MEASURING AND TRACKING THE GLOBAL PANDEMIC ECONOMY

罗汉堂
Luohan Academy

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Z Space, No. 556 Xixi Road, Hangzhou, China
www.luohanacademy.com

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Abstract

Economic prosperity and the functioning of an economy depend on the mobility and connectivity of various factors of production and in many sectors of consumers. Some of these essential mobility and connectivity is being shut down by the COVID-19 pandemic and the containment policies that countries have adopted, causing major contractions in most economies.

We find that the degree of reduction of people's mobility has become a useful indicator to directly measure the level of economic contraction. It helps explain the differences of economic performance between countries. By early May, among the 19 countries and regions that have announced GDP in the first quarter of 2020, a large majority (3/4) of the variation in GDP growth, or more accurately contraction, can be explained by the difference in mobility decline. This would not be true in normal conditions.

It is important at this time to define and grasp the nature of the pandemic economy, which is much more complex than the simple addition of an extra word before economy. At the macro level, the pandemic economy and policy responses have been tightly linked, profoundly affecting each other. In face of unprecedented uncertainties, decision-makers are trying to understand the dynamic interactions between the epidemic and the economy, and to track progress in the economy and in the spread of the virus, in order to make robust decisions about the pace and sequencing of re-opening the economy.

After the outbreak of the COVID-19 disease, most countries decided that the first priority was to effectively control the epidemic at the considerable cost of sacrificing the flow of people and incurring a sharp contraction in economic activity. Containment was driven initially by the goal of avoiding unnecessary deaths. As the economy transitions to the recovery mode, virus containment, done in the right, more targeted way, becomes an important element of the reduction of risk and the resuscitation of demand. In the pandemic economy, it becomes particularly important and urgent to define, measure and track the economy and the epidemic together. The pandemic economy is not an economy superimposed on epidemic in various countries, but a triangle with deep mutual influence among epidemic, economy and policy responses. Misjudgment about the way the three interact, will bring painful economic and life costs, and the losses will rise exponentially with time.

Luohan Academy is launching a global Pandemic Economic Tracking project (PET), so that the global community can better understand the general patterns, the status of the countries in the pandemic economy, the challenges that can be expected, and the key choices to help make decisions. Initially as the online **PET platform** goes live, we track 131 economies, all at various phases of the pandemic economy. Change in mobility is used to estimate economic contraction, while the epidemic is tracked using measures of the growth rate of confirmed new and recovered cases. The tracking is updated daily, providing historical and real-time indicators of the state of the epidemic and the economy.

Measuring the Global Pandemic Economy

1. Motivation

COVID-19 is ravaging health systems and economies globally. By May 21st 2020, the virus has infected more than five million people across almost all countries, areas and territories, resulting in about 330,000 deaths.

Unfortunately, there remains a substantial uncertainty about how to deal with the pandemic. In the past few months, our understanding of the issue has undergone a painful transformation, from "Does it have anything to do with us?" "Do we need to implement special protective measures?" "Do we really have to lock down the cities?" to "how do we efficiently maintain and reboot economies during and after COVID-19?

The evolving nature of the issues surrounding COVID-19 means that it's important at this time to analyze the interaction of health and economic outcomes in the pandemic economy and then try to track their coevolution. At the macro level, the pandemic economy and policy responses are tightly coupled. Decision-makers must understand the dynamic interactions between the pandemic and the economy to make robust decisions.

The fact that the concept of herd immunity was hotly debated back in March and is still being raised from time to time, and that governments have taken rather diverse, and sometimes conflicting, decisions on when best to end the lockdowns and restart the economy, reveals two points. First, the global community does not yet have an adequate understanding of the nature of the pandemic economy which involves various inter-related trade-offs. Second, perhaps more importantly, the trade-offs are often costly, or even painful and present significant challenges to decision- and policy-makers at all levels.

While it has been nearly six months since the virus first emerged, questions still remain. How strict should social distancing measures be to effectively control the epidemic? At which stage of the pandemic should governments seriously consider allowing people to return to work in various sectors? Is it possible to contain the virus without experiencing large economic contraction? How deeply and for how long will the global economy be impacted?

Even if the world began to reach some consensus on the basic characteristics of the pandemic economy and on the alternative approaches to deal with the pandemic economy, differences in initial conditions, speed of detection, policy response and implementation, as well as in perceptions, cultures and customs, all suggest that the economic and health trajectories will vary across economies. Less certain, though presumably much more painful, is the situation in those countries and regions that have neither adequate medical care nor the ability to engineer sizeable economic stimulus responses to counteract inevitable contractions.

The longer the lockdowns last, the steeper the costs and the more prolonged the recovery. According to The Economist (2020), since 1870, if an economy contracts by 10%, it takes an average of five years to recover to its original level. As the lockdown continues, more and more enterprises will close, unemployment will rise, and the economic and financial, systems will be impacted to a greater extent. The social and economic costs can be very high, thus we need to understand better the nature of the pandemic and its relation to the economy, to measure this relation with reasonable accuracy, and to closely track their changes to help policymakers make informed decisions at each stage.

In pursuit of this goal, Luohan Academy is launching the Global Pandemic Economy Tracking project. It is intended to be a platform open to interested individuals and groups globally to access the existing information and to contribute new data and ideas. In this essay, we first highlight several major patterns we have detected in China's pandemic economy based on big data; building on this, we integrate global openly available datasets to better measure the pandemic economy in various countries, areas, and territories.

2. The core features of China's pandemic economy

Since China is one of the early countries to suffer from the virus, and may also be the first to fully recover, it is useful for the global community to learn the core features of China's pandemic economy. The country has shown clear intertwined patterns among the epidemic, the non-pharmaceutical intervention (NPI) policies, and the activity levels of people and the economy.

2.1 Epidemic Growth, Intervention Measures, And People's Mobility

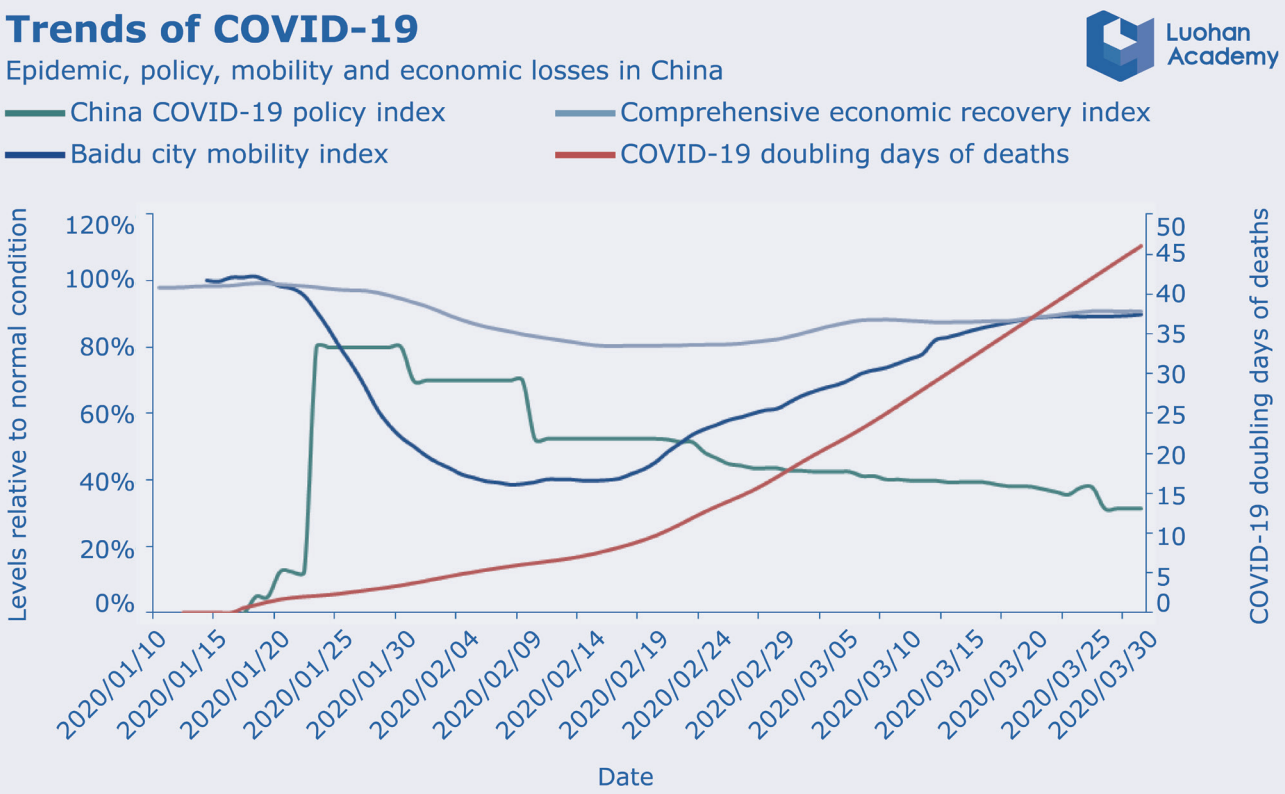
China's experience can be split into several phases. First, the epidemic was expanding at an exponential rate. As shown in Figure 1, in the early stage of the outbreak, the doubling time of COVID-19 deaths (red line), i.e. the number of days that were needed for the number of total deaths to double, was less than two days. At the same time, the COVID-19 Policy Index (green line), a measurement on the status of non-pharmaceutical interventions (NPIs) implementation, began to increase, and reached a peak in late January when Wuhan was locked down and the rest of the country also rose their emergency response to the highest level.

The direct impact of the epidemic containment and mitigation measures was a sharp decrease in people's mobility. The mobility index (blue line), based on urban travel intensity data from Baidu Migration Index, declined rapidly after January 24th by 60% within two weeks, after adjusting for the seasonal effects from the Spring Festival. The strengthening of epidemic intervention measures and the resulted reduction in mobility, was accompanied by a clear upward trend in the doubling time of COVID-19 deaths after mid-February. Note that an increase in doubling times means that the virus is spreading less rapidly. This shows that the balancing feedback loop of "Epidemic growth Intervention policies and measures Mobility reduction Epidemic containment" started to take effect.

The deceleration of the epidemic made it possible to relax some intervention measures

and re-start some economic activities. It is worth noting that, although many parts of China started to resume work and production after February 10th, the initial on-site implementation was carried out with extreme cautiousness. Consequently, there was no substantial change in mobility in the first week. At the same time, due to the requirement of 7-14 days of quarantine for workers returning to workplaces, the resumption of production and economic recovery was further delayed relative to the resurrection of mobility. At this stage, the significant economic contraction and the slow recovery of mobility form a sharp contrast. It took only two weeks for mobility to shrink to 40% of the normal level, while it took more than 50 days for mobility to rise from 40% to close to 90% by the end of March.

Figure 1. Dynamic trends of the COVID-19 epidemic, policy, mobility, and economic losses in China.



Source: PET project, using data (by the end of the first quarter of 2020) from the Baidu Mobility Index, National Health Commission of the People's Republic of China, and the Wind Economic Database.

Note: *The Baidu city mobility index* is defined as the portion of actively moving residents in a city, weighted by GDP values of 332 cities in China. A seven-day moving average is used to remove weekend effect. January 1-10, 2020 is used as the base period and the Spring Festival effect was adjusted with historical data. The comprehensive economic recovery index is computed using data from daily coal consumption by major power companies in China and Luohan Academy's e-commerce and online payment based economic recovery index. China's COVID-19 Policy Index is compiled based on data from Oxford University's Coronavirus Government Response Tracker, adjusted with provincial public health emergency response levels across China.

2.2 Epidemic Intervention Policies, Mobility, And Economic Activities

We examine the influence of strengthening epidemic intervention and the decline of mobility on economic activity. To this end, we construct a daily economic activity index for China, based on the big data from Alibaba and Ant Financial. We combine high-frequency macro indicators such as power generation and coal consumption with data on online e-commerce transactions and offline mobile payments, from both consumers and merchants. Comprehensive economic activity indicator (gray line in Figure 1), which combines both consumption and production, began to decline significantly with the tightening of social distancing and quarantining measures and the downward trend of mobility, reached about 80% of the normal level in late February, and then began to recover with the resumption of businesses and work.

Intervention policies, mobility, and economic activity are highly correlated, and the coefficients are -0.72 between interventions policies and mobility, -0.65 between policies and economic activity, and 0.81 between mobility and economic activity.

Here we observe two patterns. **First, economic activity fluctuated less than mobility. While mobility fell by 60%, the overall economic activity shrank by only 20%. The decline in mobility had the most significant negative impact on services such as offline retail, catering, and transportation, but less on other sectors such as e-commerce. Sectors of the economy vary considerably in the extent to which they can function with reduced mobility.**

Second, the correlation between intervention measures and economic activity was weaker in absolute term than that between mobility and economic activity. This is because mobility is not only the result of containment measures but also the result of people's proactive responses. One example is that in Great Britain, while there were no restrictions on the construction industry, the industry chose to stop on-site work. Different countries and regions have different interventions that vary in intensity, cultures, habits, and views on the pandemic, as well as different responses from individuals and communities in terms of their compliances with the new distancing rules.

