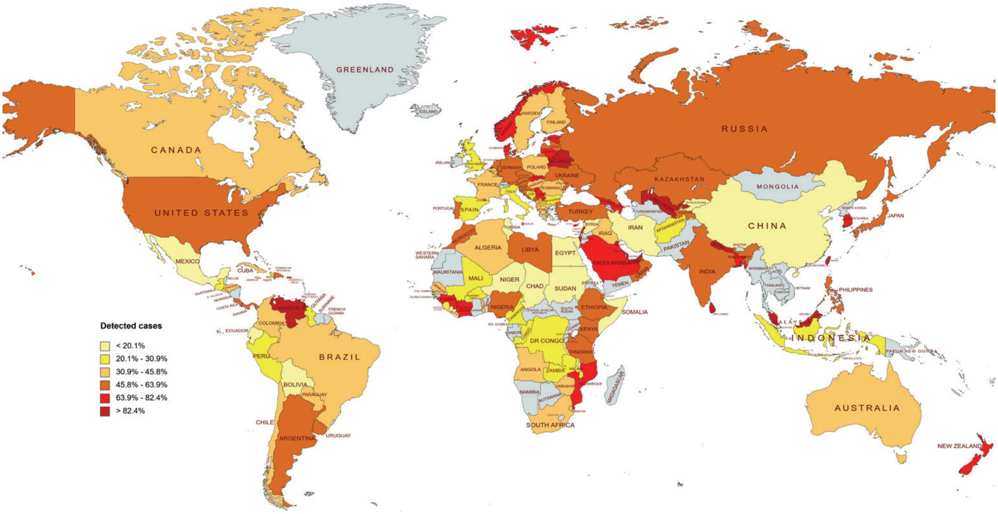



**Figure 2:** The geographical distribution of case detection.

*(ii)* $dCFR_{it} = \frac{\sum_{t=0}^{T} d_{it}}{dC_{it}}$ is the delay-adjusted case fatality ratio in $t$[2]. The delay-adjusted case fatality is given by the ratio of the number of daily deaths $d_{it}$ to $dC_{it}$, which is a correction of the cases accounting for the proportion of them with known outcomes:

$$dC_{it} = \sum_{t=0}^{T} \sum_{s<t} c_{i,t-s} g_s \tag{2}$$

where $g$ represents the probability density function between confirmation to death and $T$ is last date for which data are available[3].

# 3 Preliminary Evidence

Figure (2) below plots the estimated median geographical distribution of the cumulative case detection in percentage across the world by December 14[4]. As observed, there are important differences between the countries with minimum values such as Sudan (7.8%), Chad (8.7%) or Mexico (10%, with those of the

[2]For example, if a country has an adjusted CFR that is higher to the (e.g. 20%), it suggests that only a fraction of cases have been detected (in this case, 1.25/ 20 = 6.25% cases have been reported approximately.

[3]$g_s$ represents the probability that an eventually fatal case leads to death during the s-th day from the day of confirmation. We follow Russell et al.[6] by assuming a log-normal distribution with a mean delay of 13 days and standard deviation of 12.7 days.

[4]Obviously, there are countries where the uncertainty over the true detection rate is higher than others but for simplicity here we just focus on the median values across 1,000 simulations of the bCFR.

most advanced countries like Qatar (99%), Singapore (98.3%) or Israel (90.6%) who have managed to detect a large share of their infections. It is also worth mentioning than the group of medium to low level of detection we find a variety of European countries that were strongly hit by the pandemic like Spain (29.3%), Italy (25.5%) or UK (24.3%).

To complement this information, Figure (3) provides preliminary evidence on the link between the level (and growth rates) of the detection of cases and lethality. The two scatter plots suggest the existence of a negative relationship between mortality outcomes and country detection rates during the Covid-19 crisis. This means that on average, countries with higher levels of detection experienced lower CFRs and that countries that improved the most their detection of cases, were characterized by a lower mortality growth rates. Indeed, the pairwise correlation between the two variables is statistically significant ($\rho = -0.58$ and $-0.28$ with p-value = 0.00, respectively). Nevertheless, the information provided by Figure (3) should be treated with caution, as the observed connections may simply be a spurious correlation resulting from the omission of other variables. For this reason, we develop a more formal treatment in the next section.

# 4 Methods

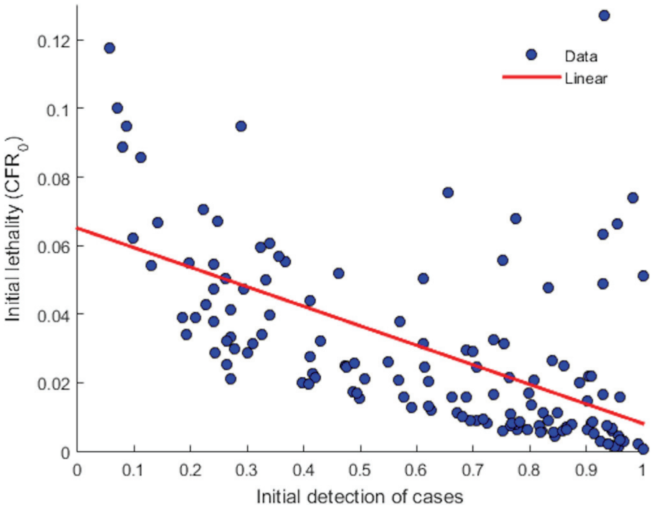
We now turn our attention to the convergence dynamics in the CFR and the detection of cases focusing on two different convergence tests.

The first one, is that of $\beta$-convergence, proposed by Barro and Sala-i-Martin.[7] The notion of $\beta$-convergence in the context of epidemic analysis, measures *the extent to which countries with higher fatality ratios (lower detection) catch up with countries with lower fatality ratios(higher detection) over time*. The hypothesis basically tests if: $Cov\left(y_{i0}, \frac{y_{iT}-y_{i0}}{T}\right) < 0$ ,where $\frac{y_{iT}-y_{i0}}{T}$ is the long run average growth rate of the corresponding variable and $y_{i0}$ is the initial sample value. The initial CFR $y_{i0}$, is calculated as the average CFR during the time interval $[t_{p-h}(i), t_{p+h}(i)]$ where $t_p(i)$ denotes the peak date of cases during the first wave of the outbreak for country $i$ and $h$ is a time window used to smooth the data. We proceed in this way to minimize administrative noise and fluctuations in the data and because of a large share of cases by the time of the peak had no closed outcomes. We set $h$ to 25 to absorb most of the probability of the delay distribution from detection to death during the first wave[5].

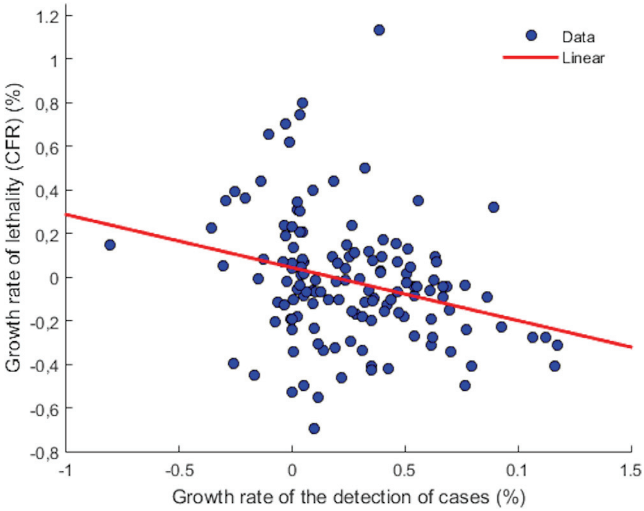
The regression model employed to test the $\beta$-convergence hypothesis is given by:

$$\frac{\Delta \ln y_{i,[0,T]}}{T} = \alpha + \beta_1 \ln y_{i,0} + \epsilon_i \tag{3}$$

[5]Note that the Log-normal (13,12.7) time-delay distribution taken from[6] implies that 95% of cases die after 33 days.




