Knowledge management in turbulent times: time-based scenario analysis of vaccinations against COVID-19

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Abstract

Purpose – *This paper aims to estimate the delay or timely effects of the national vaccination strategy for COVID-19 on Italian gross domestic product (GDP). By adopting a knowledge management lens, the study highlights the importance of ''time'' for Italian recovery. Indeed, recovering an adequate growth rate is crucial for the future of employment, well-being and management of Italian public debt.*

Design/methodology/approach – *This study applies an epidemiological model of a universal access vaccination programme against COVID-19. The economic model is based on the time-shift of available quarterly projections deriving from the expected delay or acceleration of the national vaccination plan against COVID-19.*

Findings – *The basic concept underlying the scenario analysis is that the sustainability of the expected recovery of the Italian economy due to the COVID-19 shock, and consequently the growth of the GDP, is time-dependent on the rollout of the national vaccination plan.*

Research limitations/implications – *A delay in the vaccination campaign could have a twofold negative impact on the growth of the Italian gross product: it reduces the quarterly growth over the previous year in the short term and it delays the quarterly upwards trend over the next two years. Policymakers and practitioners are called to promptly face new dynamic scenarios due to public and economic policies to fight the COVID-19 crisis.*

Originality/value – *To the best of the authors' knowledge, this is the first attempt of research that focuses attention on the synchrony between the economic time necessary for recovery and the real-time necessary to achieve vaccination coverage for the restart of production activities.*

Keywords *COVID-19, Scenario-based analysis, GDP, Vaccination*

Paper type *Research paper*

Executive summary

In this real impact research article, the authors investigate the impact of timely and delayed vaccination of population against COVID-19 on Italian GDP. The authors recognize the relevant role of "time" on the Italian economy recovery at large. Through the lens of knowledge management, the paper assumes that collective knowledge and empirical information allow decision makers to manage the potential effects of economic forecasting. Moreover, in a turbulent time, scientific data and knowledge are often used to implement original simulation-based projections for the next future. Specifically, the paper applies an epidemiological model by adopting scenario-based projections for Italian GDP in 2021 and 2022. In this vein, the authors find that the growth of the GDP is time-dependent on the rollout of the national vaccination plan.

Finally, the article provides implications for policymakers, practitioners and managers for strategizing about actions to assets to fight the COVID-19 crisis and to trigger the national recovery.

Introduction

Uncertainty on the economic impact of the COVID-19 pandemic is very high. In 2020, Italian gross domestic product (GDP) at current prices fell by 10.05% compared with the previous year (IMF Data Mapper, 2021). The timing of recovery will depend on several factors that are hard to predict: the duration and geographical dispersion of infection, developments in the global economy, the impact on confidence and hence on household spending and firms' investment decisions and the effectiveness of economic policies (Bank of Italy, 2020). To a significant degree, the recovery will also depend on the effectiveness of the national COVID-19 vaccination programme.

On 2 December 2020, The Italian Minister of Health, Roberto Speranza, presented to the Parliament the guidelines of Italy's strategic plan for COVID-19 vaccination, drafted by the Ministry of Health, the Extraordinary Commissioner for the COVID-19 emergency, the Higher Institute of Health, the Italian National Agency for Regional Healthcare Services and the Italian Medicines Agency. The National Vaccination Plan was centred on the principle of universal access: the vaccine is a common good, a right that must be guaranteed free of charge to everyone, regardless of income, age, gender and region of residence. Immunisation priority was given to the elderly, fragile population, health and social workers (Mennini et al., 2021) and gradually extended to everybody else. Concerning the administration of vaccines, the Italian Ministry of Health declared that the immunisation program was expected to start from Q1 2021 and with a more significant distribution of vaccine doses in Q2 and Q3, to be completed substantially in Q4 2021. The complex interlocking game between the need to ensure maximum safety for citizens, the enormous financial effort of the European States, the production capacity of pharmaceutical companies and the geopolitical tensions triggered by the emergency determined a series of missteps in the expected rollout of the vaccination programme. A textbook example, in this sense, is the temporary precautionary stop of the AstraZeneca anti-Covid vaccine ordered by several countries, including Italy, after reporting some serious adverse thromboembolic events following a very small number of administrations. The administration's suspension was then revoked following a further green light from the European Medicine Agency, after a series of checks and analyses of the reported cases (European Medicine Agency, 2021).

