The impact of COVID-19 on the economic performance of Wuhan, China (2019–2021)

Mario Arturo Ruiz Estrada[1,2] · Evangelos Koutronas[3] · Donghyun Park[4] · Alam Khan[5] · Muhammad Tahir[6]

Abstract

This paper attempts to evaluate the impact of massive infectious and contagious diseases and its final impact on the economic performance anywhere and anytime. We are considering to evaluate the case of Wuhan, China. We are taking in consideration the case of COVID-19 to be evaluated under a domestic, national, and international level impact. In this paper, we also propose a new simulator to evaluate the impact of massive infections and contagious diseases on the economic performance subsequently. This simulator is entitled "The Impact of Pandemics on the Economic Performance Simulator (IPEP-Simulator)" Hence, this simulator tries to show a macro and micro analysis with different possible scenarios simultaneously. Finally, the IPEP-Simulator was applied to the case of Wuhan-China respectively.

✉   Mario Arturo Ruiz Estrada
    marioruiz@um.edu.my; m.ruizestrada@vizja.pl

    Evangelos Koutronas
    evangel_gr@um.edu.my

    Donghyun Park
    dpark@adb.org

    Alam Khan
    alamkhan@kust.edu.pk

    Muhammad Tahir
    tahirm@ciit.net.pk

[1]   Centre of Latin America Studies (CLAS), University of Malaya, 50603 Kuala Lumpur, Malaysia

[2]   University of Economics and Human Sciences, Okopowa 59, 01-043 Warszawa, Poland

[3]   School of Mathematical and Data Sciences, West Virginia University, 26506-6310 Morgantown, U.S.

[4]   Asian Development Bank (ADB), 6 ADB Avenue, 1550 Mandaluyong City, Metro Manila, Philippines

[5]   Department of Economics, Faculty of Economics, KUST, Kohat 26000, Khyber Pakhtunkhwa, Pakistan

[6]   Department of Management Sciences, COMSAT Institute of Information Technology, Abbottabad, Pakistan

1 Introduction

From December 2019, an outbreak of a pandemic is emerging caused by a novel coronavirus (called "COVID-19") that was identified in Wuhan City, China. Chinese health ministry have reported thousands of infections with COVID-19 in China, with the virus reportedly spreading in conglomerate places in different parts of China. Infections with COVID-19, most of them associated with travelling from different regions to Wuhan, also are being reported worldwide. At the time of this research paper, WHO[1] reported 32,000 confirmed COVID-19 incidents of which 5000 are in critical condition, 700 died, and 2000 recovered, affecting 200 countries (WHO 2021).

World Health Organization (WHO) is estimated that the COVID-19 case fatality rate has been estimated at around 3.1 percent. The incubation period of the virus may appear in as few as 2 days or as long as 14 (World Health Organization (WHO): 2–15 days and the China's National Health Commission (NHC): 2–15 days, during which the virus is contagious but the patient does not display any symptom. All population groups can be infected by the COVID-19, especially, seniors and people with health problems antecedents followed by: asthma, diabetes, and heart disease appear to be more vulnerable to becoming severely ill with the virus.

The COVID-19 belongs in the coronavirus category that can generate fever, breathing difficulties, pneumonia, and diarrhoea. Others can cause the relatively mild common cold or critical cases. The Severe Acute Respiratory Syndrome (SARS) and the Middle East Respiratory Syndrome (MERS) are prominent examples (see Table 1). It is possible that for a certain number of these illnesses, a yet unknown viral causative agent may be found. Screening for the presence of COVID-19 requires the use of an integrated virology analysis of subsequent biochemical, structural, and phylogenetic studies that can find any virus known at present.

Beyond the public health impacts of global pandemics events lay wider economic consequences that are often not considered in the economic vulnerability. Pandemics set in motion a complex chain of events in the economy in any country. They are rare events, highly volatile over time and across regions. Estimating a pandemic risk depends upon several factors that varied by the type of economic activity. The idiosyncratic nature of any pandemic is based, among others, on the duration of the pandemic, the size of the domestic economy, the business locations affected, the population density and the time framework. If the calculation of the benefic/costs associated with death loss, chronically ill cattle marketed prematurely at a discount, and treatment are readily traceable. The estimation of indirect costs such as reduced performance of the local labor force can be an onerous task.

This paper proposes an analytical framework for estimating the economic consequences of a pandemic both in terms of immediate policy response in the aftermath of the desease and of medium-term policy implications for fiscal policy. The Impact of Pandemics on the Economic

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[1] Our sources include the United Nations Population Division, World Health Organization (WHO), and World Bank.

Table 1 Five pandemics and influenza epidemics in China

Spanish Flu (1918–1920)	Spanish flu (H_1N_1), which occurred during 1918–1920 and now outbreak in China which caused approximately 40–50 million deaths. This disaster in history is known as the greatest medical holocaust (Waring (1971). This pandemic has three different waves, the first was the spring (1918), and the second was fall (1918), while the third was winter (1918–1919) (Johnson and Mueller 2002 and Humphries 2013). The first and third was considered as mild, while second was considered globally disastrous, that caused about ten million deaths. The number of deaths toll revised and told that the original deaths were more than the earlier declared. The revised estimates in 1920s were about 21.5 million, while in 1991 it is recalculated and estimates were between 24.71 and 39.3 million (Jordan 1927; Patterson and Pyle 1991)
Asian flu (1957–1958)	Asian flu(H_2N_2), which occurred during 1957–1958 due to (H_2N_2) strain that outbreak in China and caused one to two million deaths approximately. In 1957, a new type of influenza strain was detected in the Chinese province (Yunnan) (Pyle 1986). Human under the age of 65 years did not possess immunity to this type of strain. From China this type of virus first spreads to Hong Kong, then to Taiwan, Singapore, Japan and then spread all over the world (Fukumi 1959). This pandemic spread mainly through sea and land routes, while some of the proportion through air travel (Pyle 1986). The global transmission mostly occurred through land routes from Russia to Scandinavian countries and then to Eastern Europe (Payne 1958; Langmuir 1961)
Hong Kong Flu (1968–1970)	Hong Kong flu (H_3N_2) that occurred during the period 1968–1970 due to the H_3N_2 strain and it outbreak in China and caused deaths from 0.5 to 2 million (Guan et al. 2010; Reperant et al. 2016). The interesting things is that this type of pandemic is mostly spread through the air travel (Cockburn et al. 1969; Longini et al. 1986). Although this pandemic is highly transmissible, but this was milder than the earlier Asian flu
Swine Flu (2009–2010)	While the Swine flu (H_1N_1) that occurred over the period from 2009 to 2010 in Mexico and deaths toll reached to 575,000 (Guan et al. 2010). This influenza pandemic spread in 30 countries within weeks (Smith et al. 2009) and within four months it reached almost in 122 countries, while 134,000 cases were confirmed and 800 deaths recorded (Henderson et al. 2009)
Wuhan Coronavirus (2020)	This type of virus detected currently in Wuhan (China) and more than 4500 peoples are affected and spreading very rapidly to other areas and countries, so far more than 240 deaths have been recorded. This type of virus causes pneumonia like illness with fever and coughing in many cases of infection. With the fear to affect other people and areas, Chinese government did not allow the citizens of Wuhan to move freely to other regions, and many countries stopped travelling to China with the fear to spread virus