(a) Detection rate and lethality rates

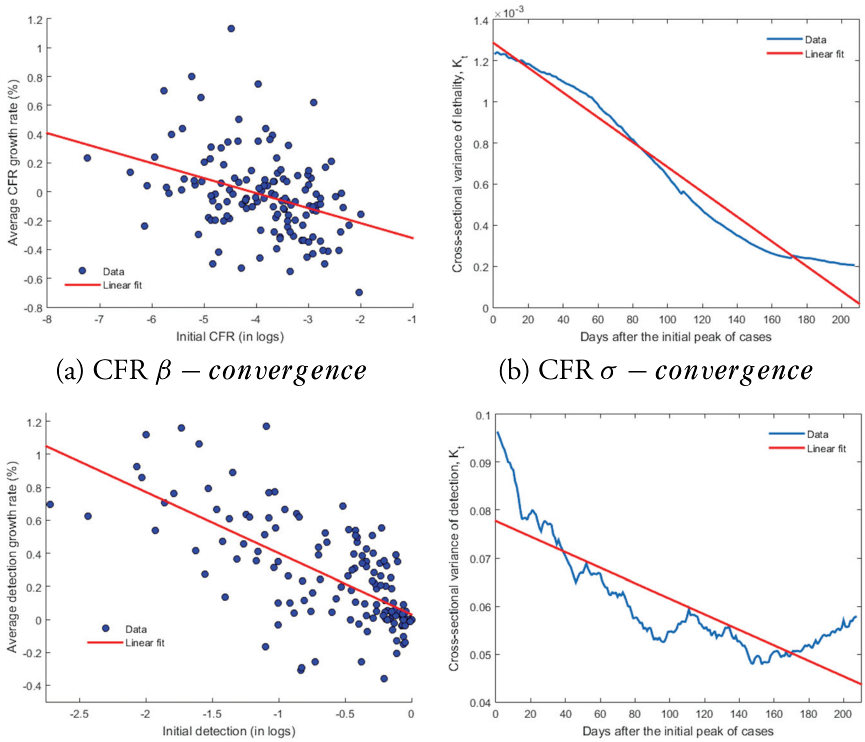



(b) Detection growth and lethality growth

**Figure 3:** The link between case detection and lethality.

In this context, $\phi = -\ln\left(1 + \hat{\beta}_1\right)$ is the speed of convergence towards the long run values of either the CFR or the detection rate.

Other authors like Kong et al.[8] and Sul[9] consider that *true convergence* implies that cross-sectional dispersion should be decreased over time. The process of consistent decrease of variance along the cross-sectional dimension over time, has received the name of (ii) $\sigma$*-convergence* in the specialized literature. Letting $K_t = \frac{1}{n}\sum_{i=1}^{n}(y_{it} - \bar{y}_t)^2$ denote the cross-sectional variance in a panel setting,




(a) CFR $\beta - convergence$ (b) CFR $\sigma - convergence$

(c) Detection $\beta - convergence$ (d) Detection $\sigma - convergence$

**Figure 4:** Convergence dynamics in lethality and reporting.

testing this hypothesis is equivalent to verify if $Cov\,(K_t, t) \leq 0$. As described in[8] and,[9] the weak $\sigma$-convergence test is given by the t-statistic of the OLS estimate $\hat{\rho}(L)$ based on the Newey-West HAC estimator with lags $L = int(T^{1/3})$, from the following simple trend regression:

$$K_t^y = \alpha + \rho t + u_t \tag{4}$$

Graphical evidence on how each variable fits these notions of convergence is provided in Figure (4). On the one hand, Figure (4.a) reports the relationship between the average growth rate of the CFR and the logarithm of the CFR at the beginning of the pandemic outbreak for each country whereas Figure (4.b) plots the evolution of the cross-sectional dispersion of the CFRs across countries over time, thereby capturing the notion of $\sigma$-convergence. Figure (4.c) and (4.d) provide the same information for the share of detected cases. Importantly, both the $\beta$-convergence and $\sigma$-convergence panels presented in Figure (4) point to the same stylized fact: (i) lethality and reporting disparities across countries have

**Table 1:** Convergence test results.

| | $\beta$-convergence | | | $\sigma$-convergence | | |
|---|---|---|---|---|---|---|
| | $\hat{\beta}$ | Implied $\phi$ | Half-life | $\hat{\rho}(L)$ Full sample | $\hat{\rho}(L)$ First half | $\hat{\rho}(L)$ Second half |
| CFR | 0.0011 | 0.11% | 666.30 days | -0.0000067*** | -0.0000087*** | -0.000005*** |
| | (-4.47) | | | (-17.83) | (-5.69) | (-16.57) |
| Detection | -0.0036*** | 0.36% | 191.79 days | -0.0002*** | -0.0002*** | -0.00005*** |
| | (-12.77) | | | ( -10.68) | ( -3.11) | ( -3.37) |

Notes: Entries in columns 1-2 of this table correspond to the key statistics of the $\beta$-convergence test. The dependent variable in the $\beta$-convergence regressions is in all cases the average growth rate of the CFR during in the period that goes from $t_p(i) + h + 1$ to December 14, 2020, where $t_p(i)$ stands for the peak of new cases during the first wave and $h = 25$. Estimates of $\phi = -log(1 + \hat{\beta}_1)$. Columns 4-6 are provide the trend parameter estimates $\hat{\rho}$ of the weak $\sigma$ convergence test for different windows of time after $t_p(i)$. The t-ratios, $t_\rho$(L) indicate whether or not $y_{it}$ is weakly $\sigma$-converging ($t_{\hat{\rho}} < -1.65$), fluctuating ($t_{\hat{\rho}} \rightarrow^d N(0, 1)$), or diverging ( $t_{\hat{\rho}} > 1.65$). * Significant at 10% level, ** significant at 5% level, *** significant at 1% level. *** denote significant at the 1%. t-statistics computed using the HAC estimator in brackets.

narrowed over time, which has been (ii) mainly driven by a catch-up process of countries that either had either very high CFRs or very low reporting-rates, respectively.

# 5 Results

The results of formal statistical tests regarding the existence of convergence are provided in Table (1). The results regarding the weak $\sigma$-convergence test and the $\beta$-convergence one show that the key parameters involved in each of them are statistically significant at the 1% level and display the expected signs. The estimate absolute daily speed of convergence in lethality is the 0.18% which implies a half-life of 666 days (i.e the time span which is necessary for current disparities to be halved) whereas the 0.36% implies a half-life of 191 days. Therefore, it is possible to conclude that although at different speeds, cross-country differentials in mortality and detection have been narrowing over time, irrespective of the notion of convergence under consideration.

However, to investigate if the observed convergence dynamics of lethality are a byproduct of the evolution and the cross-country differentials in the share of detected cases, we now extend the growth model used to investigate $\beta$-convergence as follows:

$$\frac{\Delta \ln y_{i,[0,T]}}{T} = \alpha + \beta_1 \ln y_{i,0} + \beta_2 \frac{1}{T} \ln R_i + \beta_3 \frac{\Delta \ln R_{i,[0,T]}}{T} + \mathbf{X}_i \gamma + \epsilon_i \quad (5)$$

where $\frac{\Delta \ln y_{i,[0,T]}}{T}$ denotes the average growth rate of the CFR of country $i$ during the period $[0, T]$, $\ln y_{i,0}$ is the logarithm of the initial CFR, $\ln \bar{R}_i$ is the log of average level of reporting, $\frac{\Delta \ln R_{i,[0,T]}}{T}$ is the average growth rate of the detection of

**Table 2:** Results

| Variables | (I) | (II) | (III) | (IV) | (V) |
|---|---|---|---|---|---|
| Constant | -0.005*** | -0.004*** | -0.005*** | -0.004** | -0.004* |
| | [-4.62] | [-3.73] | [-2.63] | [-2.25] | [-1.69] |
| Initial lethality (logs) | -0.001*** | -0.001*** | -0.002*** | -0.001*** | -0.001*** |
| | [-4.73] | [-5.10] | [-6.07] | [-5.39] | [-3.44] |
| Case detection rate (logs) | -0.002*** | -0.002*** | -0.002*** | -0.001*** | -0.002*** |
| | [-4.92] | [-3.13] | [-3.05] | [-3.94] | [-5.15] |
| Growth rate of detection | -0.144** | -0.133** | -0.134** | -0.126** | -0.507** |
| | [-2.27] | [-2.19] | [-2.16] | [-2.33] | [-2.62] |
| Population density | | -0.0007** | -0.0008*** | -0.0005** | -0.0004*** |
| | | [-2.55] | [-2.88] | [-2.03] | [-5.19] |
| Population > 65 years old (in %) | | -0.015*** | -0.023*** | -0.016** | -0.016** |
| | | [-4.84] | [-5.37] | [-2.49] | -[2.54] |
| Individualism | | 0.001 | 0.001 | 0.001 | 0.0001 |
| | | [0.94] | [0.68] | [0.68] | [0.33 ] |
| Liberal democracy index | | | 0.002*** | 0.003*** | 0.002** |
| | | | [2.67] | [3.01] | [2.41] |
| Epidemic policy stringency | | | -0.0001 | -0.0001 | -0.0001 |
| | | | [-0.53] | [-0.85] | [-0.65] |
| GDP per capita | | | | -0.00003** | -0.0001 |
| | | | | [-2.61] | [-0.92] |
| Hospital beds | | | | -0.00004 | -0.00004 |
| | | | | [-0.33] | [-0.03] |
| Initial lethality (logs) × | | | | | -0.104** |
| Growth rate of detection | | | | | [-2.05] |
| $R^2$ | 0.195 | 0.338 | 0.506 | 0.508 | 0.706 |
| N | 137 | 137 | 137 | 137 | 137 |

Notes: The dependent variable is in all cases the average growth rate of the CFR of each country $i$ during in the period that goes from $t_p(i) + h + 1$ to December 14, 2020, where $t_p(i)$ stands for the peak of new cases during the first wave and $h = 25$. *** denote significant at the 1%, ** significant at the 5% and * significant at the 10%. t-statistics computed using the HAC estimator in brackets.

cases and **X** is a matrix of control variables that may affect both the CFR and the level of reporting. In turn, $\epsilon_i$ is the disturbance term.