GDP is the most commonly used measurement of economic activity, and it's natural to wonder how good a proxy our economic activity index is for the official GDP figure? Based on the comprehensive economic activity index in the first quarter, considering the relative economic contribution of different industries, we estimated that China's economic output in the first quarter of 2020 to shrink by 10.3% compared with the fourth quarter of 2019, and 6.4% compared with the same quarter of 2019, very close to the official figures of 9.8% (QoQ) and 6.8% (YoY).

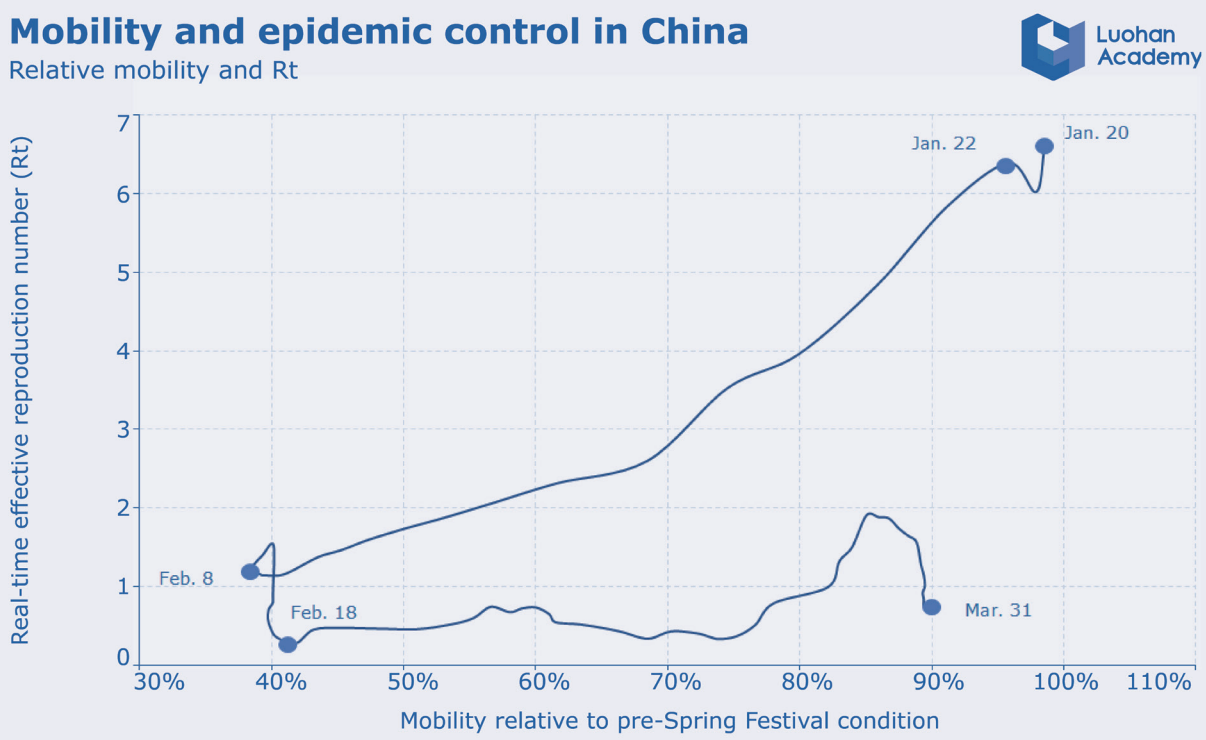
2.3 Mobility and Epidemic Control

The key indicator that measures the speed of the epidemic growth is the effective reproduction number (Rt), which is the average number of people that can be infected by a patient during a full infectious period (7-12 days in moderate cases and on average 14 days in severe cases [1]). If the Rt is greater than 1, the epidemic will grow exponentially. Therefore, in order to containing the epidemic the key is to reduce the rate of infection from being exponential (Rt>1) to one that is significantly lower than 1.

Figure 2 shows the evolution of Rt and mobility in China. Since the lockdown in Wuhan on January 23rd, a series of stringent epidemic control measures were implemented nationwide. For the whole country Rt rapidly dropped from as high as around 6 before the lockdown, similar to the estimation in Sanche et al. (2020), to below 1 in roughly two weeks, and further down to about 0.3 by February 18th. After that, with the resurgence of mobility, Rt rose again and fluctuated slightly. Overall, before an apparent rise of imported cases in mid-March in China, Rt was maintained at a rather low level of about 0.5.

The same figure confirms that suppressing Rt came at the cost of substantial reduction in mobility. When Rt was significantly lower than 1, intervention measures were loosened, and mobility rose again as some laborers returned to work. This process needs to be carefully managed so that Rt is kept below 1.

Figure 2. COVID-19 epidemic in China was quickly contained as mobility declined within a month and stayed below 1 afterwards.



Source: PET project, using data (by the end of the first quarter of 2020) from the Baidu Migration Index and National Health Commission of the People's Republic of China.

[1] *EU CDC, Q & A on COVID-19,"The infectious period is now estimated to last for 7-12 days in moderate cases and up to two weeks on average in severe cases." https://www.ecdc.europa.eu/en/covid-19/questions-answers .*

Note: Based on the pandemic data and the parameters of the serial interval distribution of COVID-19 (Zhang et al. 2020), Rt is estimated by applying the Bayesian framework (Wallinga and Teunis, 2004).

Therefore, the pandemic economy of China experienced sizeable contraction in both mobility and economic activity, largely caused by the epidemic intervention policies. Economic recovery began when the epidemic was effectively contained. Notably, indicators of intervention policies and mobility seem to track economic activity well, with smaller fluctuations in the latter. Even in China, where the containment measures came late but were very aggressive, the speed of economic recovery is far slower than that of economic contraction.

3. Key Features of The Global Pandemic Economy

3.1 Global pandemic, COVID policies and measures, and mobility

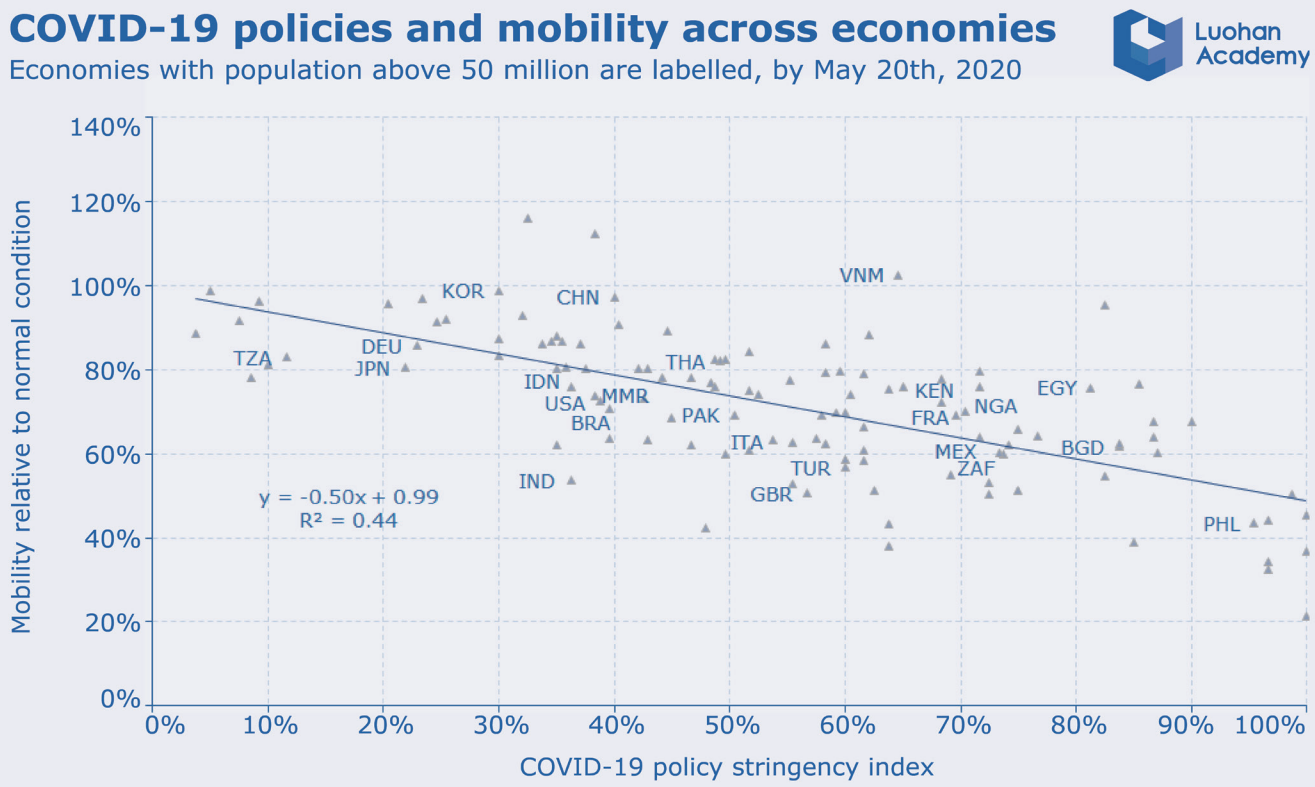
In combating the epidemic, are there general patterns that can be discerned globally? There are two interesting questions: how do interventions in other economies, if effective, compare to China's experience? Is there any economy that can effectively control the epidemic without reducing mobility? What can other countries learn from China's experience?

Without effective pharmaceutical measures (either vaccines or medicines), non-pharmaceutical interventions (NPIs) are the main tools to cope with the pandemic, through restricting human-to-human contact rates, and limiting the further spread of virus – specifically reducing the prevalence of the virus among people who are in circulation. These include quarantines, the prohibition of gathering and/or public activities, closure of workplaces and schools, suspension of public transportation services, domestic and international travel restrictions, and large-scale voluntary and/or compulsory social isolation, including comprehensive lockdowns in specific locations. Most of these measures are classic public health policies to deal with infectious diseases, but in many countries, especially some high-income countries,

they were implemented with unprecedentedly high levels of intensity and coverage. To a large extent, such measures resemble China's recent experience. Note however that targeted measures to remove infectious individuals from the population in circulation are not feasible when the virus is widespread and growing rapidly.

Epidemic intervention policies appear to significantly inhibit mobility across economies (Figure 3). or a ten percentage points increase in policy stringency, the average level of mobility drops by 3.7 percentage points relative to normal times. At the same time, we observe that the impact of the policy stringency index on mobility vary substantially across economies, likely due to variations in how the policies were implemented, as well as other social-cultural differences.

Figure 3. COVID-19 policies stringency negatively correlates with mobility across 119 economies



Source: PET project, using data from the Oxford Coronavirus Government Response Tracker and the Google Community Mobility Reports.

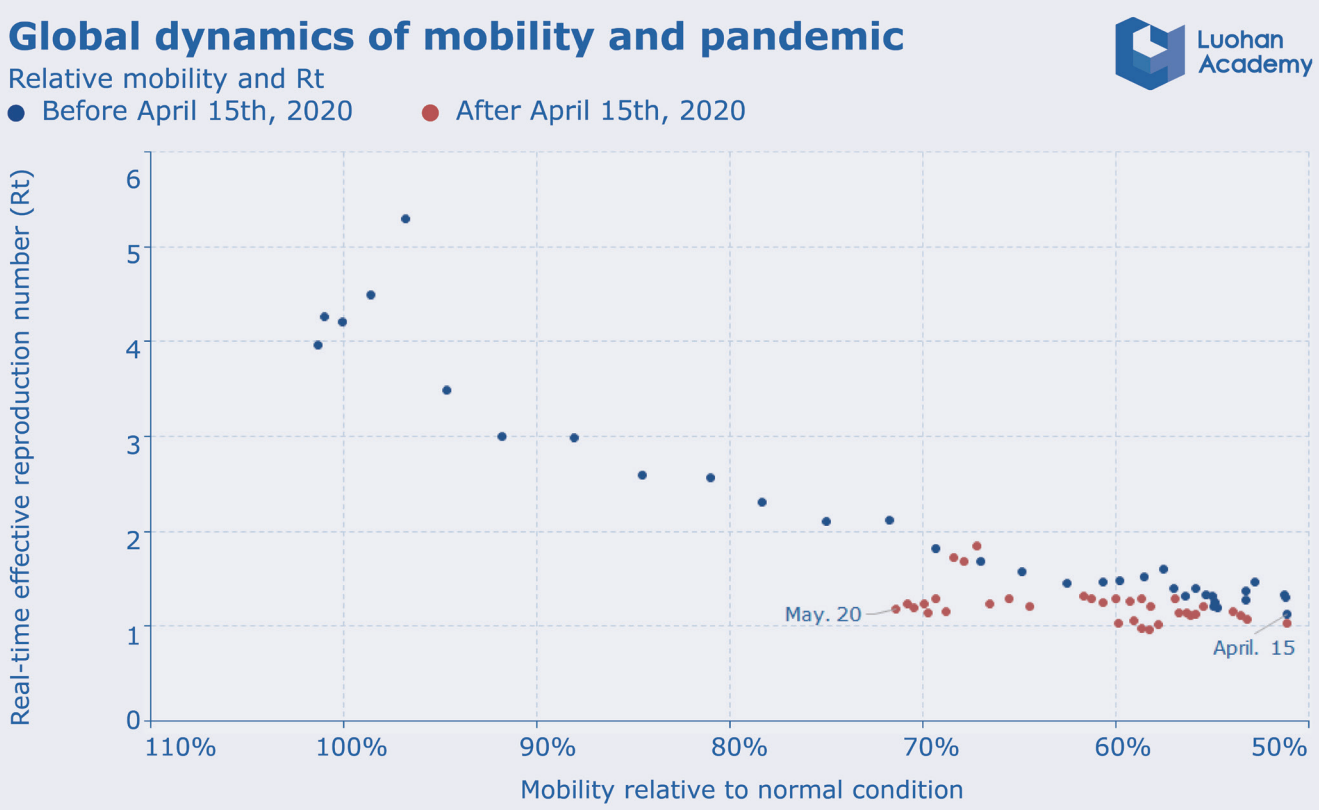
Note: COVID-19 Policy Stringency Index is calculated using data from the Oxford Coronavirus Government Response Tracker, weighted on the scope and intensity of eight types of NPI measures according to their potential economic impacts. Mobility index is calculated as a weighted average of three sub-indices from Google Community Mobility Reports. The sub-indices of grocery and pharmacy (25% weight) and transit (25% weight) are considered to be related to consumption and the sub-index of workplace (50% weight) is considered to be related to production. A seven-day moving average is used to remove weekend effect.