Performance Simulator (IPEP-Simulator)–to evaluate an economy in times of massive infections and contagious diseases The IPEP-Simulator is based on seven basic indicators-(1) the pandemic spread intensity (psi), (2) the level of a pandemic treatment and prevention level (ptp); (3) the massive pandemic causalities ($-$mpc); (4) the economic wear from a pandemic (Пp); (5) the pandemic multiplier effect (Mp); (6) the total economic leaking from a pandemic (ELp); and (7) the economic desgrowth from a pandemic ($-$δp). To illustrate and illuminate the IPEP-Simulator, we apply the simulator to the case of COVID-19. The model investigates the uncertainty and behavioral change under a new perspective within the framework of a dynamic imbalanced state (DIS) (Ruiz Estrada and Yap 2013) and the Omnia Mobilis

assumption (Ruiz Estrada 2011). The different between the IPEP-Simulator and other models. Basically, it is in the strong mathematical background and multidimensional graphical modeling that can give us better results in the short and long run. The major limitation is the lack of data and information from different sources and its consistency. Additionally, the outlook on future research about the impact of pandemics on the economic performance in any country or region consist in the implementation of new models and analytical tools to consolidate better results in the near future to governments and international organizations such as World Bank (WB), International Monetary Fund (IMF), World Health Organization (WHO), United Nations (UN), and NGO's respectively. The paper is organized as follows. Section 4 offers an overview of pandemics in China for the last twenty years. Section 5 describes Wuhan's economy. Section 4 introduces the model. Section 6 sets a simulation framework and presents model findings for the Wuhan province. Section 6 concludes.

2 A general review of the pandemics and influenza epidemics in China

The world and specially China have witnessed the pandemics and influenza epidemics from ancient time to now. It affected millions of people in China and all over the world through different ways of emergence and its transmission. One of them is the pandemic influenza, which is emerged and transmitted in various forms from centuries. Human pandemics are produced by emergence of novel strains of influenza, which caused widespread death, illness and disruption. The history showed there are five influenza pandemics occurred in the last hundred years (see Table 1). During this period, the improvement in medicine, epidemiology, and globalization process changed the way of these pandemics. From the literature it is cleared that these pandemics are the outcomes of human development and due to the eruption of global landscaping according to Kuszewski and Brydak (2000). On the other hand, there are continuous improvements in the prevention, treatment and control of these infectious diseases. Now with the technological advancement human beings are able to control these types of outbreaks, emergence and its transmission. But if proper care is not taken, then due to globalization, free mobility, demographics and human behavior can increase spread of these pandemics easily from one place to other place and it can spread globally. Therefore, it is necessary that proper planning must be present at any to avoid such types of pandemics and when it arises should not be transmitted to other areas and people. There are two subtypes of Influenza virus characterized on the basis of antigenic properties of two surface glayco proteins, i.e. hemagglutinin (H), and neuraminidase (N). There are 18 H subtypes and 11 N sub types identified by the US Centres for Disease Control and Prevention (2014). However, only three of them H_1, H_2, and H_3 are causes transmission from human to human (Webby 2003). Due to drift in Antigenic, causes changes in the encoding of genes H and N antigens. This occurs continuously, and it shrinks the immune system, that causes the occurrence of seasonal influenza (Zambon 1999). Within the last hundred years there are five pandemics occurred due to the emergence of the novel influenza strain, for that human beings had no or weak immunity.

3 A general overview of Wuhan and its economy

Wuhan is basically the capital city of Hubei province and is located in Central China. The Wuhan city is comprising of three sub-parts Wuchang, Hankou and Hanyang. The Wuhan city has a total physical area of 8494 km^2. The total population is 10.60 million which makes

Wuhan one of the most populous cities of central China (Gain Report 2018). It is considered one of the main hubs for both industry and transport for the central China. Cheng and Zhou (2015) highlighted the importance of Wuhan city and endorsed that it is playing a vital role in economic, transportation and educational sectors of the Chinese economy. Cowley et al. (2018) discussed the importance of Wuhan city in terms of transportation and commented that it has linked East with West and South with the North. In recent times, Wuhan established itself as one of the largest hub of industry, commerce, culture and education (Bovenkamp and Fei 2016). The establishment of economic zones have helped the economy of Wuhan a great deal in subsequent years. The establishment of development and high-technology zones have contributed to the industrialization process of the Wuhan economy significantly. The report published by Hubei government in 2013 demonstrated that both development and high-technology zones promoted industrial growth of Wuhan city and the value of output from high-technology industry reached to more than 230 billion RMB. Miura (2017) demonstrated that in 2015, the contribution of high-technology industries in Wuhan's GDP increased to 20.5 percent which is indeed a reflection of strong industrial capability of the Wuhan economy. The official report of Hubei government of 2018 reflected that in 2017, the output value of three strategic industries such as IT, health and life and intelligent manufacturing has been increased by more than 17 percent which is indeed remarkable. Lastly, the Wuhan is also famous for its tourist attractions and in 2014 it earned 28.9 billion dollars from tourism.