The choice of control variables in **X** is mainly guided by the need to account for factors which may affect both the CFR and reporting scores and, consequently, whose omission might bias the estimated effect of the level of reporting and its growth rate on registered mortality. To that end, we consider (i) the GDP per capita (at PPP), (ii) the population density, (iii) an index of liberal democracy, (iv) an index of individualism, (v) the number hospital beds per capita, (vi) a composite index reflecting the stringency of the epidemic policy and (vii) the share of population above 65 years old[6].

The results of running lethality growth regressions by progressively including our set of controls are shown in Table (2). As observed, the negative effect of

[6]For more information and descriptive statistics see Table A1 in the Appendix.

initial lethality shows the result of $\beta$-convergence is robust after controlling for other variables. After controlling for disparities in exogenous factors in $X$ we observe a slightly faster convergence speed than that of Table (1) (0.14% vs 0.11%). Overall, the results of the regressors are in line with previous evidence in the literature: income, age and density are negatively related to the growth rate of mortality whereas liberal democracies have performed poorly when compared to other alternative forms of political organization. On the other hand, the health-policy stringency index, the hospital beds per capita and the level of individualism are not statistically significant in this context.

Turning our attention to the main goal of this study, we find a robust negative significant effect of the level of detection and its growth rate on the growth rate of mortality. In fact, the two coefficients are statistically significant at the 5% level in all the model specifications. This suggests, that the negative effect of detection and the faster the improvement in the detection of cases are relevant factors to explain why some countries have experienced lower lethality growth rates. As a further check, in Column (5) of Table (2) we report the results of a model extended with an interaction term between the initial lethality and the growth rate of detection. This interaction term allows us to compute estimates of the speed of convergence (i.e, the speed at which lethality decreases) as a function of the growth rate of case detection. $\hat{\phi}\left(\frac{\Delta \ln R_{i,[0,T]}}{T}\right)$. As observed, the effect is negative and statistically significant at the 5% level, which implies that the convergence speed increases with the growth rate of detection as shown in Figure (5).

## 6 Conclusions

This study analyzes the role of case detection in the global dynamics of Covid-19 mortality.

To investigate this relationship, in a first step we estimate the share of detected cases for a global sample of 137 countries for the period that goes from January 2020 to December 2020. By applying $\sigma$-convergence and $\beta$-convergence tests on the evolution of infection detection and mortality rates, we find that there has been a marked reduction in disparities across countries over time in the two variables.

Secondly, we extend the baseline growth lethality regression of the $\beta$-convergence framework including the average level of case detection and its growth rate. We find that not only higher detection rates reduce lethality growth but also that countries that increased their levels of detection over time more rapidly, have also experienced faster reductions in mortality rates during 2020.

Furthermore, we observe a statistically significant conditional relationship between initial lethality, detection growth and lethality growth, which suggests

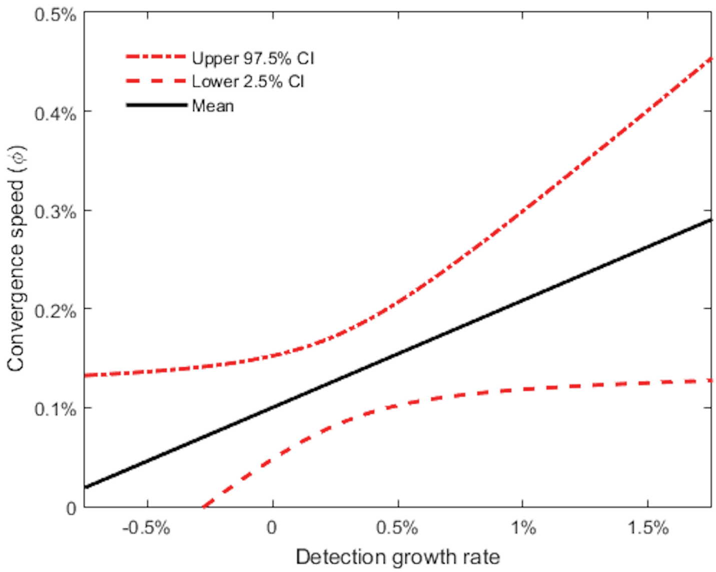



**Figure 5:** The link between case convergence speed and detection growth.

that the convergence dynamics of cross-country lethality disparities towards a lower long-run equilibrium mortality threshold are strongly influenced by those of the share of detected cases.

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# Could Emergency Calls and Twitter Activity Help to Prevent Health System Overloads Due to CoViD-19 Epidemic? Wavelets and Cross-Correlation as Useful Tools for Time-Frequency Signal Analysis: Lessons from the Italian Lombardy Region

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The history of the Italian CoViD-19 epidemic began on 2020, February the 20th, in Lombardy region, which quickly became the most stricken geographical area of the world. This first outbreak caught national health system unprepared, and hospitals experienced patients overload, facing an unknown infectious disease. Thus, it is of primary importance to provide public health services with tools which can help to potentially prevent health system stress periods. To this aim, we performed a time-frequency analysis of regional emergency calls, CoViD-19-related Twitter data and daily new cases through wavelets, and a comparison of the signals in the time domain using cross-correlation. Our findings show that emergency calls could be a good predictor of health service burdens, while Twitter activity is more related to personal and emotional involvement in the emergency and to socio-political dynamics. Social media should therefore be used to improve institutional communication in order to prevent "infodemia".

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# 1 Introduction

After the first Italian case of CoViD-19 was identified in Lombardy region, on 2020, February the 20th,[1] several countermeasures were put in place until the national lockdown.[2,3] The outbreak displayed a huge geographical heterogeneity,[4] and Lombardy was the worst hit region of the world.[5–7]

Many factors can explain this disaster and hospitals overloading. Among these, unpreparedness[8,9] and the consequences of the fragmentation of the National Health Service into different regional systems[10] had a prominent role. Indeed, both national and regional pandemic plans were obsolete,[11–13] and in Lombardy a local reformation dismantled public territorial medicine services in favor of a hospital-centered system and of private healthcare facilities.[9,14]

Moreover, the debate on CoViD-19 was not limited within the scientific community, having being conducted even on mass media and social networks. Thus, an "infodemia"[15] led to different psycho-emotional reactions in common people.

Therefore: (i) regional emergency numbers were overwhelmed by calls from people searching for information and reassurance and/or needing medical assistance;[16,17] (ii) the Emergency Departments became the first line against the virus, despite the opposite regional pandemic plan recommendation;[12] (iii) social media were "overcrowded" by messages from people sharing "thoughts" about the pandemic.[16]

Given these features, emergency calls could be a potential predictor of new health system overloads, and social networks might represent a tool to monitor feelings about CoViD-19 spread and management. Social media analysis has already been used in digital epidemiology,[18,19] and in the case of CoViD-19 it has been applied even for contact tracing and outbreak control.[20] Particularly, Twitter high-speed communication capability allows super-fast spread of information, and its "follow model" can be described as an interest graph, differently from Facebook.[21] Thus, as a very dynamic platform, Twitter is the ideal probe to study CoViD-19 social context.

The aim of this work is to investigate the anticipation capability of daily emergency calls and Twitter trends with respect to CoViD-19 spread dynamics. It is of crucial importance to provide health services with useful tools for surveillance, monitoring, control and prevention of new burdens.

# 2 Materials and Methods

Data analysis was conducted using MatLab R2020a.

## 2.1 Data

The following daily time series were considered:

- calls to unique emergency number 112 from February 18, 2020 to March 30, 2020;[22]
- calls to medical emergency number 118 from February 18, 2020 to March 30, 2020;[23]
- calls to regional CoViD-19 toll-free number from February 23, 2020 to March 30, 2020;[23]
- Twitter data (tweets, replies, likes, retweets) from February 18, 2020 to June 29, 2020;[24]
- CoViD-19 new cases from February 24, 2020 to June 29, 2020.[25]

All data were regionally aggregated, except Twitter ones which were not geolocalised. The first days of 112 and toll-free number series were discarded as outliers.

### 2.2 Twitter Data Analysis

We submitted a query to the Twitter Search Application Programming Interface in order to select all the tweets in the period of interest containing the term “112" or “118" or both (“search terms"), discarding retweets.[24] Then, the text of each tweet was lemmatised and tokenised through spaCy:[26] only nouns and verbs were considered. After that, we manually identified 283 common words related to the emergency (“keywords"). The co-presence of one (or both) of the search terms with one (or more) of the keywords led us to the selection of 16,216 tweets. In this way, we discarded the tweets in which the search terms were used with a meaning not related to the pandemic.

### 2.3 Wavelet Analysis

For non-stationary signals, wavelets represent the most suitable tool to perform a time-frequency analysis. In fact wavelet transform displays a variable time-frequency resolution and is able to highlight the changes over time (i.e. the non-stationarity) of the frequencies contributions.[27–35]

Wavelets can detect in the time-frequency (scale) plane both long-period backgrounds (trends) and short-period discontinuities (anomalies). So, anomalies represent high-frequency hidden signals and - despite their limited temporal location - possess a huge amount of information content.[36,37]

Wavelet analysis is therefore useful to “capture" stress moments in health systems during emergencies, as in the case of CoViD-19 pandemic. Namely, in the early epidemic outbreak, peaks in the emergency calls should possibly anticipate those for new infections and hospitalizations.