Since the early months of the COVID-19 alert, scholars and practitioners have started to focus their attention on the impact of knowledge management (KM) on the uncertain healthcare scenario (Ashok et al., 2021; Danõa et al., 2020; Lee et al., 2020; Orlando et al., 2020). By adopting a KM approach based on collective sharing knowledge processes, decision makers can manage the emergency scenario by combining and using data coming from participative approaches (Caputo, 2017; Iandolo et al., 2020). Moreover, by leveraging information technology (IT), policymakers can implement an original simulation-based outline to analyse the potential effects of the crisis on economic forecasting (Lee et al., 2020; Papa et al., 2020). As a matter of fact, simulations must rely mainly on scenario analyses, based on knowledge and assessment of the impact of alternatives. Without a doubt, in these crisis scenarios, economic forecasting becomes exceptionally challenging. Specific, the range of forecasters' estimates for Italian GDP growth in 2020 and 2021 is indeed exceptionally wide: the output fall projected for this year ranges between −6% and −15%, the recovery in 2021 from 2% to 13% (Bank of Italy, 2021; Marcellusi et al., 2021). Uncertainty is similarly high in the other Euro-area countries. In the first half of 2020, GDP was 12% lower than the same period in 2019. In April, industrial production was over 40% below the level at the beginning of the year (Bank of Italy, 2020).

Italy manages an exogenous shock with an economy that structurally struggles to grow and highly indebted public finance. The crisis has produced markedly heterogeneous economic, social and health effects under the territorial, economic, income, gender and generational profile. In this scenario, the worldwide vaccination campaign should have

started as soon as possible for several reasons. Firstly, a recent analysis shows how the vaccination strategy can effectively reduce the health consequences, especially in terms of preventing deaths generated by the pandemic. This remarkable public health outcome could not be matched by the economy's growth due to a time-lag effect between epidemiology and production/consumption recovery. Secondly, a large vaccination campaign could have helped Italian production and economy by triggering the development of GDP in the next future. Finally, by focusing on the "time", stating timely, the vaccination campaign could have stopped the rapid progression of the virus at the national and international level, avoiding heavy, restrictive measures.

To combine the health effect with the economic effect (economic recovery, catch-up effect of commercial and production activities, resumption of school activities, GDP growth), it would therefore be necessary to have recourse to a universal access vaccination of the Italian adult population (OECD, 2021). That can allow accelerating the achievement of vaccination coverage to allow a resumption of economic life by the end of the first two quarters of 2021. Recovering an adequate growth rate is crucial for the future of employment, well-being and management of public debt. From all this, "time" is a fundamental variable, particularly at this moment, which is often little considered and instead is a central aspect. For this reason, the study focuses attention on the synchrony between the economic time necessary for recovery and the real-time necessary to achieve vaccination coverage for the restart of production activities.

Theoretical background

National, regional and local public organizations are currently facing an unpredictable and complex socioeconomic environment (WHO, 2021). The COVID-19 pandemic has strongly challenged the ability of public institutions for implementing rapid and effective responses to the crisis (Mascio et al., 2020), concurrently highlighting the importance for these to innovate their KM approach by reconfiguring processes and then public goods and services (Lee et al., 2020).

Knowledge is the most valuable resource that organizations possess, and its optimal use is critical in ensuring that firms survive and thrive against uncertain times (Giraldo et al., 2019; Caputo et al., 2021). KM can be viewed as the process of identifying, capturing, storing, sharing, applying and leveraging knowledge to improve organizational performance (Caputo, 2017; Caputo et al., 2019; Giraldo et al., 2019; Ashok et al., 2021). In this perspective, public administration should turn into "learning organizations", able to leverage and effectively combine knowledge, people and technologies (Caputo et al., 2019, p. 1315). Lee et al. (2020) discuss how transparent internal communication by organizations towards employees during crises times is a crucial strategy to foster collective knowledge and overcome uncertainty in creative ways. Similarly, Caputo et al. (2021) noticed that perceptions about internal organizational assets and environmental dynamics are relevant to protect individual knowledge in risky scenarios. Finally, Ltifi and Hichri (2021) found that, during the crisis, governance systems highly impact the knowledge of the firms' social responsibility in the banking sector.

Hence, since the digital era dramatically expanded value co-creation processes among stakeholders, public organizations must carefully consider their KM processes from the perspective of collective intelligence creation. According to Iandolo et al. (2020, p. 5), "a framework based on the collective intelligence can aggregate multiple sources of knowledge reducing time for data processing and supporting decision-making processes". Organizations can be more resilient by embracing the new paradigmatic change taking place in the practice of managing collective knowledge creation and sharing in digital economies. In line with prior studies (Ashok et al., 2021; Iandolo et al., 2020; Papa et al., 2020; Danõa et al., 2020), the application of smart technologies can leverage value-added knowledge resources within organizations. Big data and artificial intelligence improve

knowledge sharing between public and private actors, facilitating the decision-making processes through knowledge sharing and reuse (Caputo, 2017; Iandolo *et al.*, 2020; Danõa *et al.*, 2020; Magdinceva-Sopova *et al.*, 2020). This is particularly relevant in turbulent times. Indeed, crisis management requires timely decisions, which can be ensured only by a rapid acquisition and sharing of critical knowledge (Papa *et al.*, 2020).