The economic performance of the Wuhan has been phenomenal indeed over the years. According to the reports of the government of Hubei, the Wuhan economy achieved a growth rate of 7.8 percent in 2019. The economic growth of Wuhan economy is even higher than the national average growth of Chinese economy. The contribution of high-technology sector and digital economy was estimated to be 24.5 and 40 percent of the GDP respectively. Similarly, in 2018, the Wuhan economy grew at a remarkable growth of 10.7 percent and reached to 1484 billion RMB (Daxueconsulting 2019). According to statistics, the GDP of Wuhan was 1090.56 billion RMB in 2015 and the growth rate of the economy was 8.8 percent which is indeed a significant improvement as compared to previous years. The breakdown of GDP shows that the contribution of industrial sector is 45.7 percent in GDP followed by service sector 51 percent. The share of agriculture sector in Wuhan GDP is marginal as its contribution is only 3.3 percent. In 2013, Wuhan economy was the ninth largest urban economy in China as its GDP crossed 900 billion RMB (Ke and Wang 2016). The policy makers set targets of achieving GDP worth 1900 billion RMB in 2020 with an ambitious growth rate of 11 percent (Gain Report 2018). Overall, the growth of Wuhan economy is directly linked with the growth of Chinese economy. Wuhan is considered the industrial, financial and transportation hub of Chinese economy and therefore, its growth is important for the rest of Chinese economy. Important growth-promoting industries such as automotive, manufacturing, iron and steel, electronic and food processing are located in Wuhan. The contribution of Wuhan economy in the overall growth of Chinese economy is quite substantial. In 2019, the growth of Wuhan economy was higher than the average growth of Chinese economy. The statistics of 2019 shows that the GDP growth of Wuhan was 8.8 percent which was highest in Central China and it secured 8th position among 100 major cities in China (Canada Trade Commissioner Report).

4 An introduction to the impact of pandemics on the economic performance simulator (IPEP-Simulator)

The primary objective of this paper is to set forth a simulator—The Impact of Pandemics on the Economic Performance Simulator (IPEP-Simulator)–to evaluate an economy in times of massive pandemic. The IPEP-Simulator is based on seven basic indicators—(1) the pandemic spread intensity (psi), (2) the level of a pandemic treatment and prevention level (ptp); (3) the massive pandemic causalities (− mpc); (4) the economic wear from a pandemic (Пp); (5) the pandemic multiplier effect (Mp); (6) the total economic leaking from a pandemic (ELp); and (7) the economic desgrowth from a pandemic (− δp). The methodology and approach used in the IPEP-Simulator applies different elements from an alternative mathematical and graphical analytical framework. To illustrate and illuminate the IPEP-Simulator, we apply the simulator to the case of COVID-19. We believe that our research makes a significant contribution to a more systematic, analytical and accurate measurement of the economic impact of a pandemic anywhere and anytime.

An important value-added of the IPEP-Simulator, in the context of contributing to a more precise understanding of a pandemic, is that it accounts for the uncertainty and behavioural change inherent in new pandemics or consolidation of old pandemics respectively. The simulator does so within the theoretical framework of a Dynamic Imbalanced State (DIS) (Ruiz Estrada and Yap 2013) and the Omnia Mobilis assumption (Ruiz Estrada 2011). The idea is to move beyond classical economic models–e.g. CGE modeling and any classic econometric modelling—to a new economic mathematical modeling and mapping of a pandemic—e.g. ex-ante (before the pandemic appear) versus ex-post (after the pandemic appear)—by utilizing high resolution multidimensional graphs (Ruiz Estrada 2017) and maps. This alternative analytical framework can yield interesting and relevant insights which can improve and strengthen the measurement of the economic effects of any pandemic.

In this section, we derive the IPEP-Simulator presents firstly three basic indicators: (1) the pandemic spread intensity (psi); (2) the level of a pandemic treatment and prevention level (ptp); (3) the massive pandemics causalities (− mpc). The IPEP-Simulator uses three different groups of organizations. The first group is the domestic health organizations–hospitals-(H_i; i=(1, 2,…, ∞)). The second group is the regional health organizations (RH_j; j=(1, 2,…, ∞)). The last group is the large international health organizations (LH_k; k=(1, 2,…, ∞).

4.1 Initial pandemic stage

The IPEP-Simulator assumes that there are four root causes of the infection and contagious disease: (1) MERS (R_1); (2) SARS (R_2); (3) Ebola (R_3); and (4) COVID-19 (R_4). These four factors directly affect "the pandemic spread intensity (psi)", which is a function of four variables (see Expression 1).

$$psi = f\left(R_1, R_2, R_3, R_4\right) \tag{1}$$

So, the following measure is to compute the minimum and maximum level of the pandemic spread intensity (psi) through the application of the first derivative according to (2) and (3).

$$f'(\text{psi}) = \left(\partial\text{psi}/\partial R_1\right) + \left(\partial\text{psi}/\partial R_2\right) + \left(\partial\text{psi}/\partial R_3\right) + \left(\partial\text{psi}/\partial R_4\right) \tag{2}$$

$$f'(\text{psi}) = \sum \left(\lim_{\Delta R1 \to 0} \Delta\text{psi}/\Delta R_1\right) + \left(\lim_{\Delta R2 \to 0} \Delta\text{psi}/\Delta R_2\right) + \left(\lim_{\Delta R3 \to 0} \Delta\text{psi}/\Delta R_3\right) + \left(\lim_{\Delta R4 \to 0} \Delta\text{psi}/\Delta R_4\right) \tag{3}$$

Moreover, the pandemic spread intensity (psi) applies a second derivative to find the inflection point according to Expression 4.

$$f''\left(R_1, R_2, R_3, R_4\right) = \left(\partial^2\text{psi}/\partial R_1^2\right) + \left(\partial^2\text{psi}/\partial R_2^2\right) + \left(\partial^2\text{psi}/\partial R_3^2\right) + \left(\partial^2\text{psi}/\partial R_4^2\right) \tag{4}$$