All the time series were first pre-processed to identify trends. Since all the signals displayed a typical weekly “seasonality", a moving average linear filter of a 7-days amplitude was applied to smooth them. The resulting data sequences were decomposed through the continuous wavelet transform (CWT) and then normalised to their maximum values. Tweets-dependent data (replies, likes, retweets) were also normalised to the corresponding number of tweets.

To measure the similarity between signals, we computed the wavelet cross-spectrum (WCS) and the magnitude-squared wavelet coherence (MSWC) in the time-frequency plane, resulting in a value of coherence for each point, i.e. for each pair of time-frequency coordinates. To discard edge-effects, coherence values outside the boundaries of the cone of influence were not considered. Moreover, since we were interested in quantifying the time delay between signals, we used a complex analytic Morlet (Gabor) wavelet through which the phase lag was computed. Finally, we converted phase data into time information.

### 2.4 Cross-Correlation Analysis

While coherence measures signals similarity in the frequency domain, cross-correlation is its counterpart in the time domain. The lag corresponding to the maximum value of the cross-correlation sequence represents a synthetic estimate of the time delay between two discrete sequences. Consequently, to quantify the time anticipation of the leading signal with respect to the lagged one, we also computed the cross-correlation function.

A 90% confidence interval was calculated for the lag corresponding to the cross-correlation function peak, through: (i) a z-Fisher statistics on the original data;[38] (ii) a random phase test for 1,000 simulations.[39]

## 3 Results

### 3.1 Twitter Trends

Figure 1 shows Twitter raw data. The first increase, shared by all the time series, occurs from 2020/02/21 to 2020/02/25 (days -3 to 1), and can be ascribed to the detection of the CoViD-19 first case and the subsequent establishment of the 'red area' in the involved municipalities. A second sharp peak in common is clearly visible on 2020/03/14 (day 19) and is due to the death of a healthcare worker in Bergamo, the most stricken province. Therefore, Twitter activity seems mostly triggered by political decisions and chronicle news, and only partly by the epidemic dynamics.

### 3.2 Time Course Analysis

Table 1 shows the signals time-to-peak differences. All the emergency calls series share a relevant time anticipation (almost two weeks) and thus can be further considered as potential predictors. Regarding to Twitter data, instead, only tweets display a 7-days anticipation, while the remaining tweets-dependent series lose this capability, and replies are even lagged with respect to new cases.

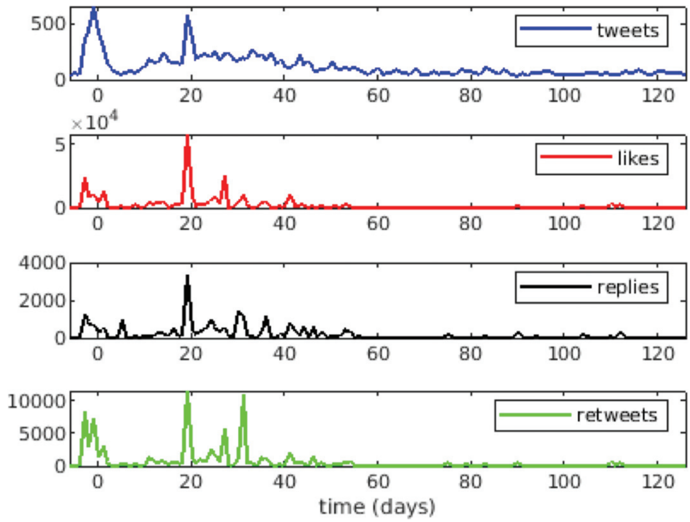


**Figure 1:** Twitter trends. Conventionally, “day 0" corresponds to the date of February 24, 2020, when the Italian Department for Civil Defense released the first official epidemic report.

### 3.3 Wavelet Analysis

The WCS and the MSWC were calculated for each time series in relation to new cases data. The focus will be for coherence values higher than 0.5. Besides, we will consider only high frequency discontinuities (the most informative variations from the trend). Finally, we will take into account only the ascending phase due to its importance from a public health viewpoint: consequently, we will exclude the replies whose peak is delayed compared to that one of the new cases.

Calls to toll-free number, likes and retweets do not reveal any strong coherence with respect to the infected signal. Thus, we will consider only calls to 112, calls to 118 and tweets data, and the remaining time series will not be further discussed.

**Table 1:** Time-to-peak analysis. Differences are smoothed and normalised values.

| $x$ | $TTP_x$ (days) | $TTP_i$ (days) | $\Delta TTP$ (days) |
|---|---|---|---|
| Calls to 112 | 16 | | -13 |
| Calls to 118 | 15 | | -14 |
| Calls to 800.89.45.45 | 15 | | -14 |
| Tweets | 22 | 29 | -7 |
| Likes | 28 | | -1 |
| Replies | 33 | | +4 |
| Retweets | 28 | | -1 |

Notes: 800.89.45.45 is the regional CoViD-19 toll-free number. x = potential predictor; $TTP_x$ = time-to-peak of the potential predictor; $TTP_i$ = time-to-peak of the infected time series; $\Delta TTP = TTP_x - TTP_i$ = time-to-peak difference.

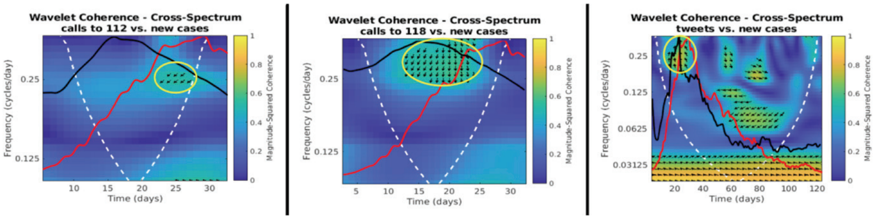


**Figure 2:** Wavelet analysis. WCS/MSWC representations are superimposed to the corresponding time plots (smoothed and normalised data): on the left, calls to 112 vs. new cases; in the middle, calls to 118 vs. new cases; on the right, tweets vs. new cases. The infected time course is depicted in red, the potential predictor in black. The yellow circles highlight the discontinuities between the peaks.

In Figure 2 the time plots of the smoothed and normalised series are superimposed to the WCS/MSWC charts. The cone of influence is shown as a white dashed line. For areas where the coherence exceeds 0.5, the charts display arrows representing the phase lag between signals. The direction of the arrows designates the relative phase on the unit circle (rightward meaning in-phase, leftward indicating anti-phase). The corresponding lag in time depends on the duration of the cycle (period).

In all the cases the anomalies are time-confined between the peaks of the curves, and a frequency component of about 0.25 cycles/day (i.e. a period duration of 4 days) is shared. These high-coherence discontinuities display different phase lags, and thus time delays, for the three pairs of signals:

- 2.5-2.6 days for calls to 112 (Fig 2, left panel);
- 2.4 days for calls to 118 (Fig 2, middle panel);
- 0.5-1.4 days for tweets (Fig 2, right panel).

### 3.4 Cross-Correlation Analysis

In Table 2 for each pair of signals the time delay with the corresponding 90% confidence interval is reported. The computation was done in two ways, to compare parametric and non-parametric estimates. Negative values denote by how many days the time series of infected patients should be shifted backward along time axis to be 'aligned' with the potential predictor.

## 4 Discussion

Indicators that can anticipate a rise of cases are of paramount importance to plan interventions of the health service organization. Our study shows that the number of calls to emergency services could be a good indicator that can precede

**Table 2:** Cross-correlation analysis. For each pair of signals the time delay with the corresponding 90% confidence bounds is indicated. The confidence interval has been constructed via both the Fisher's z-transformation (left column) and a random phase test (right column).

| | Time lag of the cross-correlation function peak (days) 90% confidence intervals | |
|---|---|---|
| **Time series** | **Fisher's $z$ transformation** | **Monte Carlo simulation** |
| Calls to 112 | -3 [-8, 1] | -4 [-11, 1] |
| Calls to 118 | -5 [-11, 1] | -6 [-13, 1] |
| Tweets | -6 [-8, -2] | -3 [-11, 4] |

the need for hospitalization in the early pandemic outbreak. The current results are not necessarily expected to be found for subsequent burdens.

Our step-by-step analysis made us discard four time series as potential predictors. In the end, only calls to 112, calls to 118 and tweets were analysed in the time domain.

To the best of our knowledge, this is the first time that wavelet analysis and cross-correlation are used to detect health system stressful periods during the CoViD-19 pandemic. However, a first limitation of our study is the short period of availability of emergency calls data. In fact, due to mathematical reasons, this deficiency “shaped": (i) the time-frequency resolution of wavelet analysis; (ii) the location of the cross-correlation function peak. A future perspective would be to obtain a more complete dataset. Moreover, even if aggregated regional data probably possess a greater anticipation capability, taking into account the geographical heterogeneity of CoViD-19 spread, there is a limited usefulness for public health monitoring. One more direction would be to analyse these data at a more local level. Other indicators are under investigation, keeping in mind also that the impact on the health system is more related to the patients' characteristics rather than to the number of new cases.

