



Does COVID-19 Pandemic Impact on China's Economy Structure and Sustainability of Deep Economic Determinants?

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ABSTRACT

The outbreak of COVID-19 has impacted on the global economy since 2020. This paper employs regression models to investigate China's economy structure and sustainability of deep determinants, such as human capital, business environment. It finds that the central government likes to adjust China's economy structure to mitigate the impact of crucial crisis to remain economic sustainability. Additionally, COVID-19 like SARS has no impact on Chinese economic sustainability, because this pandemic is unable to effect economic deep determinants in the short run. Human capital accumulation is the significant deep factors, and COVID-19 epidemic has no impact on these long-run factors during a short period. It suggests further human capital including labor quantity and education is currently the most significant determinants for China's economy sustainability, followed by the upgrading business environment.

Keywords: COVID-19, Economy Structure, Deep Determinants, Economic Sustainability

JEL Classifications: O11, O40, O53

1. INTRODUCTION

A wide range of media coverage reports that COVID-19 pandemic has impacted on not only the Chinese economy, but also the global economy. While a year late, some studies suggests that China's economy is achieving the V shaped economic recovery from the COVID-19 pandemic¹. These points of view are demonstrated by some latest research (Pan et al., 2020; Liu et al., 2020; Liu, 2021). In fact, China's economy did it. According to the annual report by National Bureau of Statistics of China, China's GDP had growth of 2.3% and initially reached 100 trillion (RMB) in 2020. By the first quarter, China's economy growth has been back to 6.7% over the rate before COVID-19.

Why is China the first country to recover from the pandemic? And what drives China's economic sustainability? This is the motivation

to do this research. Some reasons were uncovered. Liu (2021) attributes it to Chinese government policy measurements, and Duan et al. (2020) attribute it to the Chinese suppressed consumption demands. Mckibbin and Fernando (2020) documents that economic costs could be significantly avoided with greater investment in public health systems in all economics, where health systems are less developed and population density is high, such as China.

According to Piccarozzi et al. (2021), vast majority of COVID-19-related research mainly focuses on the short-term impact of the pandemic on financial markets, such as Papadamou et al. (2021), Liu (2021) and Liu et al. (2020), most of them are survey-specific studies. Few studies theoretically discuss COVID-19 potential impact on economy in the long run. This paper, from economy structure and deep economic determinant perspective, evaluates the potentially impact of COVID-19 pandemic on Chinese economy sustainability. Based on economy data of 1978-2020, This study employs regression models from Chen and Feng

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(2000) to identify the steady-going factors, namely deep economic determinants (Bhattacharyya, 2004; Glawe and Wagner, 2019) driving China's economy in the long run.

This paper suggests that the Chinese government adeptly in adjusting economy structure actively to recover from COVID-19 as quick. Meanwhile, this pandemic is unlikely to hit Chinese deep economy determinants within short period, such as political stability (Jong-A-Pin, 2009), human capital (Chen and Feng, 2000), economy integration (Bhattacharyya, 2004), which drive China's economic sustainability. Thus, Adjustable economy structure secures economy recovery and ongoing deep economic determinants maintains economy sustainability.

The rest of the paper is organized as: Section 2 reviews literature and develops a hypothesis; Section 3 describes data, methodology and variables; Section 4 presents some results and discussions; Section 5 concludes this paper.

2. LITERATURE REVIEW AND HYPOTHESIS

Although a wide range of literature documents that COVID-19 beats global economy remarkably, majority of research investigates COVID-19 impact on financial markets, (Papadamou et al., 2021; Liu et al., 2021; Zhang and Hamori, 2021). For instance, Papadamou et al. (2021) collecting daily data on bond and stock returns investigate the impact of COVID-19 on time-varying correlation between stocks and returns. Liu et al. (2021) conduct a time-frequency analysis of the macro-financial variables, such as total credit, house prices and equity prices to assess their resilience. In addition, Zhang and Hamori (2021) analyze the return and volatility spillover between crude oil market and the stock market during the pandemic period.