To probe the pandemic spread intensity (psi), we apply the Jacobian determinants under the first-order derivatives (see Expression 5).

$$|J'| = \begin{pmatrix} \partial\text{psi}/\partial R_1 & \partial\text{psi}/\partial R_2 \\ \partial\text{psi}/\partial R_3 & \partial\text{psi}/\partial R_4 \end{pmatrix} \tag{5}$$

On the other hand, the application of the Jacobian determinants under the second-order derivatives can help to find the inflection point in the pandemic spread intensity (psi) between the two players: (1) the health organizations effectiveness (hospitals) (P_1) and (2) all infected cases from COVID-19 under control (P_2) see Expression 6.

$$|J''| = \begin{pmatrix} \partial^2\text{psi}/\partial^2 R_1^2 & \partial^2\text{psi}/\partial^2 R_2^2 \\ \partial^2\text{psi}/\partial^2 R_3^2 & \partial^2\text{psi}/\partial^2 R_4^2 \end{pmatrix} \tag{6}$$

Consequently, the initial massive infections and diseases contagious stage is necessary to assume that any pandemic spread intensity (psi) (endogenous variable) is going to determine the level of the pandemic treatment and prevention level (ptp) (exogenous variable) in the form of interaction among the domestic health organizations–hospitals-(H_i; i = (1,2,…, ∞)), the regional health organizations (RH_i; i = (1, 2,…, ∞)), and the large international health organizations such as world health organization (WHO) (LH_k; k = (1, 2,…, ∞)). In this part of the IPEP-Simulator if the pandemic spread intensity (psi) is escalating then the level of the pandemic treatment and prevention level (ptp) is going to be more intensive until all possibilities to eradicate less causalities and potential causalities are exhausted. Hence, the level of the pandemic treatment and prevention level (ptp) depends directly on the pandemic spread intensity (psi) in the short run.

Figure 1 shows the relationship between the pandemic spread intensity (psi) and the pandemic treatment and prevention level (ptp). The relationship is an exponential curve in the 2-dimensional Cartesian plane. The interaction of three organizations such as the domestic health organizations (DO), the regional health organizations (RO), and the large international health organizations (LO) such as world health organization (WHO) may play a crucial role in the pandemic treatment and prevention level (ptp). If the pandemic spread intensity (psi) rises, then the pandemic treatment and prevention level (ptp) will play an important role in reducing number of causalities from any pandemic efficiently according to Fig. 1.

4.2 The fast pandemic spread stage

The rapidly pandemic spread stage consists of two stages—(1) the national pandemic spread stage and (2) the worldwide pandemic spread stage.
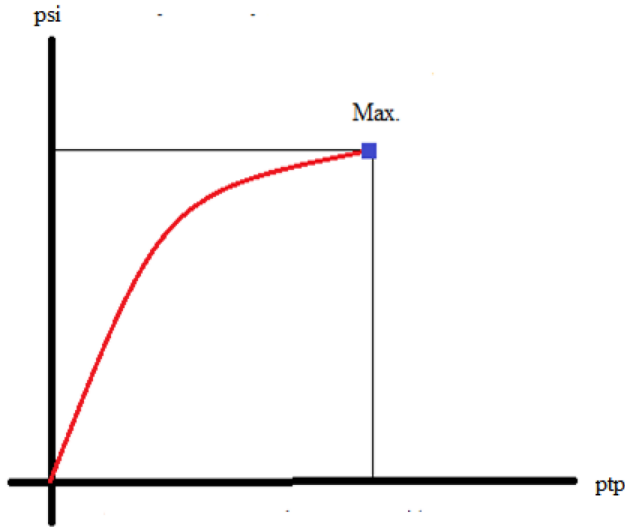
Fig. 1 The relationship between the pandemic speed intensity (psi) and the pandemic treatment and prevention level (ptp). *Source*: Authors

4.2.1 The national pandemic spread stage

In the national pandemic spread stage, it is necessary to assume that both players such as (1) the domestic health care effectiveness–hospitals—control a massive infected cases (P_1) and (2) all sick patients from a pandemic is under control (P_2) have different levels of Respond (R) and Safety (S) [see (7)].

$$P_1(R) \Leftrightarrow P_2(S) \tag{7}$$

Therefore, the pandemic spread intensity (psi) for both players (P_1, P_2) have different proportions (Δ) according to (8).

$$P_1(\Delta\text{psi}) \Leftrightarrow P_2(\Delta\text{psi}) \tag{8}$$

Thus,

$$P_1\left(\Delta\text{psi}^{\text{respond}}\right) \Leftrightarrow P_2\left(\Delta\text{psi}^{\text{safety}}\right) \tag{9}$$

In the psi, both players fully exist different proportions of expansion to find its critical point and solve fully complete to cover fully the national psi. This means that if the psi reaches its maximum limit then the ptp success. Accordingly, this part of the IPEP-Simulator requires the application of a second derivative to observe the estimate the inflection point.

4.2.2 The worldwide pandemic spread stage

If a worldwide infection and disease spread starts now then the respond (R) and safety levels (S) needs to take fast actions quickly, butt in different magnitudes [$P_1(\Delta R)P_2(\Delta S)$]. The psi is going to define the ptp worldwide respectively. The massive pandemic causalities

($-$mpc) is calculated using nine main variables. These nine variables are based on: (1) poor mass media access (V_1); (2) the limited beds in hospital (V_2); (3) poor access to medicines (V_3); (4) weak social platform protections access (V_4); (5) water pollution levels (V_5); (6) air pollution (V_6); (7) limited healthiness measures (V_7); (8) poor international health cooperation (V_8); and (9) poor knowledge about diseases (V_9) see Expression 10. The IPEP-Simulator also assumes that in the long run a high psi is going to define $-$mpc directly. Hence, an uncontrolled national psi albeit to different places worldwide dramatically.