Finally, our analysis shows that Twitter trends correlate more with social factors rather than with the number of cases. This finding suggests that social media analysis could improve and address public health strategies and institutional communication to the population.

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# Public Management after Managerialism? Lessons from Covid-19

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This work aims to highlight the importance of the co-creation of public value and how the lack of integrated territorial networks of care have impacted in the management of the COVID-19 emergency. It shows how decisions made in response to wicked problems must consider different policy areas (clinical, social, economic) that are highly correlated and differently experienced by different publics. From our analysis it has emerged that in a first phase of the emergency the focus was on the creation of new organizational models such as the creation of integrated territorial networks of care and assistance, the continuous monitoring of the territory and the strengthening of the hospital system. However, these interventions are effective only if citizens are fully involved and engaged in the fight against the epidemic. Thus, community co-creation is important to manage COVID-19 and to assure the provision of public services while improving community resilience.

## 1 Introduction

European healthcare systems have been called upon to respond to the pressures of a drastic and unexpected increase in demand for care and assistance to high numbers of patients affected by the coronavirus. At the same time, they are struggling to maintain the provision of adequate (timely and sufficient) levels of non-COVID healthcare services.

The waves of the epidemic have clearly shown the lack of integrated territorial networks of care and assistance. For example, during the first wave, the application of instruments for prevention, the tactics adopted for containment, and the management of hospitalizations in most European countries were the result of decisions taken by individual health organizations rather than by interdependent and cooperative place-based health systems as a whole.

This is the result of a series of reforms which have been focused into the restructuring of internal processes for delivering healthcare services (such as for example lean management and operations management, see[1]), especially for

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those services related to emergency and acute settings. This approach is coherent with the efficiency-focused managerial reforms[2] developed in the past decade to tackle the severe reduction in the health budget to rein in public spending after the financial crisis[3]). Less attention has been paid to the exploitation of the networks between public and private healthcare providers and the collaboration with other stakeholders involved (communities, group of citizens, patients, etc.).

## 2 COVID-19 as a Wicked Problem

The challenges of COVID-19 clearly fall under those requiring management approaches and tools suitable for wicked issues.[4]

Wicked problems are known as such because they do not have a definitive solution within the traditional toolbox. Moreover, the components of a wicked problem are interrelated and interdependent in systems where actions to deal with some elements may have other counter-related effects on other components of the same system: for example, enforcing a lockdown is good for public health but uncomfortable for the economy.

European governments recognized COVID 19 as a wicked problem too late. In order to guarantee the best response to the epidemic and, in the near future, the sustainability of the decisions made today, it is necessary to understand that the different policy areas (clinical, social, economic) are highly correlated and differently experienced by different publics.[5–7] For example, the response to the pandemic through the creation of integrated territorial networks of care and assistance, the continuous monitoring of the territory and strengthening of the hospital system are only a partial solution to the wicked problem of Covid-19. These interventions are most effective only if citizens are fully engaged and committed in the fight against the epidemic. As Cepiku et al. have shown,[8] community co-production is important to manage COVID-19 and to deliver public services while enhancing community resilience.

## 3 Public Management for a Post-Managerial Era?

COVID-19 made us aware that public values are at the heart of our social, economic and political systems. All organisations are indeed part of society, and as such they play a crucial role in shaping it, for good or bad.[9] In this respect, COVID-19 has re-affirmed the centrality of the importance of public management. However, while management is needed to plan and control for the best use of the resources available, managerialism as an ideology and rhetoric[10] has had side effects - for example, when emphasizing a competitive focus among single organizations. From the point of view of the individual organization, the focus on performance often drives decision-makers and managers to search for organizational rather than a public value optimum, which can lead to the creation of a culture of standardization of activities and the search for ultra-specialization.[11]

In other words, organizations have closed in on themselves in the relentless search for the best operational and financial performance on which they are evaluated, thinking less about the public value and community outcomes from a systemic and place-based perspective.[7] For example, a recent literature review on the performance evaluation of lean management in healthcare shows a lack of interest in the external effects of such a practice.[12]

This brings us to open a reflection on the role of public management and managerialism. Hood[13] has discussed managerialism, linking it with its values, which might be different even within managerialism. For example, in Hood's terminology, sigma-type values which call for frugality and a focus on outputs are different from lambda-type values which call for resilience and a focus on inputs and processes. To make a practical example, in normal times having extra beds in an intensive care unit might not be good from a frugal point of view, but it is good from a resilience point view if a pandemic occurs.

Now that public services are getting a new centrality in the public debate, we believe it is important to discuss which public management we do want for a post-Covid-19 era. It seems to us that we have at least three main options: to keep going as it is now like if nothing was happened; to reconcile public values and managerialism for an era of new managerialism; to open up a public management for a post-managerial era, where public purpose and democratic logics are prioritized over managerial logics. Distinguishing between public management and managerialism is important. For example, Pollitt[14] (p.44) wrote that while "public management is important...the ideology of managerialism is founded on an exaggeration". How will public management look like in a post-COVID-19 and (post-)managerial world?

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# Reassessment of New Normal Along with Its Typical Measures Against Covid-19 via an Optimal Decision Framework

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Challenges set by COVID-19 in terms of deadliness, propagation speed, and gained immunity remain unprecedented. As the vaccine production races against virus mutations, international communities are settling toward the new normal guided by local government and health authorities. This study asks how well such transition has been applied in Germany by assessing the functionality of typical measures against the disease. We propose a mathematical model to govern mechanistic processes behind the epidemics. The analysis focuses on to what extent face mask, its efficacy, and community awareness in the likelihood of enhancing physical distancing may significantly suppress the incidence in the long run. Focusing on reemerging peaks of outbreaks during winter season, our sensitivity analysis and optimal decision framework recommend that guaranteeing the locals to uphold physical distancing during the festive season (beginning of November to the end of December) is urgent and effective in reducing the inflow of new cases.

## 1 Introduction

Promoting health guidelines for combating COVID-19 is a key measure irrespective of educational, social, and economic background of a community. This is useful in two ways as to get rid of misinformation about the disease and to apprise locals of preventive actions such as washing hands, wearing face masks, keeping physical distance, timely reporting and performing RT-PCR tests, compliance to therapeutics etc.[1–3] All these measures should essentially be met amidst the presence of vaccines whose efficacy is still variable over time due

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to advancing virus mutation.[4,5] Three main debilitating variants are identified: B.1.1.7 (UK), B.1.351 (South Africa) and P.1 (USA, Brazil).[6] Germany has also experienced the variant B.1.1.7 according to the Robert Koch Institute.[7] Higher transmission facilitates more variants leaving the vaccine efficacy in danger. Even though some vaccines show promising excesses, for example BNT162b2 (Pfizer/BioNTech) of 95% and mRNA-1273 (Moderna/NIAID) of 94.1% efficacy, achieving ultra-cold storage temperature is problematic.[8] The efficacy of AZD1222 (AstraZeneca/University of Oxford) is reported as 70.4% and Gam-COVID-Vac as 91.6%.[9] These are well above the expectation of WHO, where they prefer 70% efficacy, but with 50% minimum.[10,11] However, efficacy is solely evaluated via clinical trials and hence effectiveness in the community level may differ from the efficacy. Vaccination programs have to be suspended if mutations do not respond to vaccines as experienced in South Africa.[12] On the other hand, until effective vaccination programs are established globally, relaxing mask wearing, physical distancing and hygiene practices may worsen the pandemic situation.[13,14] Willingness to get the vaccine also varies according to socio-economic background.[15] As our main interest, in Germany, a total of roughly 3.5 million primary vaccinations have been administered by February 22, 2021. Starting on December 27, 2020, the average frequency accounted for approximately 58 thousand primary vaccinations per day, with a peak value of 95 thousand per day.[16] Given that a herd immunity is *expected* at a vaccination level of 60–70% of the population, even at the current peak frequency, it would take roughly 500–600 days to achieve, which refer to summer 2022. Hence, the need for a mid- to long-term plan is inevitable.

Our present study subsumes the use of two radical measures, namely face mask and media report, in the context of optimal decision framework applied to an epidemic model. SARS-CoV-2 is usually transmitted through respiratory droplets around 5 $\mu$m size, known as aerosols.[17] The commonly used cloth mask is usually of one layer (either of flannel, silk, or chiffon), which for aerosols of size 5 $\mu$m, gives efficacy 40% (flannel), 50% (silk), and 70% (chiffon), respectively.[18] At the start of the COVID-19 pandemic, mixed perceptions were evident on wearing face masks. Notwithstanding political and social opinions, now people are aware of the importance of face masks as a self precaution. However, the public level compliance is diverse as some people wear masks just to avoid legal actions rather than following a preventive measure. On top of this, media reporting is also positive endeavor that not only helps encourage mask usage but also makes the state of the art physical distancing and its legal enforcement come to light as the surrounding cases increase. In Germany, physical distancing is usually practiced as staying away about 2 meters against each other.[19] Travel ban, lockdown, and curfew can be considered as extended actions of physical distancing.