Methodology

Epidemiological model

A previous epidemiological study aimed to simulate the impact of COVID-19 vaccination on the Italian national healthcare system in 2021 (Marcellusi *et al.*, 2021). Hospitalisation, intensive care unit admission and death rates were modelled based on 2020 data. The impact of the introduction of a primary prevention strategy on the national healthcare system took into consideration vaccines efficacy, availability of doses and potential coverage reached over time.

A base-case scenario was built based on the expert opinion elicited from medical doctors at the Policlinico of the University of "Tor Vergata" in Rome, one of the 321 vaccination centres designated by the Italian health ministry national immunisation delivery plan. In this simulation, the model assumed that immunising 75% of the population would be achieved by the third quarter of 2021. The model predicted a reduction ranging between 60% and 67% of deaths compared with the world without vaccination. In case of a delayed or inefficient deployment of the immunisation plan, the model predicted a reduced impact on death and hospitalisation and continued the acute phase of the COVID-19 pandemic in Italy to 2022.

All these models are based on the concept of "time". Precisely "time", a fundamental variable in economics, becomes the backbone on which to think to program and plan the economic recovery. Time, in economics, is one of the most critical variables, but, incomprehensibly, it is the least considered in the healthcare sector in Italy. Time is fundamental in the evaluation phase, both of an investment that has already been subscribed and of one in the stipulation phase because it has different forms, all fundamental importance. Time is the yardstick by which we mark all the events of our life. We must make sure that our economic concept also adapts to our temporal needs to improve the economic situation and, consequently, the social one. Time is money. The time factor in economics has been the subject of the investigation several times. Still, it will be even more so soon as the topics it involves are very complex, especially concerning the effects of the COVID-19 pandemic. Time is an element of cost under a dual point of view. Firstly, each unit of time represents a sum of potential utility that could be achieved where that unit was not consumed in other uses. Secondly, the duration of a production process is a coefficient of the magnitude of the expenditure of the individual production factors (Becker, 1965).

Italian gross domestic product forecasting method

Nowcasting and short-term forecasting GDP growth at a country-level during the COVID-19 pandemic are of vital interest for economic and policy decision-making. Unfortunately, obtaining reliable economic growth models during a crisis is very difficult, and all the peculiar features of the COVID-19 crisis make it even more uncertain (Foroni *et al.*, 2020).

We used a commonly accepted method, the expert forecast, to establish a "base case scenario". The advantage of using information from the expert forecast and extrapolating from historical data is that the estimates draw upon and appropriately weigh numerous information sources (Christensen *et al.*, 2018).

Then, we modified the base case scenario based on the expert's background information, adapting it to the vaccination scenarios drawn from our epidemiological model.

The expert model: the base case

We chose the forecast of Italian GDP growth for 2021 and 2022 published by the International Monetary Fund (IMF). The choice was determined by two factors: the credibility of the source and synchronicity. The IMF is the United Nations specialised agency with data collection, analysis and information exchange among its institutional duties. The IMF revised its forecast of the Italian GDP on 27 January 2020, estimating the growth of 3% in 2021 and 3.6% in 2022 (Bank of Italy, 2020). We can assume that the Italian GDP's revised IMF forecast accounted for the same information that informed our vaccination model.

Vaccination scenarios

Our vaccination model considered three main scenarios:

1. a **base case**, where the vaccination of 75% of the Italian population over 70 years of age will be concluded by the third quarter of 2021;

2. a **worst-case**, where the vaccination of the >70s will be completed by the fourth quarter of 2021, estimating a one-quarter delay due to the availability of vaccine doses; and

3. a **best-case** scenario, where the vaccination of the >70s will be implemented by the second quarter of 2021, one quarter earlier than expected in the base case.

Aligning the two main inputs: vaccination timing and expected gross domestic product growth

We shifted the expected growth of the Italian GDP according to the time to complete the vaccination of the population over 70 years of age.

To obtain quarterly GDP values, we used chained quarterly data (base year: 2019), a measure of the volume of national accounting aggregates that allows representing the dynamics of economic quantities net of price variations. For each aggregate and each quarter, from the second year onwards, the ratio is calculated between the value expressed at the prices of the previous year (for example, the estimates of the first quarter of 2020 expressed at the average prices of 2019) and the average quarterly value at prices currencies of the same aggregate the previous year. The volume indices in the mobile base thus obtained are chained, multiplying them consecutively starting from a value equal to 100 fixed for the average of the quarterly data of the first year (values at current prices of the four quarters of the first year standardised to 100 on average and deflated for quarterly price indices based on the same year) and then shifting the base to the year taken as reference (currently 2019). A chained volume index multiplied by the quarterly average value at current prices for the reference year (and divided by 100) determines the aggregate with chained values (Italian National Institute of Statistics, 2021).