$$|J'(\Delta V)| = \begin{pmatrix} \partial V_{1(t+1)}/\partial V_{1(t-1)} & \partial V_{2(t+1)}/\partial V_{2(t-1)} & \partial V_{3(t+1)}/\partial V_{3(t-1)} \\ \partial V_{4(t+1)}/\partial V_{4(t-1)} & \partial V_{5(t+1)}/\partial V_{5(t-1)} & \partial V_{6(t+1)}/\partial V_{6(t-1)} \\ \partial V_{7(t+1)}/\partial V_{7(t-1)} & \partial V_{8(t+1)}/\partial V_{8(t-1)} & \partial V_{9(t+1)}/\partial V_{9(t-1)} \end{pmatrix} \qquad (10)$$

The final calculation is shown in (11).

$$-\text{mpc} = 1\big/|J'(\Delta V)| \qquad (11)$$

Therefore, the economic wear from a pandemic (Π_p) depends on the changes of the psi and $-$mpc according to expression 12.

$$\Pi_p = f(\text{psi}, -\text{mpc}) \qquad (12)$$

The final step is to calculate the economic wear from a pandemic (Π_p) according to expression 13.

$$\Pi_p = \big[f'(-\text{mpc}) : f'(\text{psi})\big]^{-n} \qquad (13)$$

To find the present value of the economic wear from a pandemic (Π_p) under a uniform rate of the psi and $-$mpc per year, we assume a continuous discount rate of $-$n. Hence, we estimate the Π_t by first-order derivatives (see Expression 14). In fact, we apply the second-order derivative on the Π_p to find the inflection point see expression 15.

$$\Pi'_p = \partial \Pi_{p(t)}\big/\partial \Pi_{p(t+1)} \qquad (14)$$

$$\Pi''_p = \partial^2 \Pi_{p(t)}\big/\partial \Pi^2_{p(t+1)} \qquad (15)$$

4.3 Post pandemic contagious recovery

Initially, all sick patients from a massive pandemic contagious (P_2) show a considerable deceleration respectively. Hence, we can calculate the final amount of the massive pandemic causalities ($-$mpc) and the economic wear from a pandemic (Π_p). The IPEP-Simulator assumes that all organizations such as domestic, regional, and the large international health organizations (WHO) need to unified efforts will find it difficult to respond from the post pandemic recovery. The Π_p from the post massive pandemic recovery will levy huge burden to its own economy which will slow down the domestic economy anytime. Intuitively, recovery from the Π_p needs a considerable period of time until the pandemic has an effective medication and a massive systematic control of quarantine. To improve the Π_p

requires a post-reconstruction programs and society re-organizing in order to rebuild any economy faster.

In the long run the recovery of all sick patients from a pandemic can experience different magnitudes (Δ). At the same time, this recovery depends highly on the -mpc. Additionally, the recovery of all sick patients from a pandemic contagious highly depend on their integral health system, civil society cooperation, and political support until the $-$mpc is almost or equal to zero.

$$-\text{mpc} = 0 \qquad (16)$$

4.4 The pandemic multiplier effect (Mp)

The pandemic multiplier effect (Mp) calculation is equal to one divided by the final result from the annual population growth rate ($\Delta P_{\text{idc-annual}}$) minus -mpc growth rate ($\Delta - L_{\text{idc-annual}}$). Subsequently, we can observe how a large pandemic magnitude allows us to elaborate suitable policies using the formula below (see Expression 17):

$$M_p = 1 \Big/ \left(\left(\Delta P_{\text{idc-annual}} \right) - \Delta \left(-\text{mpc}_{\text{-annual}} \right) \right) \qquad (17)$$

4.5 Economic desgrowth from pandemics ($-\delta_p$)

In this section, we discuss the concept of the economic desgrowth from a pandemic ($-\delta_p$) (Ruiz Estrada et al. 2014), which plays an essential role in the construction of the IPEP-Simulator. The main objective of inclusion of "economic desgrowth from a pandemic ($-\delta_p$)" is to create an alternative health-socio-economic indicator that can help us to analyze how evaluate any pandemic can adversely affect GDP in the short run. Additionally, the $-\delta_p$ assumes that there are irregular oscillations. The IPEP-Simulator assumes that any pandemic is always in a constant chaos. The $-\delta_p$ applies different random intervals to evaluate unexpected shocks from different controlled and non-controlled factors. A pandemic cannot be anticipated easily by traditional methods of linear and non-linear mathematical modelling. In addition, the IPEP-Simulator assumes that the $-\delta_p$ has a substantial connection of (EL_p).

The EL_p is based on nine variables: (1) α_{11} is equal to R_1 (food security) to the power of β_1 (consumption); (2) α_{12} is equal to R_2 (exports) to the power of β_2 (industrial output growth rate); (3) α_{13} is equal to R_3 (imports) to the power of β_3 (tariffs growth rate); (4) α_{14} is equal to R_4 (airways and tourism) to the power of β_4 (tourism growth rate); (5) α_{21} is equal to R_5 (exchange rate) to the power of β_5 (currency depreciation growth rate); (6) α_{22} is equal to R_6 (government spending) to the power of β_6 (public health budget growth rate); (7) α_{23} is equal to R_7 (sells online) to the power of β_7 (PPP growth rate); (8) α_{24} is equal to by R_8 (financial service) to the power of β_8 (stock market performance growth rate); (9) α_{31} is equal to R_9 (public services –electricity, water, education) to the power of β_9 (public services demand and supply growth rate). The final measurement of the EL_p is derived by applying a large number of multi-dimensional partial derivatives on each variable (9 variables) to evaluate the changes of each variable (9 variables) based on the first derivative (between the present year ($t+1$) and the previous year ($t-1$) (see Expression 18).

$$\Delta R_i = \sum \partial R^{\beta}_{i(t+1)} \Big/ \partial R^{-\beta}_{i(t-1)} \geq R_+ \geq 0 \tag{18}$$

Next step is to convert from ΔR_i^{β} to $\Delta R_i^{-\beta}$ (see Expression 19).

$$\left[0 \leq 1 \Big/ \partial R^{\beta}_i \geq 1 \right] = \left[0 \leq \partial R^{-\beta}_i \geq 1 \right] \tag{19}$$

Next step in this part of the IPEP-Simulator need to run nine first partial derivatives simultaneously to evaluate all possible changes in each economic leaking from a pandemic (EL_p) in a fixed period of time (one year) according to all expression (20).