In fact, national economy performances are influenced by various factors, which can be included into two groups: adjustable factors and steady-going ones, so-called deep determinants (Bhattacharyya, 2004). The former one includes capital flows (Sui, 2019), government expenditure (Ghosh and Gregorious, 2008), and inflation (Fischer, 1992; De Gregorio, 1993), which are usually revised in short run by the government to stimulate economy growth rates. The steady-going ones refer to those, such as political stability (Jong-A-Pin, 2009), human capital (Chen and Feng, 2000), economy integration (Bhattacharyya, 2004). These deep determinants are unlikely to be changed frequently in short time, and drive economy growth in a sustainable rate.

Studies show these deep determinants associate with the adjusted ones. Abramovitz (1986) and Borensztein et al. (1998) show that institutional factors have a strong positive relationship with capital flows. Verdia-Jerez and Chasco (2016) argues that openness indicators is directly related to foreign direct investment. Anyanwu (2014) based on the Chinese evidence documents that domestic consumption significantly

associated with economic growth, while official development aid, population growth, inflation, credit to the private sector, agricultural material price, and oil price indices are negatively and significantly associated with economic growth.

Chen and Feng (2000) demonstrate that human capital is critical for less developed provinces to achieve high economic growth, which documents further that private and semi-private enterprises, higher education and international trade all lead to an increase in economic growth in China. This finding is supported by Vedia-Jerez and Chasco (2016), which suggests that economic growth is driven strongly by human capital accumulation in South America.

On the contrary, Fischer (1992) documents some uncertainty variables to economic growth, such as inflation rates, government spending, real exchange rates and interest rates, which are really determined by government policies. In addition, these factors have a negative influence on the future economy growth. Feng et al. (2000) shows that the government can promote long-term development through implementing a population policy that favors economic growth.

Although COVID-19 has significantly hit Chinese economy in short run (Liu, 2020), this study examines these deep determinants to account for the impact of the pandemic on China's economy sustainability, because these factors are relatively steady-going compared to others, they are unlikely to change during a short period of several months. Therefore, the hypothesis is developed below.

Hypothesis 1: These deep economic determinants are unlikely to be impacted by COVID-19 in the short run, thus China's economy sustainability is ongoing.

COVID-19 like SARS pandemic will potentially influence the Chinese economic activities in short run, particularly leisure activities, local and international transport and tourism (Beutels et al., 2009). Based on survey data, Hai et al. (2004) documents the short-term impact of SARS on China's economy, which is supported by Zeng et al. (2005). Meanwhile, the Chinese government views the crisis as an opportunity to upgrade its export-oriented into consumption-driven economy development (Namely Nei Xun Huan in Chinese), because the Chinese suppressed consumption demands are able to decrease the long-term impact of COVID-19 (Duan et al., 2020). None of the research from the perspective of China's economy structure investigates this question due to insufficient empirical data of post-COVID, only 1 year of economic data is available. This study bridges this gap, and examines these deep determinants associated to SARS to estimate the potential impact of COVID-19 pandemic on China's economy sustainability. The Chinese government has successful experience to deal with SARS pandemic. Therefore, the hypothesis is developed below.

Hypothesis 2: COVID-19 like SARS pandemic will potentially influence the Chinese economic activities in short run.

3. DATA, METHODOLOGY AND VARIABLES

The time series data was mainly hand-collected from the official website of National Bureau of Statistics of China (<http://www.stats.gov.cn/tjsj/ndsj/2018/indexeh.htm>). The time range covers from years of 1978 to 2020, since China's openness reform gets started. Data on variable of business environment was collected from the annual reports conducted by the World Bank from years of 2005 to 2020. Some data was gathered from the well-known global economy database: Trading Economics.

GDP is mainly determined by four core factors: consumption, investment and international trade, which is simply expressed as $GDP=f(Consp, Invest, Intl, Gov)$, which refer to consumption, investment, international trade, and government expenditure respectively. As such, this study develops a regression model to analyze China's economy structure. In general, GDP can basically be expressed as

$$GDP_t = \alpha + \beta_1 Consp_t + \beta_2 Invest_t + \beta_3 Intl_t + \beta_4 Gov_t + \varepsilon_t \quad (1)$$

Based on economic data from 1978 to 2019, this study investigates China's economy structure. As 1 year only of economy data available since COVID-19 outbreak, it is insufficient to examine COVID-19 impact on economy structure. Instead, this model adopts data prior and post-SARS outbreak in 2003 to figure out the different economy structure adjusted by the government after SARS, because SARS has short-term impact on the Chinese Economy (Hai et al., 2004). As such, SARS impact on China's economy structure has reference value to evaluate COVID-19 potential impact on China's economy structure.