## 2 An Epidemic Model for Covid-19 in Germany

We divide the human population $N$ into six subpopulations based on their health status: susceptible $S$ (healthy but vulnerable to infection), detected $I$ (confirmed active cases, may include asymptomatic and symptomatic type), undetected $U$ (unknown incidence level, *dark figure*, mostly asymptomatic), recovered $R$, and deceased $D$. The appearance of pre-symptomatic cases is not considered herein. Imports, migrations, net growth (births and natural deaths) are assumed to have inessential contribution to the rise of the population during the short observation period considered, rendering a constant total population $N = S + I + U + R + D$. The first appearance of the model takes the standard SIR-type including deceased subpopulation

$$S' = \mu(S + I + U + R) - \beta\frac{S(I + \varrho U)}{N} + \nu R - \mu S, \tag{1a}$$

$$I' = \alpha\beta\frac{S(I + \varrho U)}{N} - (\gamma + \mu)I, \tag{1b}$$

$$U' = (1 - \alpha)\beta\frac{S(I + \varrho U)}{N} - (\gamma + \mu)U, \tag{1c}$$

$$R' = \gamma(1 - m)I + \gamma U - (\nu + \mu)R, \tag{1d}$$

$$D' = \gamma m I. \tag{1e}$$

In the preceding model, $\beta$ denotes the infection rate, $1/\gamma$ the average infection duration, $1/\nu$ the duration of temporary immunity, and $m$ the fatality rate from the detected cases. We impose a strong assumption that the new infected cases are timely distributed into the detected and undetected cases with the proportions $\alpha$ and $1 - \alpha$, respectively. On an effort to accommodate different transmission scales from detected and undetected cases, we use the parameter $\varrho \gg 1$. Moreover, dark figure has largely been unknown, encouraging ideas for proper estimates. Ours is based on the simple consideration that the dark figure proportionates the detected cases to a certain constant, i.e., $U = pI$ for some $p$. This imposition apparently engenders equivalence of equations (1b) and (1c) under the condition $\alpha = 1/(1 + p)$.

Our model may restrain from legitimate specification due to largely non-observable variables, for example the susceptible $S$ and recovered subpopulation $R$. To ameliorate this dilemma, we cut down the complexity by assuming proportionality of $R$ to $D$ up to a certain constant or $R \simeq [\bar{\nu}/(\mu + \nu - \bar{\nu})] \cdot D$ for some $\bar{\nu} < \nu$. It thus is expected that $(\mu + \nu)R = \bar{\nu}(R + D) = \bar{\nu}[N - S -$

$(1 + p)I]$. Avoiding hulking notations, we trace back the original ones through $\beta(1 + \varrho p) \mapsto \beta$ and $\tilde{\nu} \mapsto \nu$ such that the model simplifies to

$$S' = \mu(1 + p)I - \beta \frac{SI}{N} + \nu[N - S - (1 + p)I],$$
$$I' = \frac{\beta}{1 + p} \frac{SI}{N} - (\gamma + \mu)I.$$

**2.1 Integrating the Use of Face Masks**

We are considering the application of cloth masks of average efficacy $u$. Let $v \in [0, 1]$ be the effective proportion of $S-$ and $I-$individuals who wear masks especially during contact. Infection cases happen accordingly due to contact between: (a) unmasked $S-$ and unmasked $I-$individuals $(1 - v)S \cdot (1 - v)A$, (b) unmasked $S-$ and masked $I-$individuals with a lack of efficacy $(1 - v)S \cdot (1 - u)vI$, (c) masked $S-$ and unmasked $I-$individuals $(1 - u)vS \cdot (1 - v)I$, and (d) masked $S-$ and masked $I-$individuals $(1 - u)vS \cdot (1 - u)vI$. The proportion terms in the preceding specification sum up to $(1 - v)^2 + 2(1 - u)v(1 - v) + (1 - u)^2v^2 = (1 - uv)^2$. This transforms the model into

$$S' = \mu(1 + p)I - \beta(1 - uv)^2 \frac{SI}{N} + \nu[N - S - (1 + p)I],$$
$$I' = \frac{\beta}{1 + p}(1 - uv)^2 \frac{SI}{N} - (\gamma + \mu)I.$$

Observe that the most ideal situation is prescribed by all $S-$ and $I-$individuals wearing masks during contact ($v = 1$) with a high quality and efficacy 100% ($u = 1$) such that no infection is prevailing.

In what follows, the model will be normalized under the new notations $s := S/N$, $i := I/N$ in order to avoid clash of dimensions as community awareness comes into play.

**2.2 Media-Induced Community Awareness**

The preceding model neglects the fact that media reports also help shape individual conduct and mindset during epidemics.[20,21] Assessment on the change of community awareness due to media reports have received increasing attention recently. As reviewed in,[22] there are several ways of treating epidemic models to incorporate media reports, depending on which types of feedback induced. Complementary to the face masks is then the role of media reports in educating people around the enhancement of physical distancing in the vicinity of increasing incidence, which ultimately reduce the infection rate $\beta$. Which news content is relevant should be addressed appropriately. Here, we center around news related to the number of daily cases and 'how–to' physical distancing, whereas news containing law enforcement on using masks is treated separately by the definition of $v$. We opt for the ansatz

$$\beta := \beta_0 - (\beta_0 - \beta_1)\frac{i}{\frac{1-w}{w} + i} \tag{2}$$

such that the model transforms into the final version

$$s' = \mu(1+p)i - \left[\beta_0 - (\beta_0 - \beta_1)\frac{i}{\frac{1-w}{w} + i}\right](1-uv)^2 si + \nu[1 - s - (1+p)i], \tag{3a}$$

$$i' = \left[\beta_0 - (\beta_0 - \beta_1)\frac{i}{\frac{1-w}{w} + i}\right]\frac{(1-uv)^2}{1+p} si - (\gamma + \mu)i. \tag{3b}$$

From the formula in (2), $\beta_0 = \beta|_{i=0}$ can be understood as the initial infection rate when first infection is introduced in the 'virgin' (completely susceptible) population. We assume that $\beta_0 > \beta_1$. The fact $\partial_i \beta|_{i=0} \sim -w/(1-w)$ indicates how $w \in [0, 1]$ may portray the interplay between intensiveness of media reports and resulting public awareness. As $w = 1$, the perfect individual awareness casts the largest depression angle of $\beta$ at the earliest infection. The parameter $\beta_1$ can now serve as the saturating infection rate under continuous media reports or perfect awareness, or under overwhelming incidence.

### 2.3 Reproduction Number

Attention is to be paid when deriving a reproduction number for fleeting observations. It may not be based upon the long-term behavior of the model solution around an equilibrium since the model is not designed to incorporate long-term mechanistic processes that may involve multiple peaks. We are more concerned with the short-term behavior as measured from a point of interest, which in this case is the disease-free equilibrium $(s, i) = (1, 0)$. Analysis of the local behavior of the deviation $(s - 1, i)$ around the origin falls into the standard technicality whereby the maximal real part of the eigenvalues of the Jacobian matrix determines the stability.[23] In the present context, the maximal real part is negative providing that the basic reproduction number $\mathscr{R}_0 := \beta_0(1-uv)^2/(1+p)(\gamma+\mu) < 1$. Digressing such an initial direction of endemicity, it is of great interest to see the furtherance of the disease reproduction over time as a response of various events and actions. Symptomatic persons may already draw forth new secondary cases as early as the onset of symptoms, i.e., even before hospital discharge. However, our model (3) did not capture the generation intervals that would have estimated the onsets of symptoms. Following the idea in,[24] in place of $\mathscr{R}_0$ we introduce the *instantaneous* reproduction number

$$\mathscr{R}_t := \left[\beta_0 - (\beta_0 - \beta_1)\frac{i(t)}{\frac{1-w}{w} + i(t)}\right] \cdot \frac{(1-uv)^2}{(1+p)(\gamma+\mu)} \cdot s(t). \qquad (4)$$

Observe from (3) that $\mathscr{R}_t$ gives the expected number of secondary cases in $S$ occurring at time instant $t$ attributed to one infected individual per average illness period $1/(\gamma+\mu)$. Under $i(t) > 0$, the checkpoint $\mathscr{R}_t = 1$ is equivalent to $i'(t) = 0$. Therefore, if $i(t)$ speaks about 'order of magnitude', then $\mathscr{R}_t$ gives 'direction of disease progression'. The method in[25] and its smooth variants[26,27] use estimates of the structure of $\mathscr{R}_t$ from compartmental models when data on both daily incidence and (prior density of) generation interval are known.