$$
\begin{aligned}
\alpha'_{11} &= [0 \geq \partial R^{\beta 1}_{1(t+1)} \Big/ \partial R^{\beta 1}_{1(t-1)} \leq 1]; \\
\alpha'_{12} &= [0 \geq \partial R^{\beta 2}_{2(t+1)} \Big/ \partial R^{\beta 2}_{2(t-1)} \leq 1]; \\
\alpha'_{13} &= [0 \geq \partial R^{\beta 3}_{3(t+1)} \Big/ \partial R^{\beta 3}_{3(t-1)} \leq 1]; \\
\alpha'_{21} &= [0 \geq \partial R^{\varepsilon 5}_{5(t+1)} \Big/ \partial R^{\varepsilon 5}_{5(t-1)} \leq 1]; \\
\alpha'_{22} &= [0 \geq \partial R^{\beta 6}_{6(t+1)} \Big/ \partial R^{\beta 6}_{6(t-1)} \leq 1]; \\
\alpha'_{23} &= [0 \geq \partial R^{\beta 7}_{7(t+1)} \Big/ \partial R^{\beta 7}_{7(t-1)} \leq 1]; \\
\alpha'_{31} &= [0 \geq \partial R^{\beta 9}_{9(t+1)} \Big/ \partial R^{\beta 9}_{9(t-1)} \leq 1]; \\
\alpha'_{32} &= [0 \geq \partial R^{\beta 10}_{10(t+1)} \Big/ \partial R^{\beta 10}_{10(t-1)} \leq 1]; \\
\alpha'_{33} &= [0 \geq \partial R^{\beta 11}_{11(t+1)} \Big/ \partial R^{\beta 11}_{11(t-1)} \leq 1]
\end{aligned}
\tag{20}
$$

The next step in the calculation of total economic leaking from pandemics (EL_p) is to calculate the Jacobian determinant under the first-order derivatives according to the expression 21.

$$j^{-1} = \begin{pmatrix} \alpha'_{11} & \alpha'_{12} & \alpha'_{13} \\ \alpha'_{21} & \alpha'_{22} & \alpha'_{23} \\ \alpha'_{31} & \alpha'_{32} & \alpha'_{33} \end{pmatrix} \tag{21}$$

The final step is to determine the total economic leaking from a pandemic (EL_p) by dividing 1 by the inverse matrix from expression 21 to the power of 2 refer to the expression 22.

$$EL_p = 1 \Big/ \left(j^{-1} \right)^2 \tag{22}$$

Lastly, it is possible to calculate economic desgrowth from pandemic ($-\delta_p$) as in the expression 23.

$$-\delta_p = \sqrt{GDP_r \left(1/EL_p - 1 \right)} \Rightarrow 0 \geq -\delta_p \leq -1 \tag{23}$$

The computation of the $-\delta_p$ is based on the GDP in real prices (GDP_r) and EL_p from the expression 22. This part of the IPEP-Simulator reminds us that EL_P always affects the $-\delta_p$ behavior according to Fig. 2.
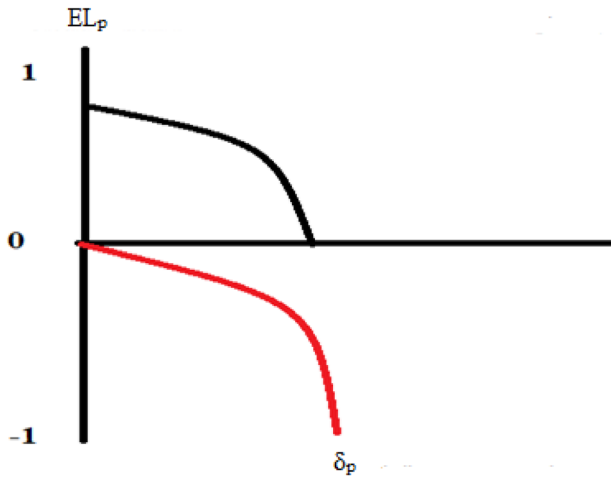
Fig. 2 The relationship between the EL_p and $-\delta_p$. *Source*: Authors

The $-\delta_p$ is based on the application of the Omnia Mobilis assumption of Ruiz Estrada and Park (2018) to generate the relaxation of the EL_p calculation and the full potential GDP_p (See Expression 24). Therefore, the *Omnia Mobilis* setting, the $-\delta_p$ generates the relaxation of the EL_p calculation (non-controlled and controlled events) and the full potential GDP_p. It is plausible to expect that the aftermath of COVID-19 outbreak to cause widespread economic disruption. The COVID-19 suggests that the likelihood and magnitude of economic desgrowth from the pandemic $(-\delta p)$.

5 The Application of IPEP-Simulator on the Case of Wuhan, China

According to the IPEP-Simulator, it is possible to observe that the psi between SARS in year 2003/2004 (Hong Kong (psi) = 0.55 with a probability of contagious is equal to P = 5/10,000 people) and Coronavirus in year 2020 (Wuhan (psi) = 0.77 with a probability of contagious is equal to P = 10/10,000 people). This calculation is based on the number of cases daily in a period of 15 days. On another hand, the massive infections and diseases contagious speed intensity (psi) in the case of SARS between domestic expansion (0.40/1) and global expansion (0.55/1).

However, the psi in the case of Coronavirus between domestic expansion (0.99/1) and global (0.95/1), it is mean that SARS shows a fast expansion globally more than locally and vice versa. Therefore, we can confirm that the Coronavirus is more deadly than SARS domestically, we can confirm from now anytime can appear a new virus mutation with more strong defences and a high difficulty to fight and control in areas with high population concentration.