There are various indicators to measure economy performance. These factors may be divided into two categories: adjustable factors, such as inflation (Stockman, 1981; De Gregorio and Guidotti, 1995), government debts (Checherita-Westphal and Rother, 2012), and capital flows (Sui, 2019). The other one is long-run factors including human capital (Romer, 1990; Barro, 1991), firm quantity (Chen and Feng, 2000), political stability (Jong-A-Pin, 2009), fertility rate, the rule of law, and the terms of trade (e.g., Barro, 1997; Barro & Lee, 1993; Chen and Feng, 1996; Feng, 1997; Persson and Tabellini, 1992). The adjustable factors are defined here as those which are more likely to be changed in a short period by the government policies. The long-run ones refer to the counterparts that are unable to be changed in short time.

To examine China's economy sustainability, this paper mainly investigates these deep determinants to see whether they are possible to be impacted by this disease. According to Chen and Feng (2000), this paper includes firm quantity (FQT) and education (EDU) into our model. Following Glawe and Wagner (2019) and Bhattacharyya (2014), both variables of labor quantity (LQT) and integration (INTG) are deep determinants for economy development. Fertility rates (FERT) is suggested

as a deep determinant (Becker et al., 2010; Chen and Feng, 2000; Barro, 1991).

This paper initially includes business environment (BEVR) to account for our research question. It is supposed that high quality business environment should be beneficial for economy development. Current account can be viewed as an index measuring national capability of capital management.

Based on the aforesaid discussion and research from Pan et al. (2020), this study employs an analysis framework from Chen and Feng (2000), accordingly, a regression model is built as below.

$$\ln GDP_t = \alpha + \beta_1 LQT_t + \beta_2 EDU_t + \beta_3 FERT_t + \beta_4 FQT_t + \beta_5 BEVR_t + \beta_6 INTG_t + \varepsilon_t \quad (2)$$

LQT is measured by employee quantity per year in China; EDU is measured by tertiary graduations per year; FERT is computed by the quantity of new-born babies every year, denoted by $\Delta Population = Population_t - Population_{t-1}$; FQT is calculated by the quantity of firms each year in China; BEVR is scored by easy-to-do-business-ranking in China conducted by World Bank per year; INTG refers to the proportion of China's GDP divided by world GDP per year, denoted by $GDP^{china}_t / GDP^{world}_t$.

Additionally, a robustness check is conducted based on data from 31 provinces and municipalities in China to investigate the significance of these determinants to GDP, because each region's economy performance varies from others. Meanwhile, COVID-19 impact is various on different Chinese provinces, to explore the impact of COVID-19 on these deep determinants, this study will investigate the results in 2019 and 2020 respectively to see the differences between them.

4. RESULTS AND DISCUSSION

4.1. Empirical Results on China's Economy Structure

SARS is a kind of epidemic outbreak in 2003 in China. Panel A in Table 1 shows the differences between the two groups of data before and after 2003. It accounts for the Chinese economy structure changing from export-oriented to supply-side structural reform, because consumption coefficient before 2003 was 0.525 and increased into 0.615. On the contrary, both variables investment and international trade decreased from 0.428 to 0.312, and 0.045 to 0.015 respectively.

Panel B shows an overview of China's economy is initially presented. This model has high goodness of fit to explain China's economy with $R^2 = .811$, and the three factors (Consumption, Investment, International Trade) have very significant Sig. value, saying they are completely able to account for China's GDP. The most prominent result is consumption has the most significant contribution to China's economy with a coefficient beta 0.571 and t value 13.75, followed by investment with beta 0.371, while international trade has less contribution.