The Italian GDP quarterly chained data at the 2019 base year were aligned with the IMF quarterly growth estimates for advanced economies (2019: Q1 = 100). The estimated quarterly growth rates applied to the Italian 2019 chained values allowed to obtain a quarterly forecast for 2021 consistent with the latest IMF estimates (3% growth 2021 vs 2020). In the absence of a 2022 expert forecast by quarter, the 2022 GDP forecast was obtained by applying a 3.6% growth to each quarter in 2021 (International Monetary Fund, 2020).

The IMF report included two alternative scenarios, based on the evolutions in the fight against COVID-19: a more protracted outbreak in 2020 (5 percentage points negative deviation vs 2021 base case) and a more extended outbreak in 2020 followed by a new outbreak in 2021 (8 percentage points lower than 2021 base case). We used both estimates two build two alternative versions of the worst-case scenario for the impact of delayed

vaccination on the Italian 2021 and 2022 GDP. For the best-case scenario, we anticipated by one quarter the growth estimates informing the base case scenario.

Results

Base case

The projections for the Italian economy were based on the revised forecast for the Italian GDP prepared by the IMF and published on 27 January 2021.

The technical assumptions included all economic, political and public health information available to the global economic analysts. The prospects remained strictly dependent on both the evolution of the pandemic and the measures taken, on the one hand, to counter the increase in infections, on the other hand, to mitigate the impact on economic activity. The projection basis presented in the base case assumed that after the second wave of infections of autumn 2020, the epidemic gradually returned under control in the first half of 2021 and that the health emergency came exceeded entirely by 2022, thanks above all to the national vaccination campaign. Similar to the main European partners, Italy was expected to see a marked contraction of GDP in 2020 (−8.9%) and a partial recovery in 2021 (+3.0%). Table 1 reported below summarises the expected trend of the Italian GDP by a quarter in 2021 and 2022.

Worse cases

The negative impact on the expected Italian GDP in 2021 and 2022 is determined, as a single factor, by the delay in attaining the planned population targets in the vaccination against COVID-19. A one-quarter delay in the vaccination of 70% of the population at highest risk of COVID infection (elderly over 70 years of age, individuals with fragile pre-existing health status and social and health workers) exposes the Italian economic output to the following two possible negative scenarios (International Monetary Fund, 2020):

■ A worse than expected scenario, which assumes that, due to the delay in the vaccination programmes, the measures to contain the spread of the virus in 2021 last longer than assumed in the baseline, up to the end of the third quarter of 2021. In terms of discretionary policy, fiscal spending is also assumed to respond to the decline in output roughly twice as strong as it would under typical business cycle fluctuations in economic activity. Table 2 below reports the shift in the expected quarterly growth of the Italian GDP: the recovery phase will start only in the fourth quarter of 2021, preceded by three consecutive quarters with a negative growth of five percentage points compared with the same period in 2020. The shift will also have a negative impact on the following year, 2022, growing at a slower than expected rate compared with in the base case.

■ The worst than the expected scenario assumes that the delay in the vaccination programme allows a third outbreak of the virus in 2021 that is roughly two-thirds as severe as in the baseline. Financial conditions are assumed to tighten by twice as much as they do in the first scenario. Because of the more significant impact on economic activity, the scarring, which materialises in 2022, is assumed to be approximately twice as large as in the first scenario. Table 3 below reports the impact of the shift in quarterly GDP growth projections: the negative impact of the third wave of COVID-19 infection hit the expected Italian GDP in the first three quarters of 2021 as hard as in 2020, with a loss of eight percentage points per quarter for the first three quarters. The recovery expected in the first quarter of 2021 in the base case will start in the fourth quarter of 2021, with an overall negative impact on the following year, 2022, compared with the base case projections.

Table 1 Base case: trend of the Italian GDP by quarter in 2021 and 2022 as expected by IMF analysts in January 2021