In the case of the ptp between SARS in year 2003/2004 (Hong Kong (ptp) = 0.87 with a capability to attend cases of 10 beds/for each 1000 people) and Coronavirus in year 2020 (Wuhan (ptp) = 0.93 with a capability to attend cases of 3 beds/for each 10,000 people). We can observe that main land China is prepared for an immediately massive pandemic action plan and infrastructure. Only, recently the Chinese government is building a mega hospital in few days at Wuhan to attend more cases with COVID-19. Hence, the COVID-19

patients' causalities ($-$mpc) between SARS in year 2003/2004 (Hong Kong ($-$mpc)$=0.45$ with a probability of SARS causalities is equal to P$=1$ causality/100,000 people) and COVID-19 in year 2020 (Wuhan $-$mpc$=0.75$ with a probability of COVID-19 causalities is equal to P$=3$ causalities/10,000 people) respectively.

The economic wear from a pandemic (Π_p) between SARS in year 2003/2004 (Hong Kong (Π_p)$=0.25$ and COVID-19 IN year 2020 (Wuhan (Π_P)$=0.77$. We can observe that the impact of COVID-19 in year 2020 is going to have 5 times more negative impact on the Chinese economy than SARS in year 2003/2004 according to our results. Subsequently, the pandemic multiplier effect (Mp) between SARS in year 2003/2004 (Hong Kong (M_p)$=0.37$ and COVID-19 in year 2021 (Wuhan (M_p)$=0.95$. These results can show us the magnitude of any pandemic multiplier effect and its impact on any economy in the short run anytime. In fact, the total economic leaking from a pandemic (EL_p) show that between SARS in year 2003/2004 (Hong Kong (EL_p)$=-0.25$ and COCID-19 in year 2021 (Wuhan (EL_p)$=-0.75$. It is mean that by each one percent of the GDP$_{\text{full-potential}}$ growth rate of Wuhan in the present year, Wuhan can lose easily approximately -0.65 per a unit of growth rate. Additionally, we can observe the next results using the nine sub-variables of (EL_p): (1) food consumption$=-0.55$; (2) exports$=-0.75$; (3) imports$=+0.55$; (4) airways and tourism$=-0.99$; (5) exchange rate$=-0.35$; (6) government spending$=+0.88$; (7) sells online$=-0.97$; (8) financial service$=-0.45$; (9) public services$=-0.85$. Finally, the economic desgrowth from pandemics ($-\delta_p$) between SARS in year 2003/2004 (Hong Kong ($-\delta_p$)$=-0.27$ and COVID-19 year 2020 (Wuhan $-\delta_p$)$=-0.77$). According to our calculations, Wuhan economy can drop its GDP$_{(\text{year 2019})}=6.3\%$ to GDP$_{(\text{year 2020})}=$ GDP$_{\text{real-price}}=2.7\%$ (see Fig. 3). We predict that Wuhan can lose from its GDP$_{\text{real-price}}$ between 2 and 3%.

6 Conclusions

The COVID-19 is a major infections and diseases contagious in Asia with outsized economic repercussions for the Wuhan economy. The Wuhan economy is the seventh biggest economy within China, a global trade and manufacturing center. The uncontrolled COVID-19 is still unclear at the time of this writing. Assessment of the potential economic effects of COVID-19 is unpredictable and inconsistent to calculate the final impact on the Wuhan economy. More recently, in line with Wuhan emergence as a China significant economic power, Wuhan has become one strategic industrial partner of the large Chines economy, which are semi-open and highly integrated into the global economy.

The central objective of this paper is to empirically assess the effect of COVID-19 in the Wuhan trade and financial markets. To do so, we develop a new simulator—the IPEP-Simulator (The Impact of Pandemics on the Economic Performance Simulator). The simulator is based on seven main indicators, (1) the pandemic spread intensity (psi), (2) the level of a pandemic treatment and prevention level (ptp); (3) the massive pandemic causalities ($-$mpc); (4) the economic wear from a pandemic (Πp); (5) the pandemic multiplier effect (Mp); (6) the total economic leaking from a pandemic (ELp); and (vii) the economic desgrowth from a pandemic ($-\delta$p). To assess the impact of COVID-19 on the Wuhan economy, we use the IPEP-Simulator to analyze and compare pandemic spread versus post- pandemic spread. The comparative analysis indicates that COVID-19 will have a deep negative economic effect on the Wuhan economy. More precisely, our simulation results indicate that the Wuhan GDP$_{\text{real-prices}}$ falls from
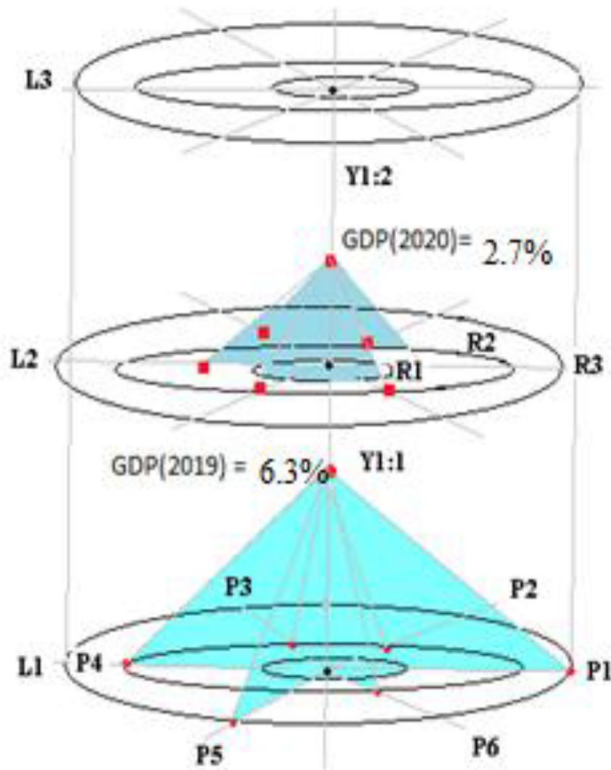
Fig. 3 The visualization of the Chinese GDP after COVID-19 effect between year 2019 and year 2020. *Source*: (Ruiz Estrada 2017)

GDP$_{real\text{-}prices}$ = 5.2% to (GDP$_{real\text{-}prices}$ = 2.3%) (See Fig. 3). In addition, the COVID-19 will affect the economic growth of East Asia and Southeast Asia considerably. Finally, it is important to note that the IPEP-Simulator represents a useful new analytical tool which can help policymakers and researchers evaluate the effect of a pandemic on the economy, international trade, and financial transactions domestically and globally. The small amount of economic studies about the impact of pandemics on the economic performance in the short run, however, important in that they highlight the areas that are disproportionately prone to be evaluated deeply, such as the role of relationship between pandemics and economic performance because of the uncertainty of appearance of any massive pandemic anytime and anywhere. To engage civil society, government, and private sector to planning and coordinate dynamic and suitable programs to monitoring any pandemic just at time should be implemented.