Table 1: China's economy structure adjustment

	Panel A: before and after SARS in 2003			Panel B: 1978-2019			
	Standardized Coefficients		t	Standardized Coefficients		t	Sig.
	Beta			Beta			
(Constant)**			0.156			-2.844	0.007
***			-2.07				0.050
Consumption**	0.615		4.54	0.571		13.750	0.000
***	0.525		39.82				0.000
Gov. expenditure**	0.079		0.587	0.041		1.054	0.299
***	0.011		1.67				0.108
Investment**	0.312		5.62	0.371		13.977	0.000
***	0.428		31.97				0.000
International Trade**	0.015		1.58	0.023		5.667	0.000
***	0.045		10.06				0.000
R Square**	0.782			0.811			
R Square***	0.774						

*Dependent Variable: GDP, Predictors: (Constant), Government expenditure, Investment, Consumption, International trade. **Data after SARS. ***Data before SARS

Table 2: China's GDP growth rates during 2002-2009

	2002	2003	2004	2005	2006	2007	2008	2009
GDP Growth	9.1%	10%	10%	11.4%	12.7%	14.2%	9.7%	9.4%

Source: National Bureau of Statistics of China

Panel B shows China's economy structure is similar with it after SARS, it is still consumption-dominated, and is oriented by investment. Both consumption and investment are expected to play significant role to drive China's economy growth, because the Chinese government has released variety of policies to actively stimulate national economy since COVID-19 outbreak. However, international trade contribution become less, and it is expected to become less, due to the worse world economy.

Table 2 indicates the China's GDP growth from 2002-2009. As it shows, China's economy maintained the same growth rate of 10% in 2004, saying a limited impact from SARS epidemic. While the growth rate increased little bit to 9.4% in 2009 after the global financial crisis, it is still very high level of growth.

As Table 3 shown, China's economy was impacted in the short run by COVID-19 in 2020, but it remains sustainable at annual growth rate of 6%, which is closed to the rate before COVID-19. Therefore, COVID-19 has less potential impact on China's economy structure, while the Chinese government is more likely to strategically to adjust it to deal with COVID-19. This finding account for hypothesis 2.

4.2. Empirical Results on Deep Economic Determinants

The aforesaid analysis shows that China's adjustable economy structure is unlikely to be impacted by the pandemic, and it contributes to China's economy recovery as quick. To test whether COVID-19 impact on economy sustainability, this study investigates these long-run determinants. Following model 2 above, Table 4 apparently shows that this model has quite significant value with 0.695 of R², and significant value of each variable are under 0.05 for EDU, BEVR and LQT which means the proposed model

Table 3: China's GDP growth rates during 2015-2022

	2015	2016	2017	2018	2019	2020	2021	2022
GDP Growth	6.9%	6.7%	6.8%	6.6%	6.1%	2.3%	6%*	6%*

Source: National Bureau of Statistics of China. *According to China's annual work report by Premier Li keqiang, China has set its 2021 economic growth target at more than 6%, and projected to around 5.9% in 2022

Table 4: Regression results on deep economic determinants

	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std. Error	Beta		
	(Constant) ^a	-9.207	4.165		
INTG	-0.005	0.844	0.000	-0.006	0.995
FQT	0.006	0.004	0.068	1.588	0.163
EDU	0.169	0.030	0.456	5.633	0.001
BEVR	0.003	0.001	0.057	3.069	0.022
LQT	0.024	0.006	0.523	4.210	0.006
FERT	-0.003	0.013	-0.005	-0.240	0.818
R Square	0.695 ^b				

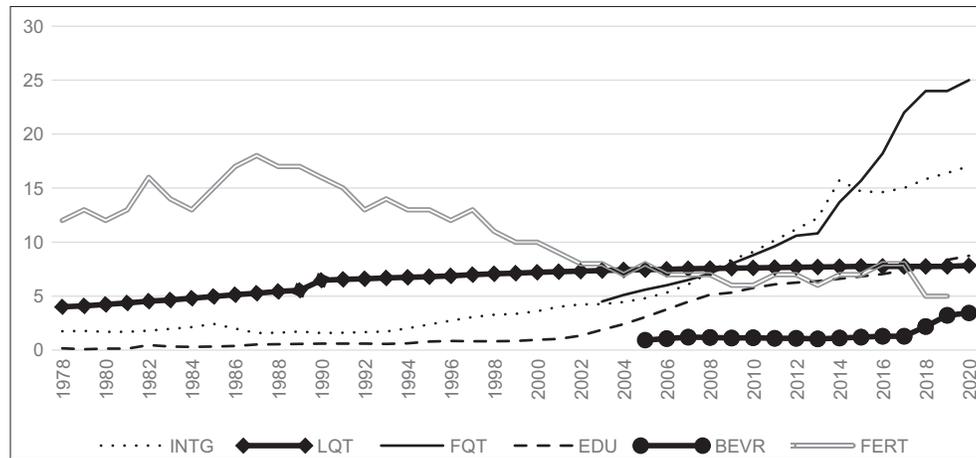
^aDependent Variable: lnGDP. ^bPredictors: (Constant), LQT, BEVR, FQT, FERT, INTG, EDU