We find that each policy has significantly negative impact on mobility when analyzed separately. Among them workplace closure is the most influential, followed by the stay-at-home restrictions, and suspension of public transportation, and restrictions on domestic mobility (See Table 1 in the Appendix). Together these four factors explain over 70% of the variation in mobility reduction across the countries.

Is it possible to contain the epidemic without compromising mobility?

To assess whether reduction in mobility leads to effective mitigation of epidemic growth, we estimated daily effective reproduction numbers in 131 economies. As shown in the left panel of Figure 4, the average effective reproduction number across all the economies declines steadily as mobility slows down: when the mobility level is at 75% or higher relative to normal situation, the effective reproduction number is generally greater than 2, and after mobility drops to about 50% of the normal level, the effective reproduction number Rt is close to 1. This shows that worldwide epidemic control often inevitably comes at the cost of mobility reduction. Since mid-April, as the epidemic situation alleviated in some economies, intervention measures have been gradually relaxed, as a result mobility started to resurrect as well. With the deployment of more targeted contact tracing and other measures by governments usually with more cautiousness, the recoveries of people's activities have not brought a systematic rebound in Rt (Figure 4).

Figure 4. Average across countries worldwide effective reproduction number (Rt) of COVID-19 went down as mobility declined before April 15th, and stayed at around 1 since then.

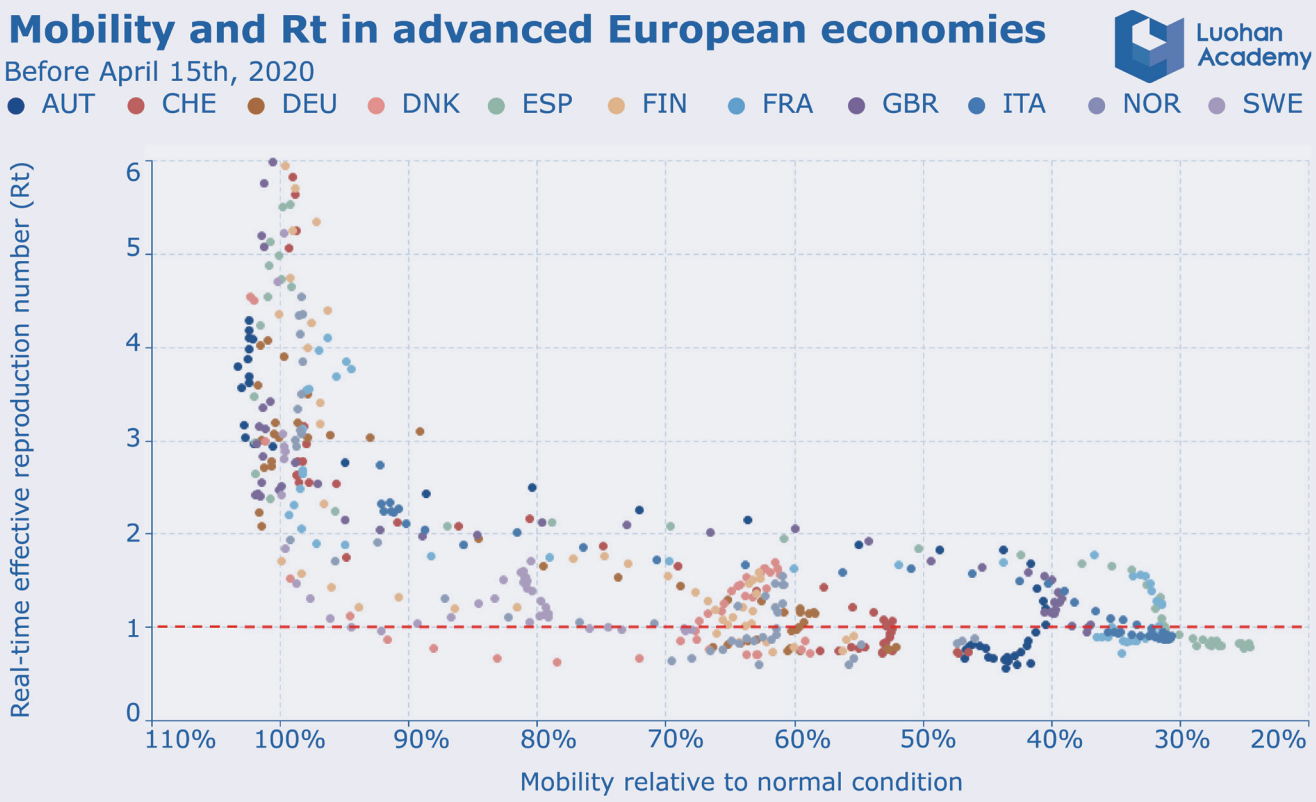


Source: We use data (March 11th to May 20th, 2020) from the Google COVID-19 Community Mobility Reports, the Apple Mobility Trends Reports, the Baidu Mobility Index, the Amap Traffic Index, the European Centre for Disease Prevention and Control, and the National Health Commission of the People's Republic of China.

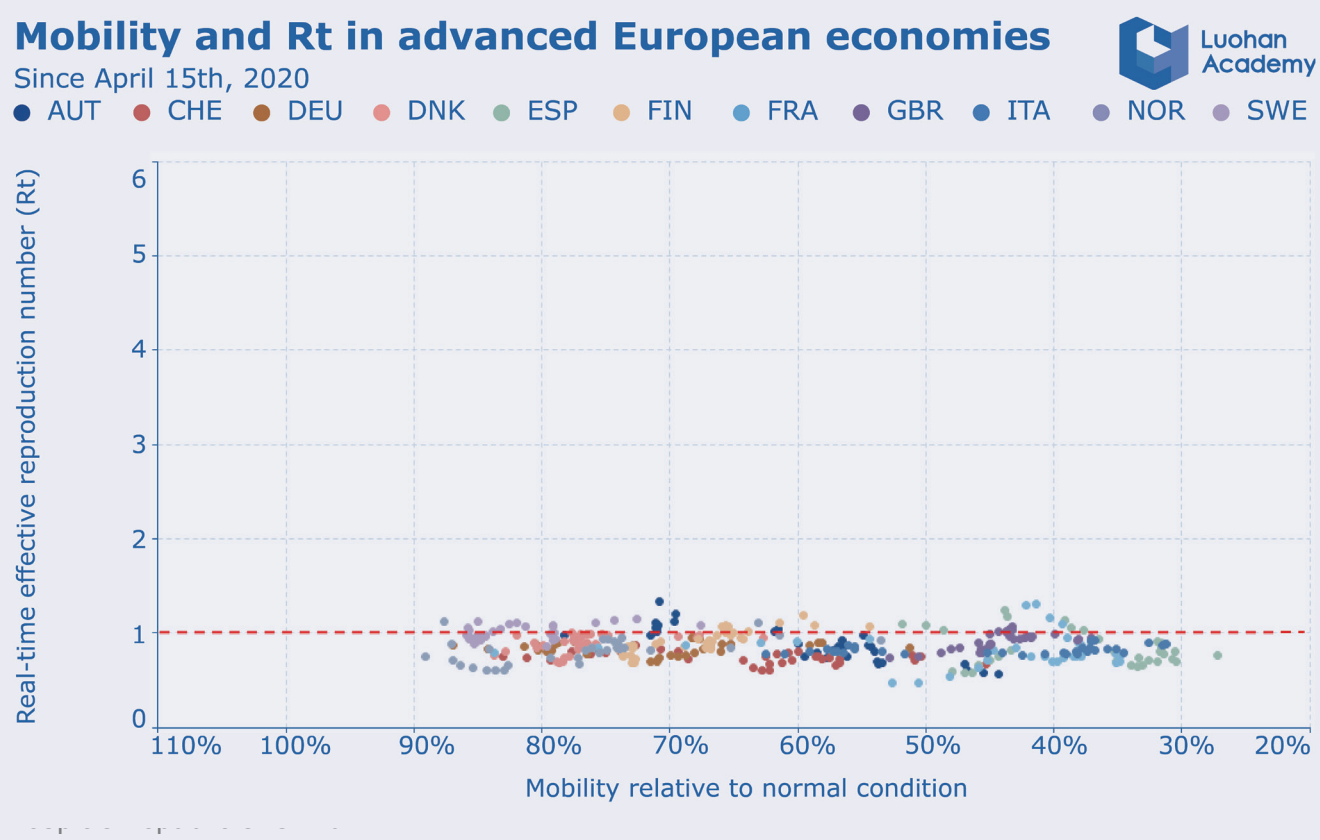
To learn the situation in different economies more accurately, we show in Figure 5 the relationship between COVID-19 epidemic and mobility in several advanced economies from Northern, Western and Southern Europe. The patterns from these economies are quite similar to what was observed in China (Figure 2) and at global average level (Figure 4). Fast decline of mobility led to reduction in Rt in most of these countries (Figure 5a), and Rt has been maintained at a low level, in most cases below 1 (Figure 5b), as mobility recovers.

Figure 5. Effective reproduction number (Rt) went down in several advanced European economies as mobility declined.

(a) Before April 15th



(b) Since April 16th



Source: PET project, using data (March 11th to May 20th, 2020) from the Google COVID-19 Community Mobility Reports and the European Centre for Disease Prevention and Control.

By mid-May, many advanced economies in Europe and North America that have attempted to reopen the economy, such as Austria, Italy, Germany, and even the US, have an overall Rt below 1. While it seems that a basic requirement (Rt<1) is met, there remains the question whether reopening may bring a significant increase in Rt and result in a second round of lockdown and economic freezing. Under such risks and uncertainties, the reopening will have to be a gradual process. This means that mobility will ascend at a speed much smaller than that of the earlier descending trend, as observed in China.

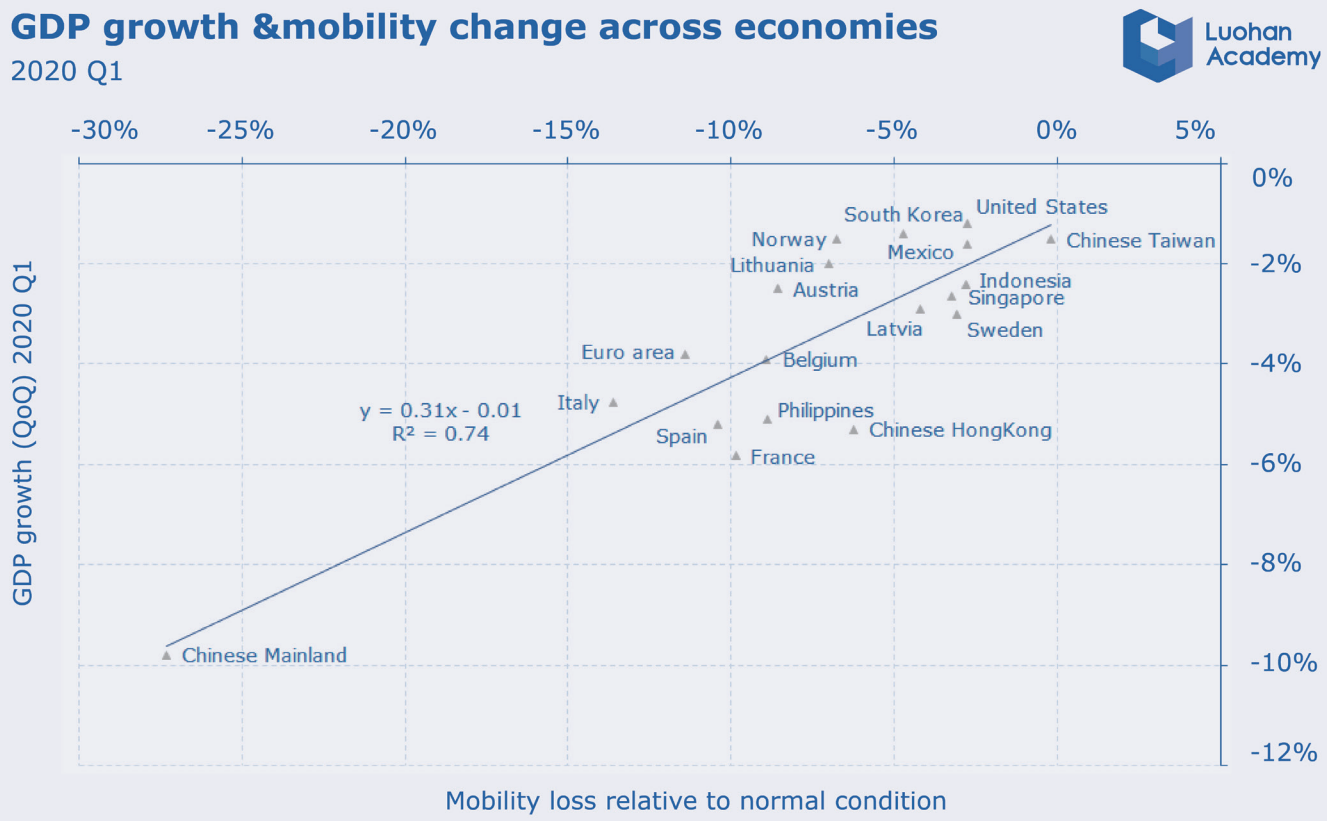
3.2 Global Mobility and Economic Activity

In spite of some variation in the pace of the epidemic and the responses, the battles against epidemic across countries still exhibit significant commonalities. In order to effectively contain and mitigate the epidemic, reducing human-to-human contacts, usually through distancing measures, is necessary and usually leads to reduced mobility. Would such reduction in mobility impact economic activities at a similar intensity and duration as what was observed in China?