Declarations

References

Bovenkamp, J., Fei, Y.: Economic overview of Hubei Province. Netherland Enterprise Agency. https://www.rvo.nl/sites/default/files/2016/08/Economic-overview-Hubei-province-China.pdf (2016). Accessed 31/01/2020

Centers for disease control and prevention: types of Influenza viruses. http://www.cdc.gov/flu/about/viruses/types.htm (2014). Accessed 31 Jan 2020

Cheng, J., Zhou, J.: Urban growth in a rapidly urbanized mega city: Wuhan. In: Singh, R.B. (ed.) Urban Development Challenges, Risks and Resilience in Asian Mega Cities, pp. 301–322. Springer, Tokyo (2015)

Cockburn, W.C., Delon, P.J., Ferreira, W.: Origin and progress of the 1968–69 Hong Kong influenza epidemics. Bull. World Health Organ. **41**, 345–348 (1969)

Cowley, R., Caprotti, F., Ferretti, M., Zhong, C.: Ordinary Chinese smart cities: the case of Wuhan. In: Karvonen, A., Cugurullo, F., Caprotti, F. (eds.) Inside Smart Cities: Place, Politics and Urban Innovation, pp. 45–64. Routledge, London (2018)

Daxueconsulting: The economy of Wuhan: a hub of commerce, education, industry and politics. https://daxueconsulting.com/wuhan-economy/ (2019). Accessed 1/2/2020

Fukumi, H.: Summary report of the Asian influenza epidemic in Japan, 1957. Bull. World Health Organ. **20**, 187–198 (1959)

Gain Report: Emerging city market report-Wuhan. Report No. CH178043. https://www.fas.usda.gov/data/china-emerging-city-market-report-wuhan (2018). Accessed 29/01/2020

Guan, Y., Yikaykrishna, D., Bahl, J., Zhu, H., Wang, J., Smith, G.J.: The emergence of pandemic influenza viruses. Protein Cell **1**, 9–13 (2010)

Henderson, D., Courtney, B., Inglesby, T., Toner, E., Nuzzo, J.: Public health and medical responses to the 1957–58 influenza pandemic. Biosecur. Bioterror. **7**, 265–273 (2009)

Humphries, M.: Paths of infection: the First World War and the origins of the 1918 influenza pandemic. War Hist. **21**, 55–81 (2013)

Johnson, N., Mueller, J.: Updating the accounts: global mortality of the 1918–1920 "Spanish" influenza pandemic. Bull. Hist. Med. **76**, 105–115 (2002)

Jordan, E.O.: Epidemic Influenza: A Survey. American Medical Association, Chicago (1927)

Ke, Q., Wang, W.: The factors that determine shopping center rent in Wuhan, China. J. Prop. Invest. Financ. **34**, 172–185 (2016)

Kuszewski, K., Brydak, L.: The epidemiology and history of influenza. Biomed. Pharmacother. **54**, 188–195 (2000)

Langmuir, A.D.: Epidemiology of Asian influenza. Am. Rev. Respir. Dis. **83**, 2–18 (1961)

Longini, I., Fine, P., Thacker, S.T.: Predicting the global spread of new infectious agents. Am. J. Epidemiol. **123**, 383–391 (1986)

Miura, Y.: China's economy. Mizuho China monthly. https://www.mizuhobank.com/fin_info/cndb/economics/monthly/pdf/R512-0099-XF-0105.pdf (2017). Accessed 1–2–2020

Patterson, K.D., Pyle, G.F.: The geography and mortality of the 1918 influenza pandemic. Bull. Hist. Med. **65**, 4–21 (1991)

Payne, A.M.: Symposium on the Asian influenza epidemic. Proc. r. Soc. Med. **51**, 1009–1015 (1958)

Pyle, G.F.: The Diffusion of Influenza: Patterns and Paradigms. Rowan & Littlefield, Totowa (1986)

Reperant, L., Moesker, F.M., Osterhaus, A.D.: Influenza: from zoonosis to pandemic. Eur. Respir. Soc. J. **2**, 1–4 (2016)

Ruiz Estrada, M.A.: Policy modeling: definition, classification and evaluation. J. Policy Model. **33**(4), 523–536 (2011)

Ruiz Estrada, M.A.: An alternative graphical modeling for economics: econographicology. Qual. Quant. **51**(5), 2115–2139 (2017)

Ruiz Estrada, M.A., Park, D.: The past, present, and future of policy modeling. J. Policy Model. **40**(1), 1–15 (2018)

Ruiz Estrada, M.A., Yap, S.F.: The origins and evolution of policy modeling. J. Policy Model. **35**(1), 170–182 (2013)

Ruiz Estrada, M.A., Yap, S.F., Park, D.: The natural disasters vulnerability evaluation model (NDVE-Model): an application to the Northeast Japan earthquake and tsunami of March 2011. Disasters **38**(S2), s206–s229 (2014)

Smith, G.J., Vijaykrishna, D., Bahl, J., Lycett, S., Worobey, M., Pybus, O.G., Ma, S.K., Cheung, C.L., Raghwani, J., Bhatt, S., et al.: Origins and evolutionary genomics of the 2009 swine-origin H1N1 influenza A epidemic. Nature **459**, 1122–1125 (2009)

Waring, J.: A History of Medicine in South Carolina. South Carolina Medical Association, Columbia (1971)

Webby, R.J., Webster, R.G.: Are we ready for pandemic influenza? Science **302**, 1519–1522 (2003)

WHO: COVID-19. www.who.org (2021). Accessed 31/01/2021

Zambon, M.: Epidemiology and pathogenesis of influenza. J. Antimicrob. Chemother. **44**, 3–9 (1999)

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