and the three variables well account for the research question of this study.

Both LQT and EDU variables have significant contributions to economy sustainability, that says human capital is vital for GDP. This result consistent with Chen and Feng (2000), which documents that human capital drives economy development in the long run. There were over 8 billion tertiary graduations from the Chinese universities, these high-quality labors certainly drive China's economy development for longer.

Followed by FQT and BEVR factors with coefficient 0.068 and 0.057 respectively, this means more firms produce more working opportunity and thereby push economy growth. Additionally, the upgrade business environment supports sustainable economy. According to reports by World Bank, China's ranking of easy doing business has stood at the 31 in 2019. While FERT has negatively association to economy at less significant level, which

Figure 1: The deep economic determinants trends



is consistent with the result by Chen and Feng (2000). Lastly, there is no evidence of INTG promoting economy development, which potentially accounts for the fact that China's economy is unlikely to be impacted by other economies. This also responds to the results from Table 1, showing international trade will gradually decrease its contribution to China's GDP.

Table 5 demonstrates these deep determinants rates within the last years. Compared with others before 2020, there is no significant evidence showing the rates in 2020 worsen than others, except FERT. FERT rates decreased due to other reasons rather than the pandemic.

Figure 1 outlines the trends of the deep economic determinants. The most determinants show upward trends in the last years, except FERT that has been suggested by Chen and Feng (2000), showing high fertility rate reduces economy growth in China. There has no significant evidence to show these trends are likely to go down much synchronously after COVID-19.

Based on the above analysis and China's economy structure, China's economy growth will be ongoing if these deep economic determinants are not be destroyed significantly by outside powers. The Chinese government is able to stimulate economy growth at a proper rate by driving some volatile factors, such as investment, industry production, monetary policies.

4.3. Robustness Check

As China is a huge country consisting of over 30 administrative regions, and each one has different GDP performance from others, some of which are comparable to some European countries in terms of total GDP and even GDP per capita. Additionally, there is a very unbalanced economic development across provinces (Glawe and Wagner, 2019). Therefore, a robustness check based on data from 31 provinces and municipalities is conducted to investigate further the significance of these determinants.

The robustness results in Table 6 are consistent with ones in Table 4. Both EDU and LQT are the most significant determinants

Table 5: Deep economic determinants annual rates prior 2020 (%)

	2013	2014	2015	2016	2017	2018	2019	2020
INTG	0.86	0.22	-1.55	10.31	12.4	3.54	3.78	1.41
FQT	0.268	0.145	0.159	0.208	0.009	0	0.041	0
EDU	0.032	0.032	0.034	0.045	0.023	0.107	0.047	0.040
BEVR	0.021	0.009	0.013	0.029	0.034	0.083	0.069	0.165
LQT	0.003	0.002	0.002	0	0	0.001	0.010	0.005
FERT	0.067	0	0.029	0	-0.005	0	-0.20	0

Source: National Bureau of Statistics of China. *According to China's annual work report by Premier Li keqiang, China has set its 2021 economic growth target at more than 6%, and projected to around 5.9% in 2022

to GDP, by contrary, both INTG and FERT are the least factors to China's economy.