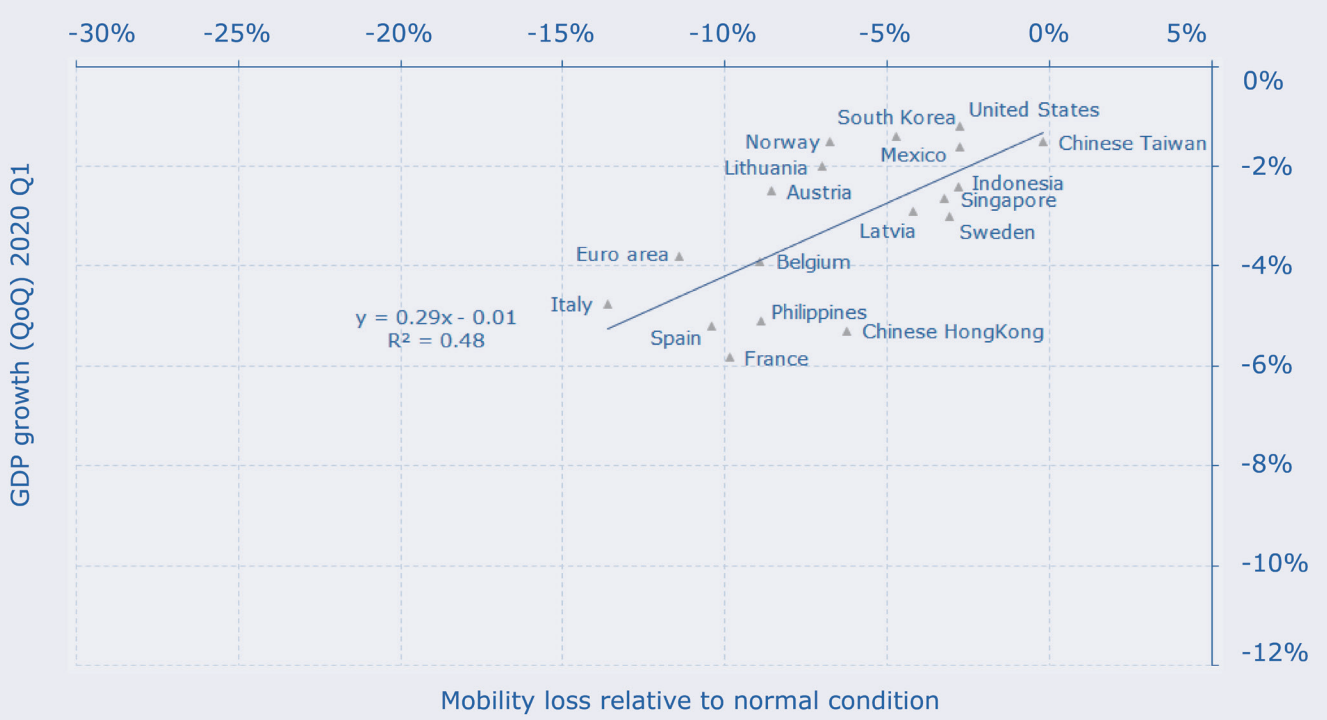
By early May, 19 countries or regions released their GDP figures for the first quarter of 2020. As shown in Figure 6a, there is a significant, in fact surprisingly high, correlation between GDP growth rate in the first quarter compared to the fourth quarter of 2019, and the corresponding gap in mobility across these countries. The large majority (3/4) of GDP growth rate variation can be explained by the differences in mobility. Interestingly, in Figure 6b, if we ignore China's data and repeat this exercise, we find that the relationship remains quite stable. If we apply the empirical relationship from the other 18 countries and use China’s mobility data in the first quarter to estimate GDP growth, we get a GDP growth rate (QoQ) of -9.1%, very close to the officially announced figure of -9.8%.

Figure 6. Mobility reduction correlates strongly with economic performance in 19 economies

(a) Chinese mainland is included.



(b) Chinese mainland is excluded



Source: PET project, using data from the Google COVID-19 Community Mobility Reports, the Apple Mobility Trends Reports, the Baidu Mobility Index, and the Wind Economic Database.

The pattern in Figure 6 is important and indicates that what was observed in China, where reduced mobility brought by epidemic control measures became the most informative factor in explaining the economic performance, also applies reasonably well to other economies. The key feature that makes the pandemic economy different from that in normal times is such reduction in mobility, unusually substantial and almost unavoidable in all economies due to the need for "social distancing".

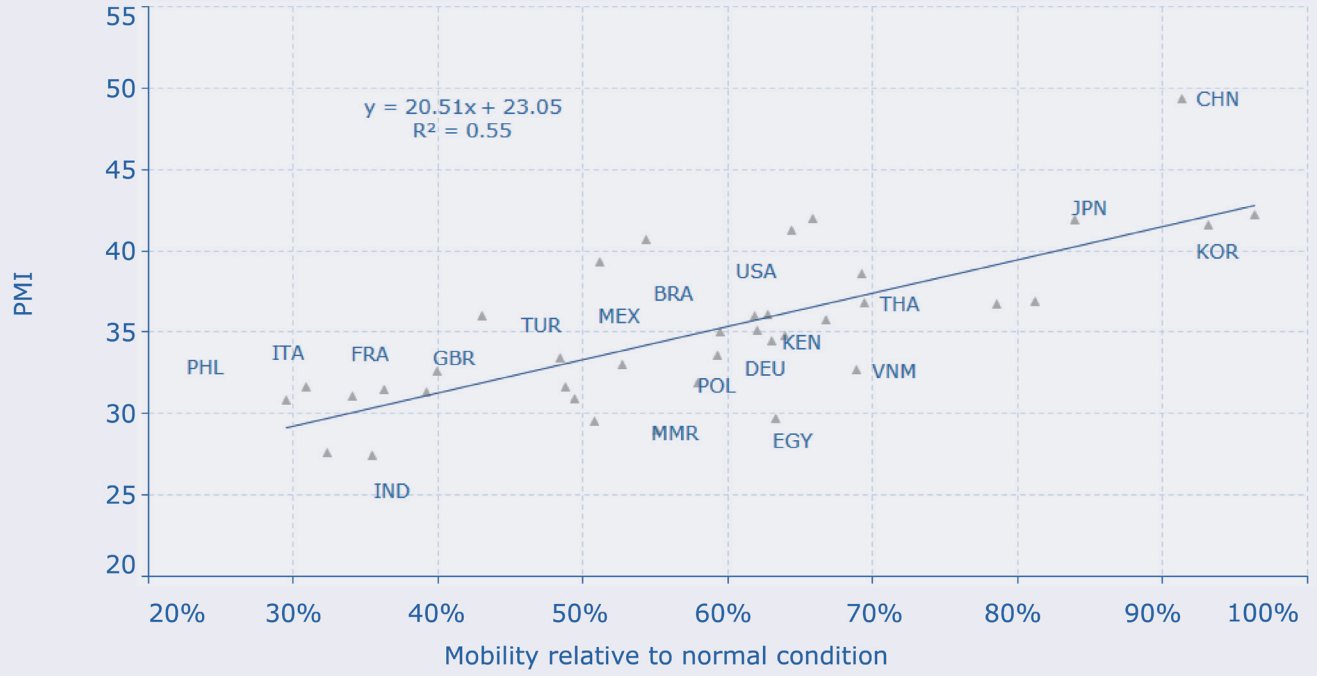
China is located in the bottom left corner of Figure 6 (Left) because of the 2-month long economic contraction in the first quarter of 2020, while many others started to shrink only from mid-March. By April most of these countries or regions stayed in a low level of operation, with a huge gap in their consumption and production relative to normal times. Thus, it can be expected that by the end of the second quarter, China will move right and upward and many others will move left and downward, as the economic impacts of the pandemic further intensifies.

A similar pattern is also observed on sentiments pertaining to future economic growth. Figure 7 shows that there is a significant relationship between the newly released purchasing managers index (PMI) of 38 economies for April 2020 and their relative mobility levels. More than 55% of the variation in PMI across these economies can be explained by mobility.

Figure 7. PMIs of April 2020 across 38 economies positively correlate with mobility.

PMI & mobility across economies

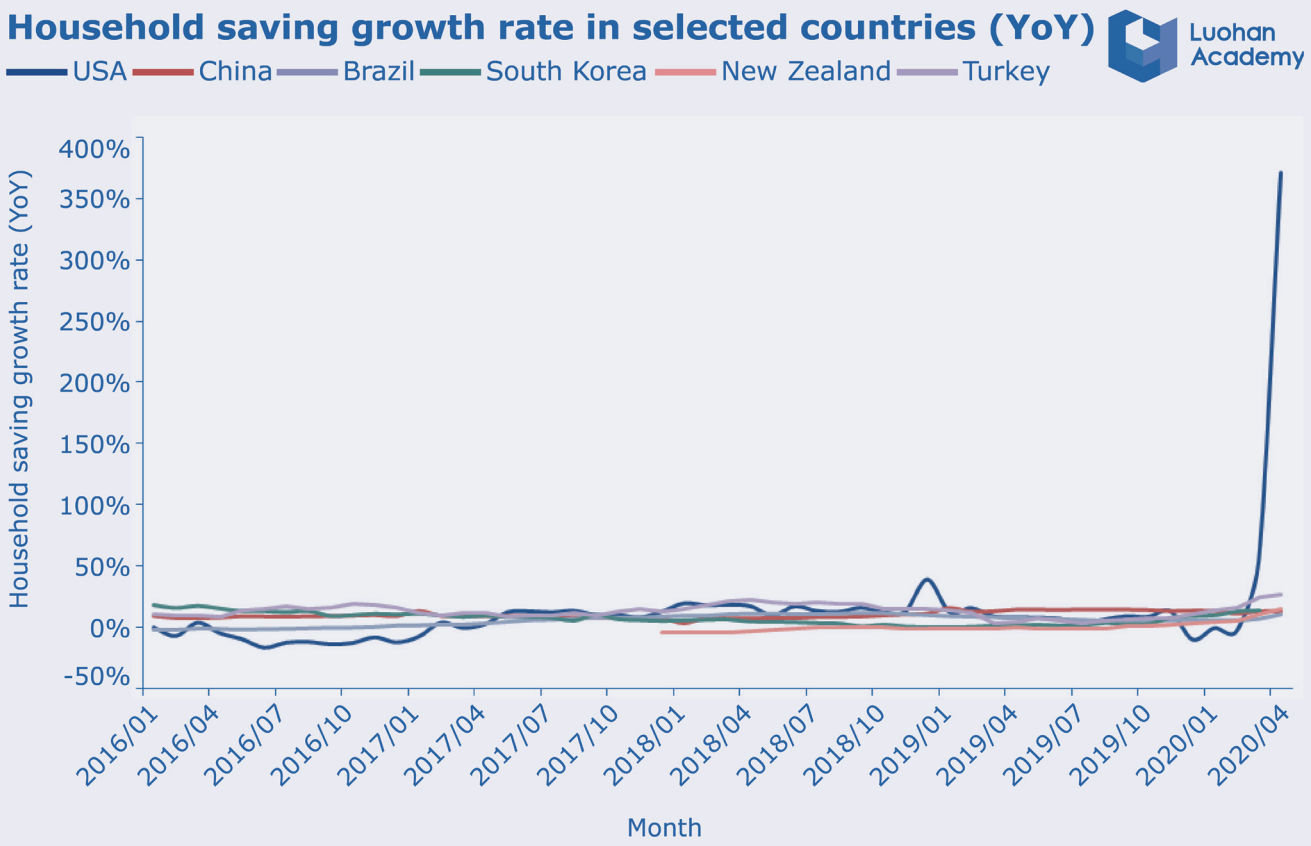
Bubble size indicates the population of an economy, April 2020



Source: PET project, using data from the Google COVID-19 Community Mobility Reports, the Apple Mobility Trends Reports, the Baidu Mobility Index, and the Wind Economic Database.