Base case 2021–2022

| | Actual | | | | Forecast | | GDP annual | |
Year – Quarter	Chain-linked values €bill base year 2015 (BankItalia)	Change % vs Last month (LM)	Change% vs Last year (LY)	Indexed values 2019–1 = 100	Change % vs Last year (LY)	Indexed values 2019–1 = 100	Forecast (FCST) €bill (IMF)	Change % vs Last year (LY)
2018 – 1	429.764	0.1						
2018 – 2	430.276	0.0						
2018 – 3	430.064	0.1						
2018 – 4	430.426							
2018 Total	1,720.53							
2019 – 1	431.251	0.2	0.3	100.0				
2019 – 2	432.106	0.2	0.4	100.2				
2019 – 3	432.287	0.0	0.5	100.2				
2019 – 4	430.725	−0.4	0.1	99.9				
2019 Total	1,726.369	0.3		400.3				
2020 – 1	406.907	−5.5	−5.6	94.4				
2020 – 2	353.832	−13.0	−18.1	82.0				
2020 – 3	410.326	16.0	−5.1	95.1				
2020 – 4	402.220	−2.0	−6.6	93.3				
2020 Total	1,573.285	−8.9		364.8				
2021 – 1					2.4	96.6	416.7	
2021 – 2					2.8	84.3	363.7	
2021 – 3					3.2	98.2	423.5	
2021 – 4					3.6	96.6	416.7	
2021 Total						375.8	1,620.6	3.0
2022 – 1					3.6	100.1	431.7	
2022 – 2					3.6	87.4	376.8	
2022 – 3					3.6	101.7	438.7	
2022 – 4					3.6	100.1	431.7	
2022 Total						389.3	1,678.9	3.6

Table 2 Worse scenario: the delay in vaccination programme allows the economic measures to contain the spread of the virus in 2021 to last longer than assumed in the baseline, up to the end of the third quarter of 2021

Worse case vaccination delayed increases containment costs In 2021	Actual				Forecast			
	Chain-linked values €bill base year 2015 (BankItalia)	Change% vs Last month (LM)	Change % vs Last year (LY)	Indexed values values 2019 – 1 = 100	Change % vs Last year (LY)	Indexed values values 2019 – 1 = 100	GDP annual Forecast (FCST) €bill (IMF)	Change % vs Last year (LY)
2018 – 1	429.764	0.1						
2018 – 2	430.276	0.0						
2018 – 3	430.064	0.1						
2018 – 4	430.426	0.1						
2018 Total	1,720.53							
2019 – 1	431.251	0.2	0.3	100.0				
2019 – 2	432.106	0.2	0.4	100.2				
2019 – 3	432.287	0.0	0.5	100.2				
2019 – 4	430.725	–0.4	0.1	99.9				
2019 Total	1,726.369	0.3		400.3				
2020 – 1	406.907	–5.5	–5.6	94.4				
2020 – 2	353.832	–13.0	–18.1	82.0				
2020 – 3	410.326	16.0	–5.1	95.1				
2020 – 4	402.220	–2.0	–6.6	93.3				
2020 Total	1,573.285	–8.9		364.8				
2021 – 1					–5.0	89.6	386.6	
2021 – 2					–5.0	77.9	336.1	
2021 – 3					–5.0	90.4	389.8	
2021 – 4					2.4	95.5	411.9	
2021 Total						353.5	1,524.4	–3.1
2022 – 1					2.8	92.1	397.4	
2022 – 2					3.2	80.4	346.9	
2022 – 3					3.6	93.6	403.8	
2022 – 4					3.6	98.9	426.7	
2022 Total						365.2	1,574.8	3.3

Table 3 The worst scenario: the delay in vaccination programme allows a third outbreak of the virus in 2021, roughly two-thirds as severe as in the baseline

Worst case vaccination delayed and new outbreak in 2021	Actual				Forecast			
	Chain-linked values €bill base year 2015 (BankItalia)	Change % vs Last month (LM)	Change % vs Last year (LY)	Indexed values values 2019 − 1 = 100	Change % vs Last year (LY)	Indexed values values 2019 − 1 = 100	GDP annual Forecast (FCST) €bill (IMF)	Change % vs Last year (LY)
2018 − 1	429.764							
2018 − 2	430.276	0.1						
2018 − 3	430.064	0.0						
2018 − 4	430.426	0.1						
2018 Total	1,720.53							
2019 − 1	431.251	0.2	0.3	100.0				
2019 − 2	432.106	0.2	0.4	100.2				
2019 − 3	432.287	0.0	0.5	100.2				
2019 − 4	430.725	−0.4	0.1	99.9				
2019 Total	1,726.369	0.3		400.3				
2020 − 1	406.907	−5.5	−5.6	94.4				
2020 − 2	353.832	−13.0	−18.1	82.0				
2020 − 3	410.326	16.0	−5.1	95.1				
2020 − 4	402.220	−2.0	−6.6	93.3				
2020 Total	1,573.285	−8.9		364.8				
2021 − 1					−8.0	86.8	374.4	
2021 − 2					−8.0	75.5	325.5	
2021 − 3					−8.0	87.5	377.5	
2021 − 4					2.4	95.5	411.9	
2021 Total						345.3	1,489.3	−5.3
2022 − 1					2.8	89.2	384.8	
2022 − 2					3.2	77.9	335.9	
2022 − 3					3.6	90.7	391.1	
2022 − 4					3.6	98.9	426.7	
2022 Total						356.8	1,538.6	3.3

Best case

The anticipated attainment of 70% coverage of the target Italian population to the end of the second quarter of 2021 would allow a faster economic recovery than expected in the base case. Table 4 reports the shift up by one-quarter of the expected growth rates of the Italian GDP, showing a positive impact in 2021 carried over in full in 2022.