### 2.4 What Flattens the Endemic Curve Most Effectively

Let us denote $uv := z$ such that achieving a larger $z$ can be done through making either $u$ or $v$ larger. The key to flattening the endemic curve is scaling down the total number of active cases $\mathcal{I}(z, w) = \int_{t_s}^{t_f} i(t; z, w)\,\mathrm{d}t$, where $t_s, t_f$ denote the starting and final observation. We are asking which parameter between $z$ and $w$ is better in doing this job through the aid of sensitivity analysis. As a means of perturbation, let $\varepsilon$ denote the percentage of gain from the current value $z$ (or $w$), i.e., such that $(z + \varepsilon z)/z = 1 + \varepsilon$ defines the total percentage post increment. In response, $\mathcal{I}$ suffers from the following change in the similar manner

$$\frac{\mathcal{I}(z+\varepsilon z, w)}{\mathcal{I}(z, w)} = 1 + \varepsilon z \frac{\partial_z \mathcal{I}(z, w)}{\mathcal{I}(z, w)} + \mathcal{O}(\varepsilon^2). \qquad (5)$$

Typically, the terms $\partial_z \mathcal{I}$ and the non-dimensionalized equivalent $z\partial_z\mathcal{I}/\mathcal{I}$ denote the first-order sensitivity and elasticity, respectively, cf. [28–30] The integrands of the sensitivity indices for all the parameters can be calculated from the linear system

$$\frac{\mathrm{d}}{\mathrm{d}t}\nabla_{(z,w)}\begin{pmatrix} s \\ i \end{pmatrix} = \nabla_{(s,i)}\begin{pmatrix} s' \\ i' \end{pmatrix} \cdot \nabla_{(z,w)}\begin{pmatrix} s \\ i \end{pmatrix} + \nabla_{(z,w)}\begin{pmatrix} s' \\ i' \end{pmatrix}, \quad \nabla_{(z,w)}\begin{pmatrix} s \\ i \end{pmatrix}(0) = 0.$$

In this context, the elasticity denotes the first-order gain percentage (in case positive) or loss percentage of $\mathcal{I}$ (in case negative) from imposing perturbation on $z$ with the gain percentage $\varepsilon$. If one were to measure the sensitivity using the elasticity, then it was with two conditions: the stepping $\varepsilon$ was considered the same for all the parameters, and that it is of the first-order stepping. In the present investigation, we are in a good position to know that the role of the

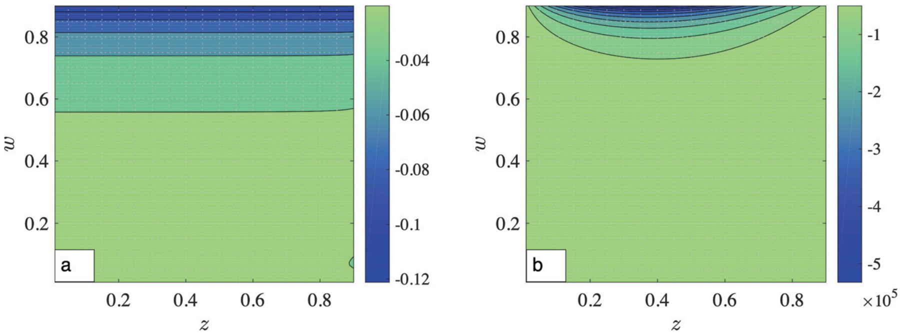


**Figure 1:** The elasticities $z\partial_z\mathcal{I}(z, w)/\mathcal{I}(z, w)$ in panel (a) and $w\partial_w\mathcal{I}(z, w)/\mathcal{I}(z, w)$ in panel (b) for the parameters in Fig. 2 except where $(z, w) \in [0, 0.91]^2$.

measures $z$ and $w$ is to inhibit the inflow of new cases, therefore it is natural that $\partial_z\mathcal{I}$ and $\partial_w\mathcal{I}$ are always negative. For general models, however, such $\mathcal{I}$ may not be a good measure as it fails to impart the distortion in $\partial_{(z,w)}i$ around zero that eventually sums up to a small number with time.

In Fig. 1, the elasticity corresponding to $w$ takes much larger absolute values than that corresponding to $z$ does. Both elasticities also jump to larger absolute values in the direction of increasing $w$, but remain essentially constant in the direction of increasing $z$ especially when $w \leq 0.7$. As small as $w$ may be in reality, it is considered the most effective way of attacking the infection rate $\beta$. The message being, shaping public perception about the disease and their self-defense system is more important than following mask-usage regulations in a dully manner.

# 3 Model Fitting

## 3.1 Known Parameters, Likelihood Function, and Goodness of Fit

In Germany, the use of medical masks has been enforced since January 19, 2021 if one were to use communal facilities.[31] Accordingly, the effective usage as well as efficacy have altered since then. Using the mathematical conventions $\mathbb{T} := \{t_s, t_s + 1, t_s + 2, \cdots, t_f\}$ and $\mathbb{1}_\Omega$ taking value 1 on $\Omega$ or otherwise 0, the preceding statement translates to $u = u_1\mathbb{1}_{[t_s,\tau)} + u_2\mathbb{1}_{[\tau,t_f]}$ and $v = v_1\mathbb{1}_{[t_s,\tau)} + v_2\mathbb{1}_{[\tau,t_f]}$ where $\tau$ denotes the switch indicating the aforementioned policy change. With such a formulation, an abrupt change is to be expected from $\mathscr{R}_t$ at $\tau$. The average lifespan of the citizens $1/\mu$ and the average illness duration $1/\gamma$ are given by 80 years[32] and 14.3 days for all patients with various treatments,[33] respectively. The Germany's population in 2020 is estimated around 83,950,000.[34] Now, estimation of the unknown parameters $\theta = (s_0, i_0, \beta_0, \beta_1, \nu, p, u_1, u_2, v_1, v_2, w)$ will serve the purpose of finding agreement between model solution $\mu_j := i(t_j)$ and empirical data $\mathscr{I}_j$. With no knowledge on the prior density of $\theta$, the usual workaround is using a likelihood function for its proportionality to the posterior density of $\theta$.[35] The likelihood for a single observation $L_j$ is assumed to be Gaussian with mean $\mu_j$ and standard deviation $\sigma$. The log of the joint likelihood for the entire observations is $\log \mathcal{L}(\theta) = \log\left(C \prod_j L_j\right)$ where $C$ helps omit the appearing constant before the exponential function, cf.[36] The final representation reads as

$$\log \mathcal{L}(\theta) = -\frac{1}{2} \sum_{j:t_j \in \mathbb{T}} \left(\frac{i(t_j;\theta) - \mathscr{I}_j}{\sigma}\right)^2. \tag{6}$$

Thanks to $\sigma$, its arbitrary value may set the log likelihood in a reasonable order of magnitude for the sake of efficient computations. Our choice was the rescaled mean $\sigma = 10^{-2} \cdot \|\mathscr{I}\|_1/|\mathbb{T}|$.

As the parameter dimension is much smaller than the data size, the *asymptotic confidence interval*[37] has been suggested to describe the parameter uncertainty, which usually is approached by negative of the inverse information matrix. The formula of the confidence interval for each optimal parameter $\hat{\theta}_k$ takes the form

$$\left[\hat{\theta}_k - \varepsilon_k, \hat{\theta}_k + \varepsilon_k\right] \quad \text{where} \quad \varepsilon_k := \sqrt{2\chi^2(\alpha, df) \cdot \left(-\nabla^{-2} \log \mathcal{L}(\hat{\theta})\right)_{kk}}. \tag{7}$$

The operator $\nabla^{-2}$ denotes the inverse of the Hessian matrix, while $\chi^2(\alpha, df)$ denotes the $\alpha$ quantile of the $\chi^2$ distribution with the degree of freedom $df$. In the present study, the Hessian matrix was approximated in the second order using the queen-type stencil, where the step size was made dependent on the parameter's order of magnitude or $\delta_k := \delta \cdot \theta_k$ for a uniformly small $\delta$. The degree of freedom can be chosen between two that further determines the type of confidence interval: $df = 1$ gives *pointwise* asymptotic confidence interval that works on the individual parameter, $df = |\theta|$ gives a *simultaneous* asymptotic confidence interval that works jointly for all the parameters.[38]

### 3.2 Data and Optimization Solver

The epidemic data for this study are collected from the Johns Hopkins University repository,[39,40] spanning the time window July 1, 2020 until February 20, 2021. We extracted the active cases ($\mathscr{I}$) by subtracting accumulated by recovered and deceased cases.[41] We employ `fmincon` in MATLAB with `interior-point` as the core method to solve the parameter estimation problem. The gradient and Hessian matrix of the negative log likelihood were supplied in separate subroutines so as to speed up the computation. The fitting results can be seen in Fig. 2(a).

| $\theta_k$ | $s_0$ | $i_0$ | $\beta_0$ | $\beta_1$ | $\nu$ | $p$ | $u_1$ | $u_2$ | $v_1$ | $v_2$ | $w$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LB | 0.7 | $0.1\mathscr{I}_1$ | 0 | 0 | $\frac{1}{365\cdot 3}$ | 0 | 0 | 0 | 0 | 0 | 0 |
| UB | 1 | $3\mathscr{I}_1$ | 1.8 | $\beta_0$ | $\frac{1}{100}$ | 20 | 1 | 1 | 1 | 1 | 1 |
| $\hat{\theta}_k$ | 0.9999959523 | $3.4411 \cdot 10^{-5}$ | 1.699 | $2.982 \cdot 10^{-9}$ | 0.000913 | 14.7619 | 0.0191 | 0.682 | $2.17 \cdot 10^{-10}$ | 0.28 | 0.473 |
| $\hat{\varepsilon}_k$ | $1.83 \cdot 10^{-5}$ | $2.46 \cdot 10^{-8}$ | $4.43 \cdot 10^{-4}$ | $4.85 \cdot 10^{-10}$ | $1.23 \cdot 10^{-6}$ | 0.0011 | $9.74 \cdot 10^{-4}$ | 0.0915 | $1.11 \cdot 10^{-11}$ | 0.0376 | 0.0015 |
| $\bar{\varepsilon}_k$ | $6.25 \cdot 10^{-4}$ | $8.41 \cdot 10^{-7}$ | 0.0151 | $1.65 \cdot 10^{-8}$ | $4.19 \cdot 10^{-5}$ | 0.0359 | 0.0332 | 3.1205 | $3.77 \cdot 10^{-10}$ | 1.2832 | 0.0521 |