Many economic rescue and stimulus policies were adopted across a range of economies, but so far, the intensities of such policies were found to be not effective in explaining the differences in either GDP performance or PMI. There might be three reasons. First, the stimulus policies existed only for a short time, and it takes some more time for their effects to be reflected in GDP or PMI. Second, to contain the epidemic, a considerable part of the closed businesses will not resume production and operation activities even with financial stimuli. Third, in the face of liquidity shock and huge uncertainties about the future in terms of employment, and the health risks associated with high contact activities, consumers' mindset has changed and may not spend immediately after receiving cash assistance. For instance, the household savings in the United States rose sharply from 8% in February to 13.1% in March, and to 33% in April, the highest level ever since the tracking of this indicator was initiated in the 1960s. Similar trends of households saving rates increase (year-on-year) were also observed in other countries, such as Brazil, China, New Zealand, South Korea, and Turkey (Figure 8).

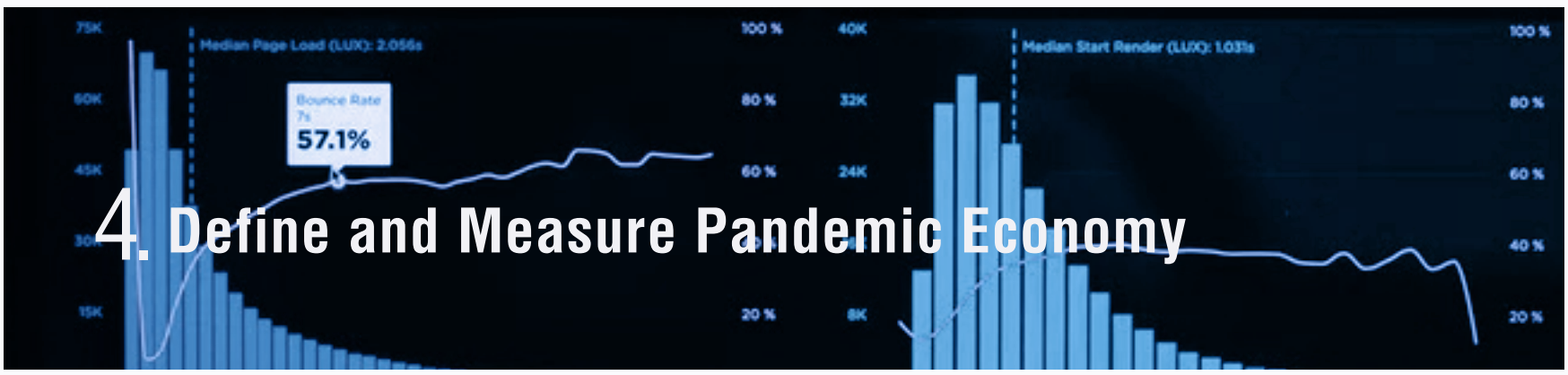
Figure 8. Significant household saving growths are observed in some countries recently.



Source: Data from the Wind Economic Database.

Economic prosperity depends on the mobility and connection of various factors of production, such as labors, resources, technology, and information, many of which are being shut down by COVID-19. People's mobility represents well the extent of limitation in the availability of the production factors, thus it's not surprising that its status links closely to economic performance.

It is obvious that mobility is only one indicator related to economic performance and cannot explain all macroeconomic phenomena. There are other direct measures like GDP, but they tend to arrive with a long lag that reduces their usefulness in the context of tracking the pandemic economy and informing real-time decisions. People's mobility action as a variable that captures the state of economic activity has several major advantages. First, it is one of the few big data measures that capture current activities and are available in more than 200 countries on a daily basis. Second, it is an endogenous variable in the sense that it captures both the impact of distancing policies (lockdowns and business closures) and people's choices, often motivated by risk aversion. Third, it appears to capture a substantial portion of GDP variation across economies, and over time. Therefore, mobility, with high levels of representativeness and accessibility, is likely the most important state variable for tracking the evolution of pandemic economies across countries and regions, based on which more specific economic analyses can be conducted in conjunction with other data.



4. Define and Measure Pandemic Economy

4.1 An Analytical Framework for The Pandemic Economy

The preceding analysis demonstrates the key commonalities on the trade-offs faced by difference economies, as well as the potential economic consequences of certain choices. This makes it more feasible to achieve the urgent task of defining and measuring pandemic economy. The "pandemic economy" needs to be defined in that it is not a simple aggregation of the two, but rather a dynamic inter-relationship among the pandemic, the economy and policy responses, similar to we see in other major crises but now with a rather different shock and corresponding policy responses. Importantly, misguided policy responses can bring about irreparable loss of life, and a major blow to the economy, severely compromising the welfare of the whole society. It is thus of considerable significance to properly recognize the nature of the pandemic economy, identify the common features, and measure and track the progress of the pandemic economy in various economies to help the global community grasp the key trade-offs.

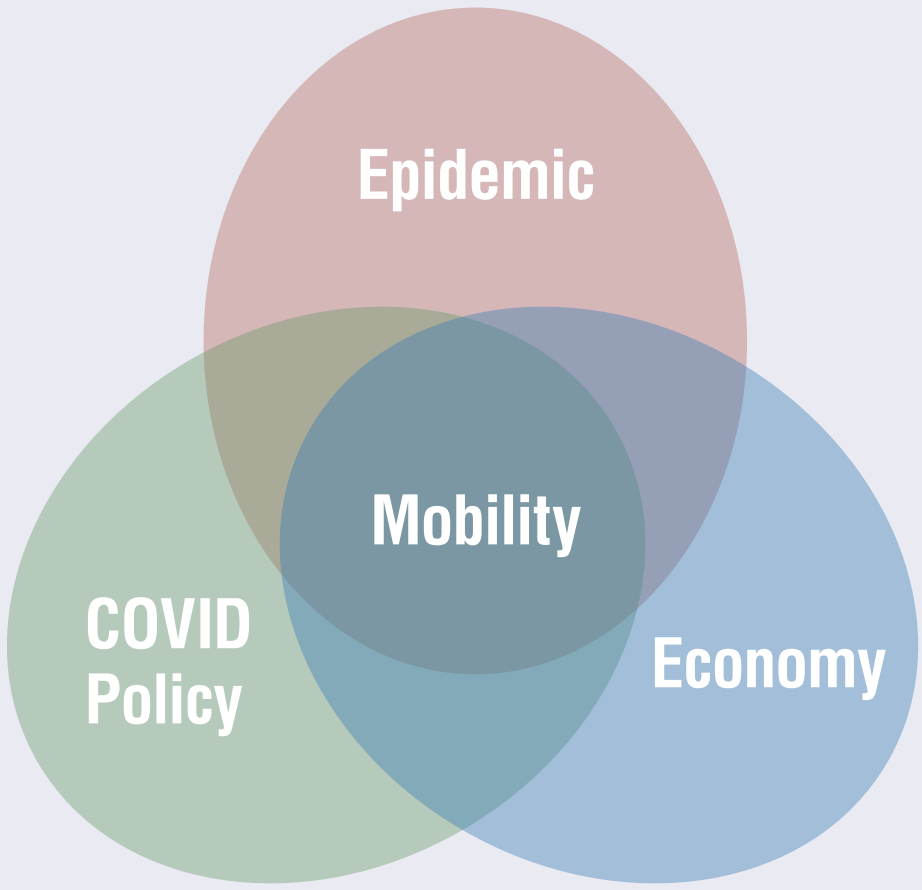
The essential feature of the pandemic economy is that the pandemic and the economy form an inescapable tradeoff, and the initial priority must be to contain the pandemic. Eichenbaum, Rebelo, and Trabandt (2020) also elaborated on the logic of this tradeoff.

Because of the distinct epidemiological characteristics, especially the high transmissibility, of COVID-19, if proactive isolation and quarantine measures are not taken very early, the virus will spread rapidly across high-density population areas. Early simulations have shown that the virus can infect most people in a country or region within just a few months (Adam 2020, Ferguson et al. 2020). In the meantime, the mortality rate of COVID-19 is significantly higher than that of seasonal influenza. Without active policy intervention, it is likely that COVID-19 would lead to a very high death toll and break the carrying capacity of the medical systems in most economies, especially the capacity of intensive care units (ICUs), further weakening a medical system's ability to treat non-COVID-19-related diseases and bringing about social unrest.

Second, the incubation period of COVID-19 is generally no more than two weeks, with an average of several days. Therefore, in the early phase of the outbreak, the virus can be contained through testing, active interventions such as case isolation and contact tracing to cut off the routes of virus transmission, effectively reducing and maintaining a low number of infections (effective reproduction number Rt<1). If containment is difficult, or the initial response is delayed, the focus of policies will be to slow down the spread of the virus, reducing medical demand due to COVID-19 while protecting those who are most likely to suffer from serious diseases related to infection, i.e., “flattening the curve.” In this way, the infected population can get better treatment without causing large-scale societal panic. The cost is a significant decline in the scale of economic activity.

The core tradeoffs of the pandemic economy can be described in the following simple triangular framework (Figure 9), in which mobility that captures the impact of "distancing", have become a key state variable to measure the progress of both pandemic and economy. Managing the pandemic economy usually requires to go through the painful process of heavily reducing mobility and economic activity before recovery. The depth and duration of the contraction in economic activity, to a large extent, depend on the timeliness and effectiveness of policy responses.

Figure 9: A basic framework to understand the pandemic economy, in which mobility is a key coupling factor for the three dimensions of epidemic, economy and policy.



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We further propose that the pandemic economy will unfold, and can be tracked and measured, in five phases.

Phase I: Early warning and preparation

With signs of an outbreak, some economies trigger early warning systems and introduce pre-emptive measures. Different levels of travel bans are deployed to ban travels from areas with virus infections. If such actions are timely, it is possible to contain the spread of the virus and prevent loss of life at a relatively small economic costs during this phase.

Phase II: Emergency response

Phase III: Trough

Delay in implementing containment measures results in the continued spread of the virus. Therefore, even after mobility drops significantly, it still needs a period to reach the point where the effective reproduction number drops significantly below 1. Some countries and regions have managed to reach this goal within a short time period (1-3 weeks) thanks to decisive and swift actions. At the same time, it took most economies more time to respond. At this phase, both the mobility and economic activity remain substantially subdued.

Phase IV: Recovery

In this phase, after the epidemic is effectively contained, an economy starts to recover gradually, first in sectors and regions where necessary conditions are met, and distancing is gradually reduced. If the pandemic intensifies due to the increased economic activities, the economy will be forced to return to the second phase.
At present, no economy has completed the fourth phase. Due to potential risks brought about by economic recovery, all economies are proceeding cautiously and exploring solutions. Consumers and investors need time to restore their confidence. Many countries and regions may stay in this phase for months, or even years, until an effective vaccine is found and deployed.

Phase V: Vaccination

This phase is marked by the successful development, production, and deployment of vaccines to all populations. This is the real herd immunity, and signals the end of the pandemic economy. But it should also be noted that, before the final goal is achieved, the economy will not decouple from the pandemic. Due to limitations in production capacities and costs, as well as differences in needs and legislations across countries, the length of this period at global level may be much longer than what is perceived and expected by the general public. Variation in the length of time staying in this phase may also be high across countries. To reach the aim of equitably and promptly deploying vaccines globally, we should start to prepare now (Atherly 2020, Bollyky et al. 2020, Weintraub, Yadav, and Berkley 2020) .

During the five phases of the evolution of the pandemic economy, there are two key variables that affect its state and direction. One is the effective reproduction number, and the other is the duration of the economy staying in a low operating model from the beginning of the response phase to the end of the vaccine phase.