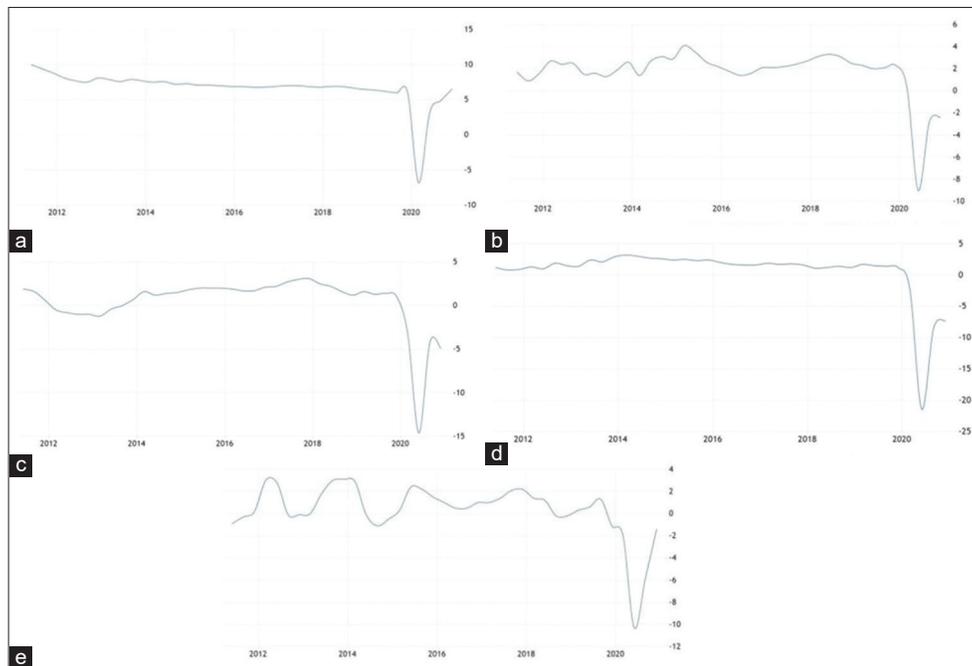
There are no significant changes between panel A and B, which means that COVID-19 has no significant impact on these deep economic determinants. As a consequence, these findings account for hypothesis 2: These deep economic determinants are unlikely to be impacted by COVID-19 in the short run, thus China's economy sustainability is ongoing.

5. DISCUSSION

As aforesaid analysis, COVID-19 has short-run effect on China's economy, this finding is consistent with some research (Pan et al., 2020, Vasiev et al., 2020). The Chinese government takes this pandemic as an opportunity to upgrade its economy structure, and COVID-19 potential effects should be limited in the long run. Thus, the Chinese economy is recovering from the pandemic.

As Figure 2 shown, while COVID-19 has impacted on global economy since 2020, China as the first country hit by the pandemic also has firstly been recovering from the pandemic. Compared with other major economies, the Chinese economy had the least impact by around -6% decline in 2020, However, the UK economy was hit significantly by over -20%, followed by European economy with about -15%. Both Japan and US had similar rates of 10% approximately.

Figure 2: GDP annual growth rates of the world's major economies within the last 10 years. (a) GDP growth rates of China¹. (b) GDP growth rates of the U.S.² (c) GDP growth rates of Euro. Area³. (d) GDP growth rates of the U.K.⁴ (e) GDP growth rates of Japan



Source: 1. National Bureau of Statistics of China; 2. US Bureau of Economic Analysis; 3. Eurostat; 4. Office for national statistics; 5. Cabinet Office, Japan

Table 6: Regression results on deep economic determinants

	Panel A: Data from 31 provinces and municipalities in 2019			Panel B: Data from 31 provinces and municipalities in 2020		
	Standardized Coefficients Beta	t	Sig.	Standardized Coefficients Beta	t	Sig.
(Constant) ^a		8.18	0.209			
INTG	0.008	0.026	0.553	0.014	0.026	0.477
FQT	0.011	3.28	0.033	0.012	3.28	0.007
EDU	0.269	7.52	0.005	0.232	7.52	0.011
BEVR	0.003	5.09	0.019	0.007	5.09	0.009
LQT	0.124	10.21	0.010	0.156	10.21	0.001
FERT	0.003	-0.052	0.781	0.016	-0.052	0.672
R Square ^b	0.323					

^aDependent Variable: lnGDP. ^bPredictors: (Constant), LQT, BEVR, FQT, FERT, INTG, EDU

The Chinese economic performance partially due to three reasons. First of all, China has successful experience to deal with the impact of SARS in 2003, which is potentially helpful for the Chinese government to mitigate the impact of COVID-19 as less as possible. Secondly, the government views each critical crisis as an opportunity to actively upgrade economy structure. The central government has significant power to adjust the national economy structure by variety of police-oriented plans to remain economy sustainability. For instance, at the very earlier stage of the pandemic outbreak, the government announced investment plans of total amount of 49554 billion RMB in the next years to stimulate national economy, and amount of 7628 billion has been invested in 2020 (Table 7).