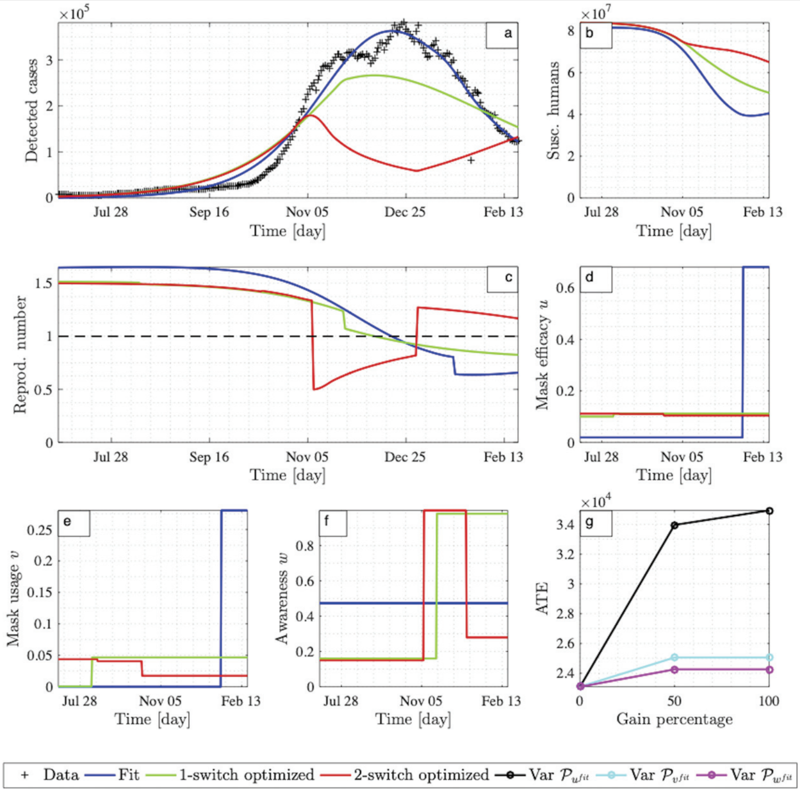


**Figure 2:** Fitting result with predetermined lower bounds (LB) and upper bounds (UB) for the parameters and the ranges for the confidence intervals with $\hat{\varepsilon}_k := \varepsilon_k(\alpha = 0.05, df = 1)$ and $\bar{\varepsilon}_k := \varepsilon_k(\alpha = 0.05, df = 11)$. The fit-trajectories and those using optimal decision and switching with the number of switches $M = 1, 2$ are shown in panel (a)–(c). The corresponding control measures can be seen in panel (d)–(f). Panel (g) displays different scenarios emanated from ATE if the price for every measure were partially increased in percentage from the current value. The largest yield of ATEs by varying $\mathcal{P}_{u^{\text{fit}}}$ returns from the fact that the measure was not used optimally in the previous optimization due to a small price.

# 4 Optimal Decision and Switching

The main point of the present investigation is to see what could have been the situation when all the non-vaccine measures were optimized. On the practical level, our model can be used to predict incidence during the next winter season based on a first take-off and may elucidate what to do with the measures in an optimal way. We suppose that switches related to national programmes against COVID-19 could have been assigned more frequently, represented by knot points $\tau_j^u = \tau_j^v$ and $\tau_j^w$ for $j = 1, \cdots, M$. The function $w$ depends on the will and political agreement between health authorities and media to disclose information to the public. Meanwhile, the efficacy and effective usage of masks $u, v$ vary from country to country due to the availability of equipment as well as different mentality. Notwithstanding these aspects, too large $M$ may also cause confusion, chaos and lack of compliance to the new regulations.

The control variables can now be formulated as $u = \sum_j u_j \mathbb{1}_{[\tau_j^u, \tau_{j+1}^u)}$, $v = \sum_j v_j \mathbb{1}_{[\tau_j^u, \tau_{j+1}^u)}$, and $w = \sum_j w_j \mathbb{1}_{[\tau_j^w, \tau_{j+1}^w)}$ (with $\tau_0 = t_s$ and $\tau_{M+1} = t_f$) living in the space of functions with bounded total variations and undetermined constants $(\boldsymbol{u}, \boldsymbol{\tau}) = (u_1, \cdots, w_{M+1}, \tau_1^u, \cdots, \tau_M^w) \in [0, 1]^{3M+3} \times [t_s, t_f]^{2M}$. To show the power of the method, we calculated the optimal constants toward minimizing the active cases subject to the same 'prices' defined from the fitting $\mathcal{P}_y := \int_{t_s}^{t_f} y \, \mathrm{d}t$ for $y \in \{u^{\text{fit}}, v^{\text{fit}}, w^{\text{fit}}\}$. With the aid of optimal parameters, the problem reads as

$$\min_{(\boldsymbol{u},\boldsymbol{\tau})} \int_{t_s}^{t_f} i^2(t; \boldsymbol{u}, \boldsymbol{\tau}) \, \mathrm{d}t \quad \text{s.t.model(3)and} \int_{t_s}^{t_f} z_y \, \mathrm{d}t \le \mathcal{P}_y, \; z_y \in \{u, v, w\}, \tag{8}$$

returning $(u^{\text{opt}}, v^{\text{opt}}, w^{\text{opt}})$. Our monitoring function is the *average treatment effect*

$$\text{ATE} := \frac{1}{|\mathbb{T}|} \sum_{j : t_j \in \mathbb{T}} I(t_j; u^{\text{fit}}, v^{\text{fit}}, w^{\text{fit}}) - I(t_j; u^{\text{opt}}, v^{\text{opt}}, w^{\text{opt}})$$

representing how many humans could have been free from infection on a daily basis by the optimal decision and switching.

Using `fmincon`, we were once again able to locate a local minimum to the problem (8) using two tested schemes ($M = 1$ and $M = 2$), as can be seen in Fig. 2. Generally, it is always possible to find optimal values for the measures as well as the switches during winter season. Our local minimum suggests that mask efficacy could have been made moderate but people's discipline toward regularity of the mask usage needs to be improved over all the observations. Focusing on awareness-driven physical distancing during the festive season (beginning of November until end of December) seems to be paramount. According to our model, minimizing the number of actives cases – by maximal ATEs – with the measures $u, v, w$ is equivalent to suppressing the inflow of new cases. It thus is not surprising that the optimal measures return more susceptible humans.

## 5 Conclusion

This study compares the real-time feedback and an early-warning system with the aid of parameter estimation from an epidemic model, applied to COVID-19 incidence data from Germany. The early warning was brought in the context *as if* the active cases in the next winter season would delineate the same trajectory as for the current winter season. With the full coverage of the season, our model solution easily agrees with the data. We have computed optimal measures focusing on face masks and community awareness apropos of physical distancing, subject to the same prices from the real-time feedback. By prices we do not only narrow-mindedly mean the cost of equipment but also assume all the situations tailored, which can be economical (e.g. loss of jobs, unemployment, healthcare cost) and social (insecurity against others, Work–from–Home). For applicability, we employed the piecewise-constant type of measures whereby switches indicate policy changes. It is generally concluded that a good combination of mask efficacy, regular use of masks, and physical distancing through the aid of media reports or educational campaigns will help reduce the significant inflow of new cases especially from the First Advent Sunday until the end of the Christmastide. Applying physical distancing on the maximum effort during this period critically diminishes the number of active cases.

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# Proceedings of the COVid-19 Empirical Research (COVER) Conference

## Milan, Italy, October 30th, 2020

*Editors*: Elia Biganzoli, Giancarlo Manzi,
Alessandra Micheletti, Federica Nicolussi, Silvia Salini

The Covid-19 pandemic has spread across the world at a rate never seen before, affecting different countries and having a huge impact not only on health care systems but also on economic systems. Never as in this situation the continuous exchange of views between scientists of different disciplines must be considered the keystone to overcome this emergency. The dramatic global situation has prompted many researchers from different fields to focus on studying the Covid-19 pandemic and its economic and social implications in a multi-facet fashion. This volume collects the contributions to the COVid-19 Empirical Research (COVER) Conference, organized by the Centre of Excellence in Economics and Data Science of the Department of Economics, Management and Quantitative Methods, University of Milan, Italy, October 30th, 2020. This conference aimed to collect different points of view by opening an interdisciplinary discussion on the possible developments of the pandemic. The conference contributions ranged in the social, economic and mathematical-statistical areas.

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