Summary of economic impact

Table 5 reports the synthesis of the scenarios included in the analysis. A one-quarter delay in attaining the target COVID-19 vaccination coverage could determine a GDP loss ranging from €100bn to €140bn in 2021 to increase up to €200–271bn in 2022. The enormity of these figures indicates that the national vaccination plan against COVID-19 represents the single most considerable risk for the recovery of the Italian economy (Table 5).

Discussion

Michal Spence, 2001 Nobel laureate in economics, emphasised the connection between time to economic recovery and acceleration of the vaccination programme in Italy.

"The crisis due to the Covid pandemic caused an unprecedented shock in the Italian economy. The impact has been felt mostly on lower incomes, on workers in closed sectors to contain the virus. Households' budgets have decreased, and there will be businesses that will have to close, despite the economic stimuli provided by the Government to mitigate the shock. The economy will restart by the end of 2022. A return to growth in tune with the times and geography of vaccination campaigns. There will be economic recovery once the population is vaccinated. Vaccination campaigns must accelerate in every aspect: from production to distribution to administration" (Spence, 2021).

The basic concept underlying our scenario analysis is that the sustainability of the expected recovery of the Italian economy from the COVID-19 shock, and consequently the growth of the GDP, is time-dependent on the rollout of the national vaccination plan. We focused on the synchronicity between the economic time necessary for the recovery and the real-time necessary to reach the vaccination coverage for the restart of production activities. A delay in the latter could have a twofold negative impact on the growth of the Italian gross product: it reduces the quarterly growth over the previous year in the short term, and it delays the quarterly upwards trend over the next two years.

Our study used an epidemiological model of a universal access vaccination programme against COVID-19 to predict the time to target coverage of the population at highest risk (elderly over 70 years of age, fragile individuals and health care and social workers). Then, we linked the expected time to target (end of third quarter 2021) to the base-case forecast of the Italian GDP. This synchronicity was informed by the economic principle of perfect information, assuming that all analysts at the end of 2020 had perfect and instantaneous knowledge of all market prices, their own utility and their own cost functions. To test the sustainability of the base case, we then shifted the time to economic recovery by a quarter in sync with different assumptions on the impact of a quarter delay in the vaccination programme. The impact of a longer than expected COVID-19 pandemic on the GDP growth was based on previously published scenarios. Linked quarterly data (the base year 2019), seasonally adjusted and adjusted for working days, were used to obtain quarterly GDP values. The growth estimates and scenarios for the impact of the pandemic on GDP derive from the IMF estimates made public at the beginning of 2021.

Our methodological choice allowed us to eliminate a potentially critical bias related to creating a new set of unpublished GDP quarterly forecasts by each scenario. In turn, using a data set already populated prevented us the opportunity to build a GDP forecast from the bottom-up, using all the macroeconomic indicators available at the end of 2020.

Table 4 Best scenario: impact on expected Italian GDP growth of the anticipated attainment 70% coverage of the target Italian population to the end of the second quarter of 2021

Best case vaccination anticipated by 1Q	Chain-linked values €bill base year 2015 (BankItalia)	Actual			Forecast			
		Change % vs Last month (LM)	Change % vs Last year (LY)	Indexed values values 2019 – 1 = 100	Change % vs Last year (LY)	Indexed values values 2019 – 1 = 100	GDP annual Forecast (FCST) €bill (IMF)	Change % vs Last year (LY)
2018 – 1	429.764							
2018 – 2	430.276	0.1						
2018 – 3	430.064	0.0						
2018 – 4	430.426	0.1						
2018 Total	1,720.53							
2019 – 1	431.251	0.2	0.3	100.0				
2019 – 2	432.106	0.2	0.4	100.2				
2019 – 3	432.287	0.0	0.5	100.2				
2019 – 4	430.725	–0.4	0.1	99.9				
2019 Total	1,726.369	0.3		400.3				
2020 – 1	406.907	–5.5	–5.6	94.4				
2020 – 2	353.832	–13.0	–18.1	82.0				
2020 – 3	410.326	16.0	–5.1	95.1				
2020 – 4	402.220	–2.0	–6.6	93.3				
2020 Total	1,573.285	–8.9		364.8				
2021 – 1					2.8	97.0	418.3	
2021 – 2					3.2	84.7	365.2	
2021 – 3					3.6	98.6	425.1	
2021 – 4					3.6	96.6	416.7	
2021 Total						376.9	1,625.3	3.3
2022 – 1					3.6	100.5	433.4	
2022 – 2					3.6	87.7	378.3	
2022 – 3					3.6	102.1	440.4	
2022 – 4					3.6	100.1	431.7	
2022 Total						390.4	1,683.8	3.6