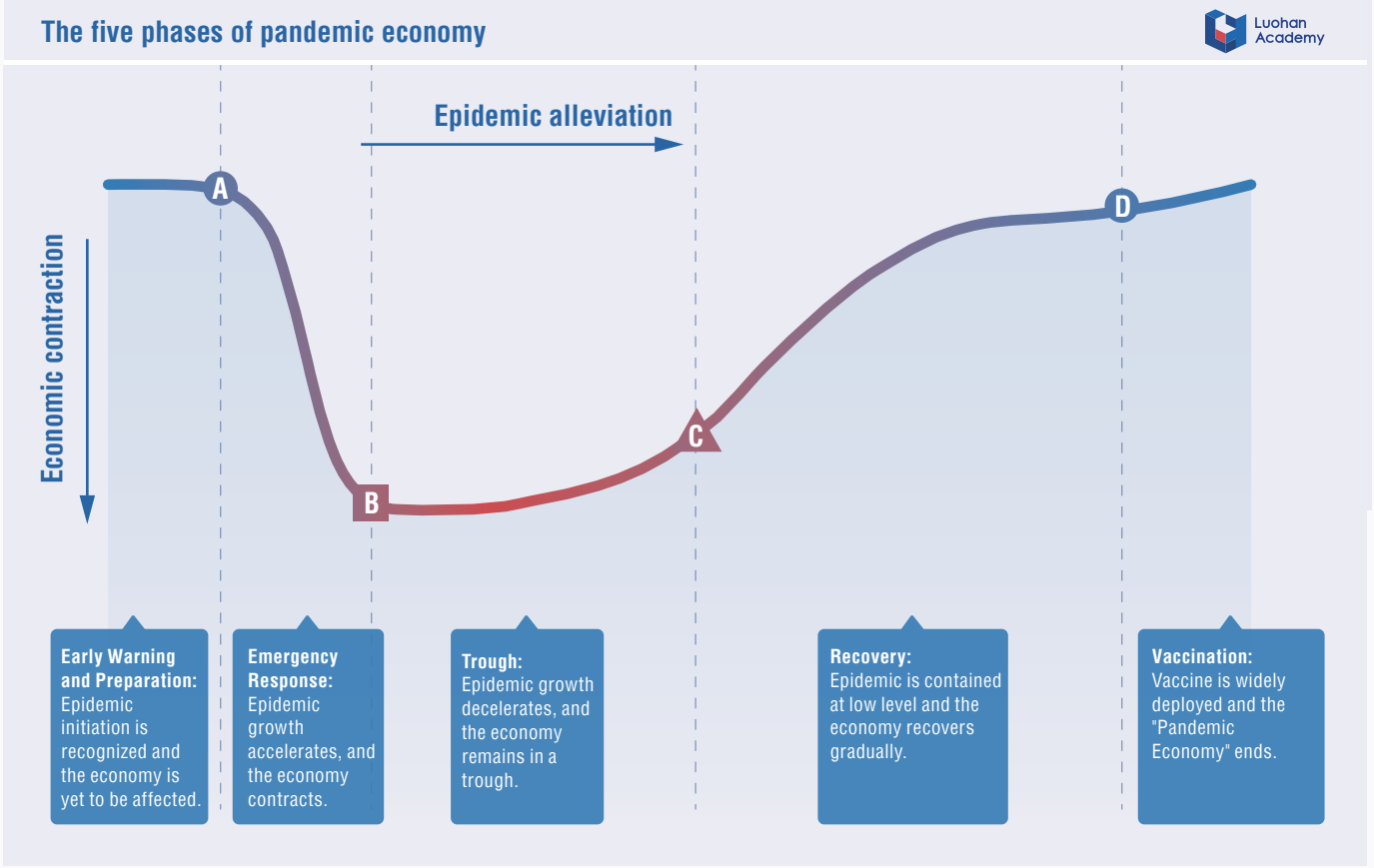
The main goal of containment measures is to first reduce the effective reproduction number (Rt) from being exponential (Rt>1) to an Rt significantly below 1. This is a sign of successful passages of the second and third phase, and also the premise for an economy entering the fourth phase. But if reopening economies lead to fast resurgence of Rt, the pandemic economy will be backflip to Phase 2.

The duration of low economic activity matters as continued contraction of an economy will inevitably bring liquidity shocks to enterprises and individuals. Cash flows of most enterprises may only sustain a few months, and household savings and balance sheets in many economies are relatively small. Continued difficulties would inevitably lead to a rise of defaults, bankruptcies and rising unemployment, destroying original contractual relationships and social coordination, destroying existing supply chains, and affecting the economic and financial systems. In the meantime, government rescues, even if available, may be limited and difficult to access. The impact of a long period of low economic activity may not be linear. As the Trough stage extends, both economic losses and social instabilities may increase exponentially.

This dynamic trajectory has special features and can be described using a pandemic economic Curve (Fig. 10). In the early stages the outbreak must be effectively contained at the expense of mobility and productive economic activity before recovery can be realistically considered. Due to the tension between health outcomes and economic goals, the speed of economic recovery will be much slower than the precipitous economic free fall that occurs at the start when lockdowns are imposed. This general pattern is confirmed in a wide range of countries whose patterns we report on below. Roughly it is a sharp and often deep contraction, followed by a period of variable duration in which the economy remains depressed followed by an S-shaped recovery - an acceleration in growth followed by a deceleration as one approaches pre-pandemic levels.

Countries have to navigate continuously through the dynamic trade-offs between epidemic expansion and economic contraction. The main challenge lies in shortening the free fall, compressing the time spent in the valley and accelerating recovery while sustaining satisfactory progress on containing the virus. Eventually the economy will decouple from the epidemic as the latter subsides.

Figure. 10. The five phases of the pandemic economic curve, including four phase transition points (A-D).



4.2 Pandemic Economy Tracking (PET) Graphs

To effectively balance containing the virus and supporting economic recovery, policy makers need tools to measure and monitor the evolution of global pandemic economy. With this goal in mind, Luohan Academy recently launched a Global Pandemic-Economy Tracking (PET) project, with the hope that everyone can better understand the general patterns of the intertwined pandemic-economic processes, the expected challenges, and key tradeoffs in different stages for various economies. It is based on multiple data sources, including three types of core indicators (see Appendix Table 2 & Table 3 for data sources and processing methods).

Based on these three types of indicators, we monitor the status of 131 economies in terms of the current phase of the pandemic economy, the depth of the economic fall, and the duration of staying in a low economic activity state, as an intuitive assessment of COVID-19 risks and the economic situation of various countries or regions. [2] We demonstrate the evolutionary processes of pandemic economies across countries and regions using the Pandemic Economy Tracking (PET) Graphs.

The PET graphs that we will see in the following sections, deal with a wide range of economies. On each graph, an estimate of the level of economic activity is on the verti-

[2] *See Table 3 of Appendix for criteria to delineate the ranges of the five phases, including the identification of transition points (A-D in Figure 10)。*

cal axis. It is expressed as a percentage contraction from the pre-pandemic level. It is derived from daily mobility data for each of 131 economies in the world, based on the empirical relation between mobility and economic activity. The horizontal axis is the number of days for confirmed infection cases to double. More precisely, it is days between the current date (the date at which the measurement is taken) and the most recent prior date at which the confirmed cases were half the current level. It is a proxy for the rate at which the virus is spreading in the population. The larger this number is, the lower the rate of spread of the virus in the population. If a region has no new cases, the doubling days will naturally increase reflecting the accumulation of days.

Each graph has a dashed vertical line which is the average doubling time of 19 days for the 45 economies that satisfy our recovery condition by May 20th 2020. We looked across all countries for the point at which there were three consecutive days in which the number of recoveries exceeded the number of new confirmed cases, a situation suggesting a pivotal point when the critical medical capacity of a country is starting to be released. It can be thought of as a proxy for when the epidemic is starting to be controlled and the opening up agenda can be started and the economic recovery agenda pursued somewhat more aggressively. Given large reporting errors in new cases, both the doubling days and the recovery date can contain considerable errors. But the general pattern remains true that the longer the doubling days, the more likely the virus spread is under control.

There is a semi-hidden time dimension in the graphs. The observations that are recorded in the graphs are taken daily. Normally you will see one date and three numbers for days on each country's graph. The date is the beginning of the economic contraction when mobility drops quickly, which we define as the starting date of the response phase. We take it as the starting point of economic contraction. The first day number refers to the days between the starting point (point A in Figure 10) and the date the economy reaches the bottom of mobility due to containment policies (Point B in Figure 10), thus the length of the Response phase. The second day number refers to the days between the starting point (Point A in Figure 10) and the date the economy reaches the beginning of the recovery (Point C in Figure 10). The third day number refers to the days between the starting point and the latest date, which measures how long the economy has been in a contraction mode. If a country only has two numbers it implies that the country has not entered Recovery phase.

Why does this matter? The economic damage in terms of lost income and output depends on the depth of the contraction and its duration. So if two PET graphs for two economies look similar, but the speed of transition is higher for one than the other, then the faster transition economy will be in better shape. It will have experienced less balance sheet damage spread across its various sectors: household, business, financial and government. The duration of programs to buffer the shock and redistribute the damage will be shorter and less costly. Deficits and sovereign debt increments will be lower.

The purpose of the graphs is to capture how infectious the pandemic is (measured by the doubling days), and how much economic activity is reduced at each point along the path. The strong correlation between mobility and GDP growth across economies in the first quarter indicates that, once we know the average contraction of mobility during the period, we have a pretty good proxy for economic contraction.

In Figures 11 and 12, we show the performance of countries or regions under the first and second waves of the COVID-19 pandemic in two dimensions, i.e. epidemic containment and economic contraction. The level of economic activity is estimated according to the general empirical relation between the global mobility and economic output. These figures show three characteristics, that best describe the nature and dynamics of pandemic economy.

First, the goal of each COVID-19-infected economy is to quickly reach the right side of the graph while limiting economic losses. To achieve this goal, the vast majority of economies have to go through the painful process of significant economic contraction, due to missed opportunities in tackling the infection in an early stage.

Second, variations in the paths taken by different economics are largely caused by the timing and effectiveness of intervention measures. In general, early actions pay off and delays often lead to expansion and intensification of intervention measures, and larger economic losses. Those economies which have experienced large and extended contractions, but with the pandemic coming under control include Spain and Italy. South Korea is an example of the rapid adoption of effective epidemic control measures, resulting in a less severe economic contraction.

Third, the contraction and recovery of the pandemic economy tend to be very asymmetric in almost all cases – sharp contraction and gradual economic recovery. China's experience shows that, even if the pandemic can be brought into control relatively quickly, economic recovery may still take much longer. Most countries and regions will need more time than China to bring the pandemic under control, and the recovery will be slower, given the trade-off between the pandemic and economic growth. This will inevitably cause a lot of economic hardships, including defaults, bankruptcies, and damages to the financial system.

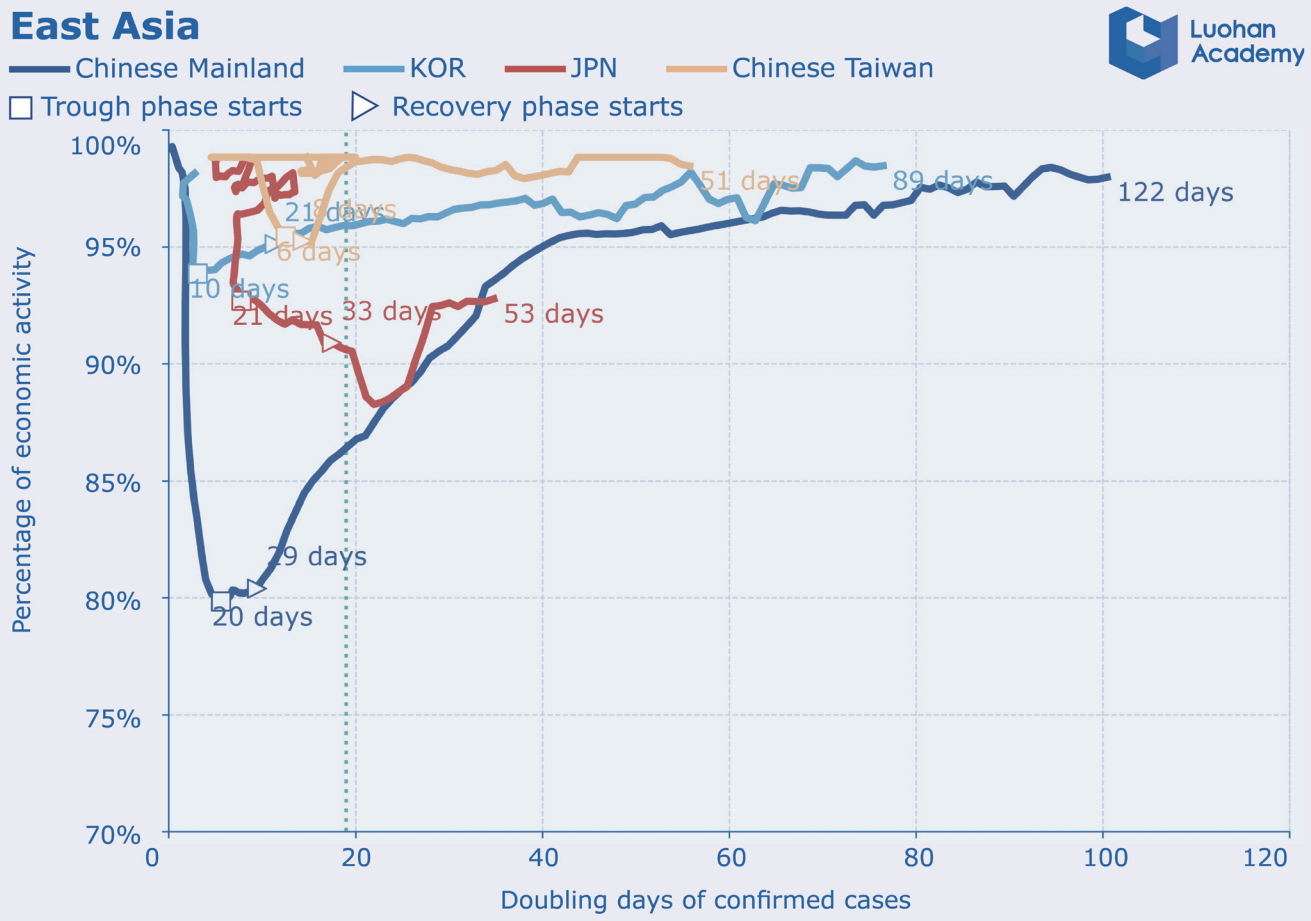
4.3 Tracking the First Wave of Global Pandemic Economy

The first wave of the pandemic hit mostly East Asian economies: mainland China, Hong Kong SAR of China, Taiwan Province of China, Republic of Korea, and Japan, covering a population of 1.61 billion. By May 20th, the total number of confirmed cases in this group of economies reached above 112,000, with a cumulative death of 5,677. This is the group with the lowest number of confirmed cases and deaths per million people.