Thirdly, the COVID-19 impact is short-term and varies on different Chinese provinces (Table 8). By carrying out policy measurements,

the central government is able to mitigate the impact as less in terms of balancing economic activities among the provinces (Liu, 2021), which is expected to remain the sustainability of the deep economic determinants. Table 8 shows the provinces with the highest and lowest GDP growth rates. As COVID-19 initially outbreak from Hubei province, this province GDP declined significantly by -5%, but other provinces overwhelmingly have positive GDP growth.

Therefore, China's economy has less impact than other major economies in the world, and China's economy has been recovering due to China's adjustable economy structure and sustainable economic determinants. The ongoing trend of China's economy is unlikely to be interrupted by COVID-19 within the short period, this short-run and regional brunt has been recovering by some stimulation policies and balancing economic activities.

Table 7: Investment plans of twenty-five provinces

Provinces	Total Investment Scale (Billion RMB)	Case Quantity	2020 Investment Scale (Billion RMB)
Guangdong	5900	1230	700
Yunnan	5000	525	440
Sichuan	4400	700	600
Fujian	3840	1567	500
Shanxi	3788	7181	815
Shanxi (陕)	3383	600	500+
Henan	3300	980	837
Hubei	3157	894	-
Shandong	2900	1021	-
Chongqing	2720	924	344
Gansu	2200	2236	450
Guangxi	1962	1132	167
Hebei	1883	536	240
Jiangxi	1119	335	239
Tianjin	1003	346	210
Hunan	1000	105	-
Zhejiang	886	537	147
HLongJiang	886	300	200
Ningxia	227	80	51
Jiangsu	-	240	541
Guizhou	-	-	430
Beijing	-	300	252
Xizang	-	179	187
Shanghai	-	152	150
Anhui	-	251	125
Total	49554	22351	7628

Source: National Development and Reform Commission

Table 8: The highest and lowest GDP growth rates by provinces

Provinces	Highest (%)	Lowest (%)
Yunnan	4.0	
Liaoning		0.6
Hubei		-5.0
Chongqing	3.9	
Hebei	3.9	
HLong Jiang		1.0
Ningxia	3.9	
Guizhou	4.5	
Beijing		1.2
Xizang	7.8	
Anhui	3.9	
Neimenggu		0.2

Source: National Bureau of Statistics of China

6. CONCLUSION

Due to limited empirical data of post-COVID impact on China's economy, this study, through analyzing SARS impact on China's economy structure, examines COVID-19 potential impact on the Chinese economy. It suggests that COVID-19 pandemic has few affections on the Chinese economy structure, and China's economy is still consumption-dominated and remains its sustainability in the future.

The Chinese economy is driven by its deep economic determinants. Human capital including labor quantity and education is currently the most significant determinants for China's economy sustainability, followed by the upgrading business environment.

Firm quantity and national current account have also contribution to national economy sustainability, but there is no evidence of economy integration accounting for GDP growth. All these steady-going variables are unlikely to be hit by the epidemic. Therefore, china's economy sustainability is ongoing.

China is expected to be the first country to recover from the pandemic and back to the pre-pandemic GDP rate, due to various reasons. But the most significant one is that the Chinese government adepts in taking the advantages from each critical crisis and strategically to upgrade its economy structure. Additionally, China has successful experiences of conquering SARS in 2003 and global financial crisis in 2008. Even the GDP slowdown in parts of industrial sections and provinces doesn't matter, as the Chinese economy is shifting from high-speed development to quality growth.

Limitation of the research is insufficient data to examine COVID-19 impact on China's economy, while only 1 year of empirical data is available.

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