Table 5 Summary of economic impact: the enormity of potential GDP losses indicates that the national vaccination plan against COVID-19 represents the single most significant risk for the recovery of the Italian economy

Scenario impact	2021 Forecast (FCST) €billion	Absolute value change vs base case €bill	% Change vs base case	2022 FCST €billion	Absolute value change vs base case €bill	% Change vs Base case	2021–2022 Impact	Absolute value change vs BASE case €bill	% Change vs base case
Base case	1,620.6			1,678.9			3,299.5		
Worst case vaccination delay	1,524.4	–96.2	–5.9	1,574.8	–104.1	–6.2	3,099.2	–200.3	–6.1
Worst case delay plus new outbreak	1,489.3	–131.3	–8.10	1,538.6	–140.3	–8.36	3,027.8	–271.7	–8.2
Best case	1,625.3	4.7	0.29	1,683.8	4.9	0.29	3,309.0	9.5	0.3

We aimed to minimise the number of variables in the scenario analysis: our economic model was then based exclusively on the time-shift of available quarterly projections based on the expected delay or acceleration of the national vaccination plan against COVID-19. Hence, the choice of the base case assumed critical methodological importance for the reliability of the entire scenario analysis. The revised IMF forecast for the Italian GDP in 2021 and 2022 reflected the primary economic, political and public health information available to the analysts at the end of 2020. The information available at the end of Q4 2020 was consistent with a cyclical decrease in GDP, interrupting the recovery process, which began in May. On average for the year, GDP would mark a marked decline compared to 2019 (−8.9%), influenced by the fall in domestic demand, which, net of inventories, would negatively contribute by 7.5 percentage points, and to a lesser extent, demand. Net foreign exchange, which would provide a negative contribution of 1.2 percentage points. In this context, the resumption of infections is expected to negatively affect the first quarter of 2021, even if the measures launched by the government should allow for partial stability of incomes and containment of unemployment. However, the November confidence data show a generalised deterioration, which has affected expectations on the economic situation and unemployment with greater intensity. For 2020, a considerable reduction in household and ISP consumption is expected in real terms (−10.0%), accompanied by a marked increase in the propensity to save. In 2021, the recovery in consumption would be contained, conditioned by the transition phase of the recovery of expenses in services and the progressive reduction of uncertainty related to implementing the national vaccination plan. In 2021, household spending is expected to pick up (+4.5%). The increase in uncertainty and negative future expectations on production levels have forced companies to review their spending plans in the presence of a low degree of plant utilisation (68.4% the average for the second and third quarters of 2020, down from 77% in 2019). Financing difficulties, albeit mitigated by government measures, constituted a further brake on investment decisions. In the coming months, the recovery of investments by companies appeared to be conditioned by the government's decisions related to the Recovery and Resilience Facility Program. In this context, for 2020, a reduction in gross fixed investments is expected (−10.1%), followed by a recovery in 2021 (+6.2%) (Italian Office of National Statistics, 2020).

The stakes are very high both from a social point of view (number of deaths and flooding of hospitals) and from a strictly economic perspective (impact on GDP). If the vaccination were to see its completion only at the end of 2021 (the so-called "the worst scenario"), estimating a quarter of delay due to the availability of vaccine doses, the overall loss in two years (2021 and 2022) would even reach 270 billion (130 billion in 2021 and 140 billion in 2022).

A scenario in which only between the third and fourth quarter of 2021 (therefore between October and December) the vaccination of 75% of the population will be completed will result in losses of up to 96 billion in 2021 and 104 in 2022 (200 billion overall in the two years).

A best (optimal) scenario, which the government also hopes, in which optimal coverage can be achieved (between 62% and 75%) between the second and third quarter of 2021 (therefore by September), would make it possible to cancel the estimated losses in the other two scenarios. Not only that, in this case, a mini growth is estimated equal to 4.7 billion in 2021 and another 4.9 billion in 2022.

Contributions for practitioners, managers and policymakers

This real impact research article provides several contributions for practitioners, managers and policymakers. The analysis unequivocally demonstrates that the Italian economy from the COVID-19 shock, and consequently the growth of the GDP, is time-dependent on the rollout of the national vaccination plan. Indeed, the failure to contain the pandemic

generates inertia in GDP growth would also cancel the impact of the resources that should come from the recovery fund. This is the fundamental problem for policymakers and managers. In this vein, decision makers must be taking timely strategic actions to fight the emergency of COVID-19. Indeed, a KM perspective can serve practitioners, managers and policymakers to promote the development of the Italian GDP growth rate due to the knowledge shared and gained by scientific evidence.