China's trajectory represents the pandemic economy curve quite well. It took China 20 days to reach the bottom, at about 80% of normal economic activity. After nine days of stay in the Trough phase, the epidemic growth was effectively stemmed, when Recovery phase started and economic activities rebounded. The contraction paid off in the sense that the curve is steadily moving to the top right direction, meaning that both epidemic and economic situations are improving. By May 20th, China has stayed in the contraction mode for 124 days. Its economic activity has exceeded 98% of the level prior to the pandemic. China's quarter-by-quarter growth will very likely be positive in the second quarter. But it should be remembered that the growth is from a very low base created by the contraction in the first quarter, which is not the same as full or even substantial economic recovery. And with strong stimulus packages, it is not hard to envision that China will experience positive growth in the second half of the year.

It's particularly noteworthy that two densely populated economies, South Korea and Chinese Taiwan, have achieved effective epidemic control without significantly mobility reduction. They have both recovered to more than 95% of normal activity level without much contraction to start with, and their infection doubling days is near 80 and 60 days respectively. Overall, the lesson from East Asia is that the faster and more decisively a country moves to contain the virus, the smaller a price, from both health and economic sense, it has to pay.

Figure 11. PET graph of selected East Asian economies, who responded promptly and usually stayed for fewer than 30 days in the Response and Trough phases.



Source: PET project team, using data (by May 20th 2020) from the Google COVID-19 Community Mobility Reports, the Apple Mobility Trends Reports, the Baidu Mobility Index, the Amap Traffic Index, and the Wind Economic Database, the European Centre for Disease Prevention and Control, National Health Commission of the People's Republic of China, and the Johns Hopkins University.

4.4 Tracking the Second Wave of Global Pandemic Economy

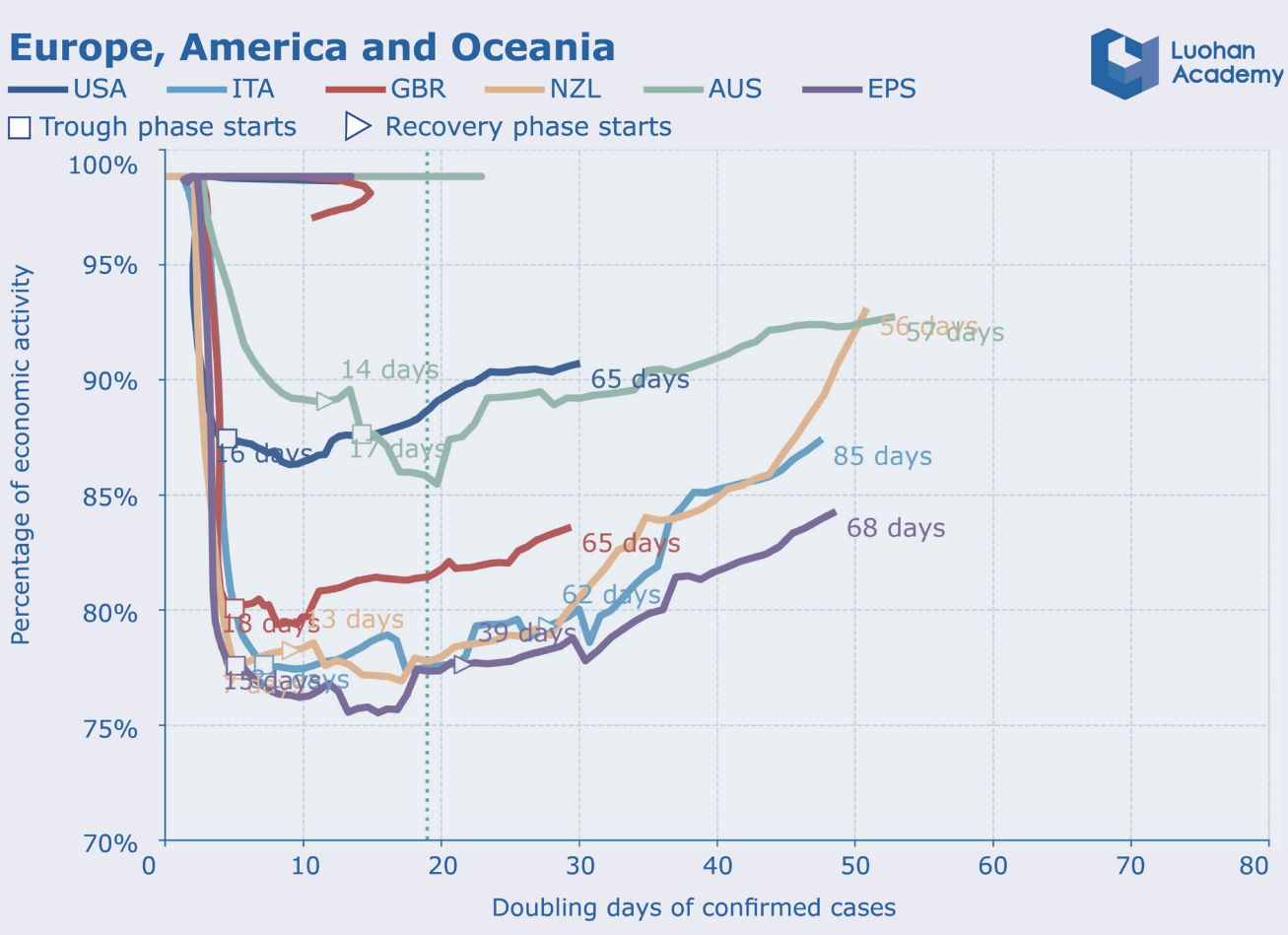
The second group includes 46 economies, mainly advanced economies in Europe, North America, and Oceania, as well as countries in the Middle East and North Africa (MENA) regions. Many of them have the best health systems but suffer from the worst epidemic losses so far. They cover a population of 1.18 billion. The group has the highest number of confirmed cases (3.35 million by May 20th), death toll (264,000 by May 20th), case per million population (2,832) and deaths per million population (223) among the three waves of economies.

Although this group of countries have observed the COVID-19 experience in the first wave of economies, except a few, they did not make adequate preparations in an early stage and learned the lessons in a hard way.

Italy has stayed in the pandemic economy for 85 days (Figure 12a). It took 62 days to satisfy our proxy condition for recovery and it has stayed in a deep contraction mode for most of the 85-day period. Spain is in a similar situation. The United States has stayed in the contraction mode for 65 days and it has not satisfied the recovery condition. Regarding the magnitude, if the United States stayed at on average a bit higher than 90% of normal economic activity during the second quarter, roughly speaking it will translate into a close to -10% of quarter-to-quarter GDP growth, or close to -40% of annualized growth, on par with the prediction by the Congressional Budget Office of the United States. In other words, 90% of normal economic activity is a very bad situation comparable to the Great Depression, during which time the worse growth rate was -12.9%. The United Kingdom is in a very similar situation as the US but has experienced worse contraction. Australia and New Zealand exceed the 50-day doubling day threshold, while that of neither the United States nor the United Kingdom has exceeded 30 days.

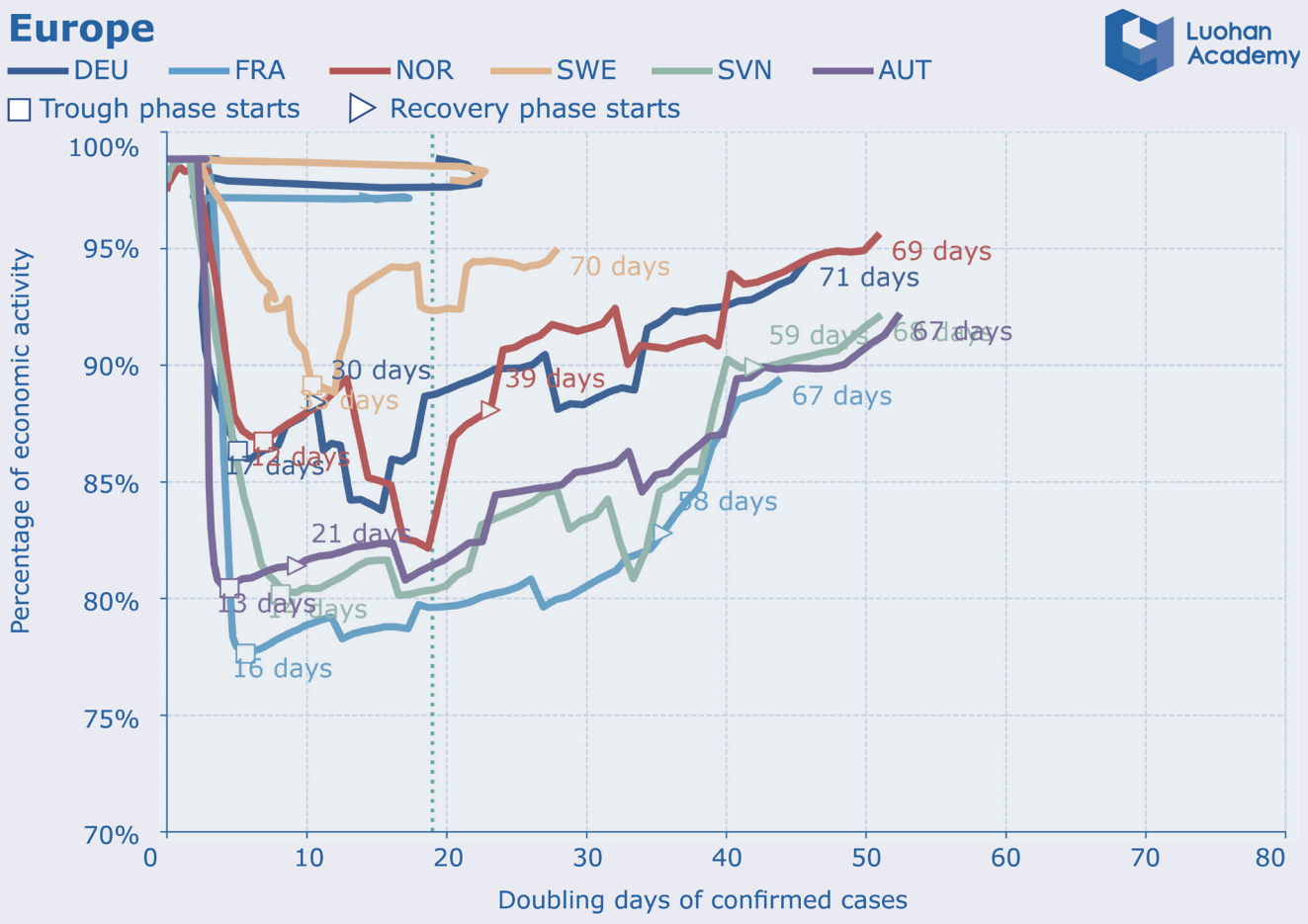
Figure 12. PET graphs for some advanced economies in the second wave, with many experiencing prolonged response and trough stages. (a) Selected European and North American countries with most severe epidemic situations VS Oceania countries with fast responses, and (b) Selected European countries

(a)



Source: PET project team, using data (by May 20th 2020) from the Google COVID-19 Community Mobility Reports, the Apple Mobility Trends Reports, and the Wind Economic Database, the European Centre for Disease Prevention and Control, National Health Commission of the People's Republic of China, and the Johns Hopkins University.

(b)



Source: PET project team, using data (by May 20th 2020) from the Google COVID-19 Community Mobility Reports, the Apple Mobility Trends Reports, and the Wind Economic Database, the European Centre for Disease Prevention and Control, National Health Commission of the People's Republic of China, and the Johns Hopkins University.

As shown in Fig. 12b, Germany, France, Austria, and Sweden have all stayed in the contraction mode between 67-71 days, but there are differences in their experience. Germany and France went through similar trajectories but Germany's economic activity contracted less. Sweden' economic activity contracted less due to deliberate policy choices, but similar to the situations in the UK and the US, it has not satisfied our proxy condition of recovery. Norway suffered more contraction than Sweden, but it now is much further along than Sweden in doubling days, and its economic activity is back to the level of Sweden. Austria fared better and has exceeded the threshold of 50 doubling days, with the economic activities rebounding from 80% to above 90%.