Through a multi-level knowledge-sharing outlook, KM approach urges decision makers to implement policies to generate the best chance of minimizing the effects of the virus. Indeed, the COVID-19 continues to represent an economic threat, and despite global progress due to vaccines, it is uncertain when the pandemic will ultimately end. As the globe come back to "normality", organizations must leverage KM to its best advantage. Specifically, public organizations should be more prone to shift towards collective intelligence by leveraging the central aspect of this interpretative and operative framework: the management of the common good through collective knowledge creation and sharing within public and private networks (Iandolo *et al.*, 2020; Caputo, 2017).

Acquisition of critical knowledge has proven to be vital for many governments in every crisis period. For example, during the COVID-19 pandemic, the Chinese Government collected a huge mole of data from citizens' devices to develop algorithms able to estimate people's exposure to the virus and to predict efficacious emergency policies. Similarly, the Republic of Korea's, turning on the experiences of the Severe Acute Respiratory Syndrome (2012) and the Middle East Respiratory Syndrome outbreaks (2015), reacted with clear responses to the public health emergency, leveraged by highly data-driven processes shared with public and private actors. The Governments of India and Malaysia launched apps for tracing and controlling the spread of the virus and obtaining knowledge supporting national emergency plans. However, during the early stage of the COVID-19 pandemic, just a few governments have followed a KM approach by implementing promptly the scientists' directives and collective knowledge: total lockdown measures were initially taken only by China, South Korea, Japan and partially, also by Israel and Jordan. After an unmanageable surge in COVID-19 infections, Italy implemented the heavy measures dictated by the scientific experts' guidelines. In the meantime, the USA, the UK and several European countries, including Spain and France, have continued to procrastinate the restrictions, implementing disparate and unified policies. These hesitations have revealed a serious difficulty for several governments to critically analyse scientific data and knowledge to implement public policies.

This study clarifies how relevant it is to collect and acquire critical knowledge to support governments to face crisis periods and how important it is to accelerate as much as possible with vaccination to ensure the start of the nations' economic recovery at the end of the second quarter of 2021. It seems trivial, but a correct analysis of the economic time would avoid rash and costly choices for the Country. We accelerate with vaccinations. We cannot waste any more time!

Today more than ever, politics is called upon to make decisions that will determine our nation's life and the organisational, management and economic structure of our welfare system in the years to come. In the stagnation of the emergency, there is the risk of not predicting what will happen tomorrow. State intervention must be peremptory to respond to the crisis of the moment and avoid even more dramatic future crises and ensure lasting economic sustainability.

The synergy between KM, trust in science and government policies in the management of COVID-19 is becoming, for all intents and purposes, vital.

Conclusion, limits and future avenues

The pandemic situation accelerated and diversified KM trends in public organizations. Specifically, the digital era opens to a new KM paradigm that embraces the systemic view

as a driving element to face negative events relying on a growing collective knowledge-oriented approach (Caputo, 2017; Iandolo *et al.*, 2020; Danõa *et al.*, 2020). Public organizations that do not perceive how relevant managing collective knowledge is may create inefficient strategies and ultimately, in the better of cases, deliver services that do not fit with the citizen's needs. In times of crisis, this failure can cost social well-being.

In 2020, the COVID-19 pandemic hit Italy hard from a health point of view and in the economic and social tissue. The economic indicators show too briefly the enormous difficulties Italian families, workers and companies endure. The problematic context has required the government to adopt a strategy articulated on different plans to contain the spread of the infection and safeguard health, which required the adoption of progressively more stringent social distancing measures, which have suddenly changed the lives of Italians. These measures had a heavy impact on the economic tissue that experienced the worst fall in the GDP in republican history.

The sustainability of the recovery of the Italian economy following the pandemic phase of COVID-19 demands accelerating vaccinations to save more lives and prevent a new great crisis in the economy. Delaying the target of herd immunity towards the end of the year and not at the end of this summer by postponing the openings of all activities without more restrictions (perhaps the obligation to mask and distancing for some) could have an impact of 200 billion on GDP spread between this year (94 billion) and next (106 billion), in practice almost six points of GDP every year after the −8.9% scored in 2020. If, on the other hand, the vaccination campaign ended quickly between the second and third quarters, then a growth of 5 billion (0.3%) could be achieved. All this, however, net of the recovery plan's effect with its investments could already inject oxygen into the economy during the year.

The main limit of the research is the focus solely on Italian GDP, leaving aside detailed analysis of other European and world forecast economies. In this sense, we cannot exclude a different government policy approach from other governments. Future studies should focus on multi-country longitudinal studies to address this challenge.

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