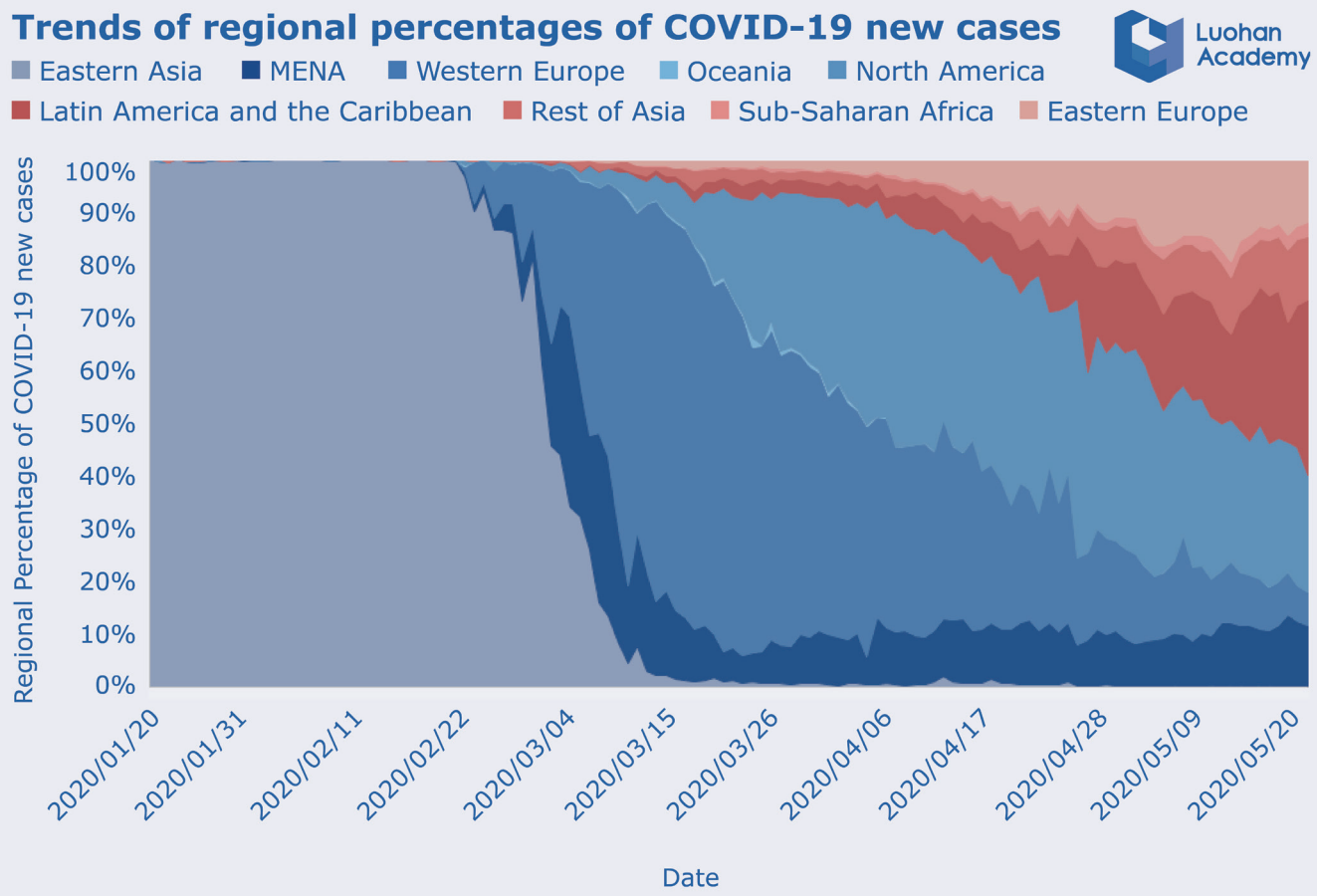
5. The Third Wave Of COVID-19

The third wave of COVID-19 pandemic is now in motion. The vast majority of high-income countries in Europe and the Americas, and some middle and high-income economies in East Asia, which are the main hubs of the international aviation network, have been the main victims of the first and second waves of the pandemic. However, with the continued spread of the virus through global transportation networks, the third wave of the global pandemic is expanding in many low- and middle-income countries and regions in Asia, Africa and Latin America (Figure 13). By the end of early May, the number of newly confirmed cases per day in Asia excluding China, Latin America and Russia has approached or even exceeded that of the European Union. Brazil, Russia, and India are becoming the economies with the largest number of new cases per day second only to the United States. In fact, the day of May 20th observed an addition of 106,000 new cases globally, largest since the beginning of the pandemic, and 2/3 of them came from the US, Brazil, Russia, and India.

5.1 Characteristics of the economies in the third wave

Most low- and middle-income economies still lag far behind the high-income economies, in terms of the public health system, the production of medical supplies and equipment, economic resilience, and the policy space. The third wave would bring even greater challenges to these economies, and the world must work together to help deal with this crisis in these lower income countries. In the end that will be to the benefit of all.

Figure 13. Emerging and developing economies are the new epicenters of COVID-19 pandemic



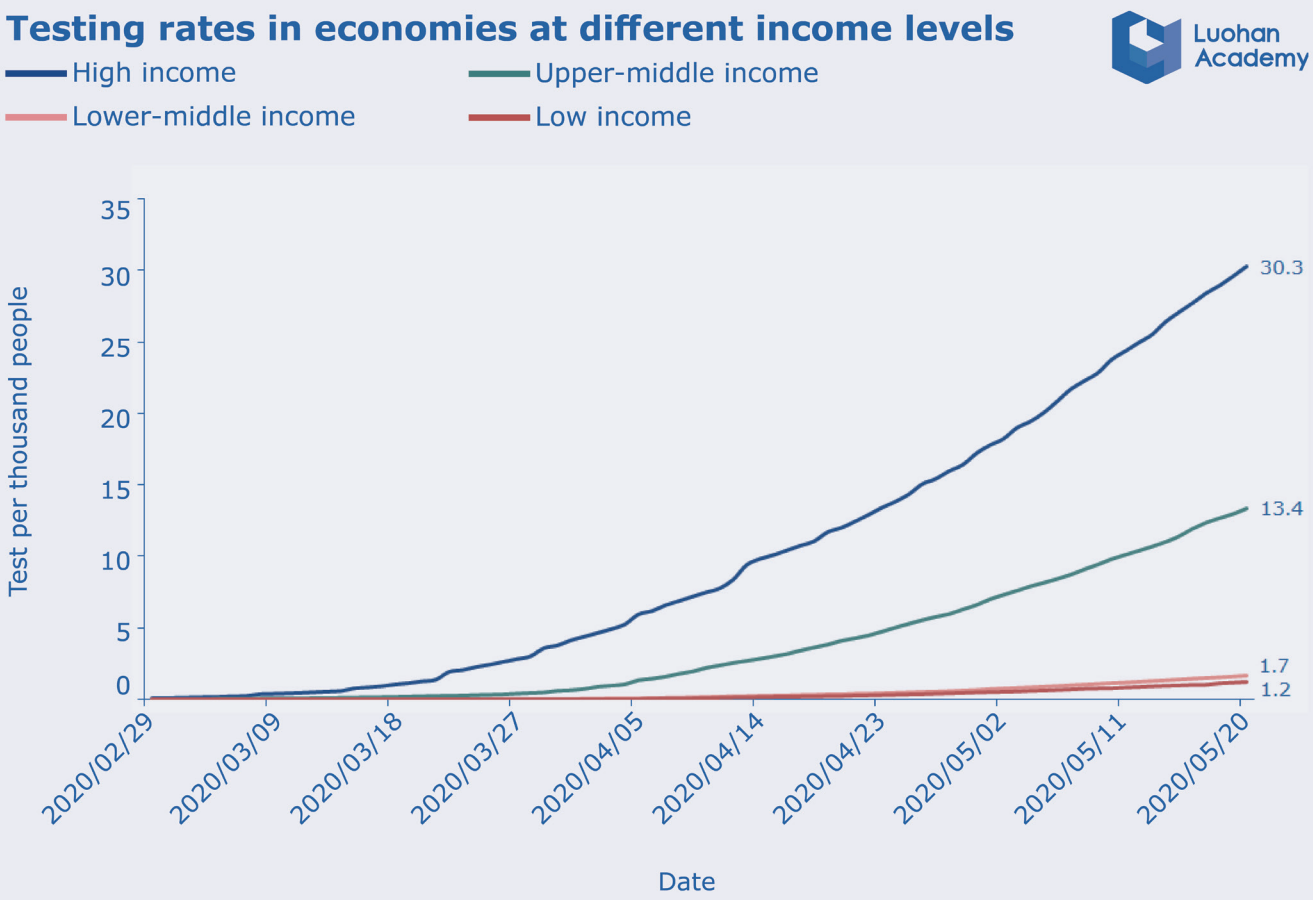
Source: PET project team, using data (by May 20th 2020) from the European Centre for Disease Prevention and Control, National Health Commission of the People's Republic of China, and the Johns Hopkins University.

In the third wave of the pandemic, developing economies face greater risks due to four major types of vulnerabilities: high-density low-income neighborhoods, especially the urban slums, unavoidably vulnerable to high risks of community outbreaks; lack of adequate public health infrastructure and medical resources leading to a very low threshold for the collapse of their public health systems; fragile economic structure and a lack of sufficiently flexible policy options including fiscal space; and a high proportion of labor force employed in the informal sector more vulnerable to economic hardship during the pandemic.

First of all, from the perspective of COVID-10 virology and epidemiology, although the population of developing economies tends to be relatively young for whom the mortality rate of COVID-19 is significantly lower than that of the elderly at the individual level, many people in developing economies reside in close-living communities. A large number of the urban population live in dense slums, and the risk of community outbreaks, i.e., fast spread of virus without being detected, is very high. With COVID-19's extremely high transmissibility, once the window of opportunity for curbing the pandemic right at the beginning is closed, a high population base might lead to extensive infections and an elevated death count. At the same time, the flu season in the southern hemisphere has begun and will reach its peak in the third quarter, this will bring further pressure, especially on governments in Southern Africa and South America. With the third wave of the pandemic, public health and economic crises may go hand-in-hand and evolve into humanitarian disasters in these areas.

Second, the capacity of the public health system in many middle- and low-income economies are often limited and funding for public health is in short supply. Hence the overall level of medical care tends to be more limited than in most advanced economies, a fact laid bare during the virus outbreak. For example, there has been a sizeable gap in COVID-19 testing, the primary tool for detecting and monitoring the pandemic. As of May 20th, the detection rate reached an average of 30.3 cases per thousand people in high-income economies as defined by the World Bank, but merely 1.7 and 1.2 in lower-middle-income and low-income economies, respectively (Figure 14). Russell et al. (2020) calculated the detection rate of virus carriers in various economies, they show that the underreporting rate (i.e., 1-detection rate) in most low- and middle-income economies was 80% or higher. There is a strong possibility that the severity of the pandemic in these economies has been vastly understated.

Figure 14. COVID-19 testing rates are much lower in low income and lower-middle income countries



Source: PET project, using data from OurWorldinData.

Note: World Bank definitions are used to define income groups.

Most developing economies lack the necessary medical resources, funding, and infrastructure to respond effectively. It is estimated that the annual funding gap for low- and middle-income economies to reach health-related Sustainable Development Goals (SDGs) is as high as USD 370 billion. However, international support for health development has been basically stagnant since the financial crisis in 2008 (Ogbuoji et al, 2019). Challenges are especially tough in Africa: while shouldering 23% of the global disease burden, it accounts for only 1% of the global public health budget. Many African countries have already faced the pressure of various infectious diseases. For example, the Ebola Virus outbreak ravaged several Western Africa several years ago, resulting in the lockdowns of a number of countries.

There is a general lack of resources specific for epidemic control in developing economies: supply is scarce, e.g., PPEs, ventilators, normal and ICU beds in hospitals. Most developing economies lack the capacity to produce these critical medical supplies by themselves. They rely heavily on the trade with China, Japan, South Korea, the European Union, the United States, among others. Such materials are already in short supply in these economies due to a sharp rise in demand: in the early days of the pandemic, some countries' ban on trade in COVID-related materials created a disaster for some economies (Evenett 2020).

Third, from the perspective of economic structure and policy buffering space, many developing economies rely on bulk commodity export, tourism and overseas remittances for income. The first and second waves of the pandemic have caused a deep slump in these income sources, and government revenues have declined drastically. While developed economies can provide large-scale stimuli to expand medical supply, protect employment, delay taxation, and reduce bankruptcy, helping firms and households survive the crisis, this is much harder for most developing economies, especially those already in debt. Many international investors started to withdraw funds from developing economies already in the early stage of the pandemic, leaving them with unprecedented funding gaps. Among others, the Ethiopian Prime Minister Abby Ahmed appealed for large-scale debt relief for African countries in late March to help them cope with COVID-19 difficulties, which has received positive response recently.

Fourth, the informal sector employs a sizeable proportion of workers in developing economies. About 50% and 60% of the labor force do not have formal, fixed jobs in lower-middle-income and low-income economies, respectively. Since many families have neither stable income nor unemployment insurance, and household savings are extremely low, social distancing policies have a large impact on people's livelihood, resulting in a much greater trade-off between human life and the livelihood. In some developing economies, social distancing is considered as "a privilege for the middle class".

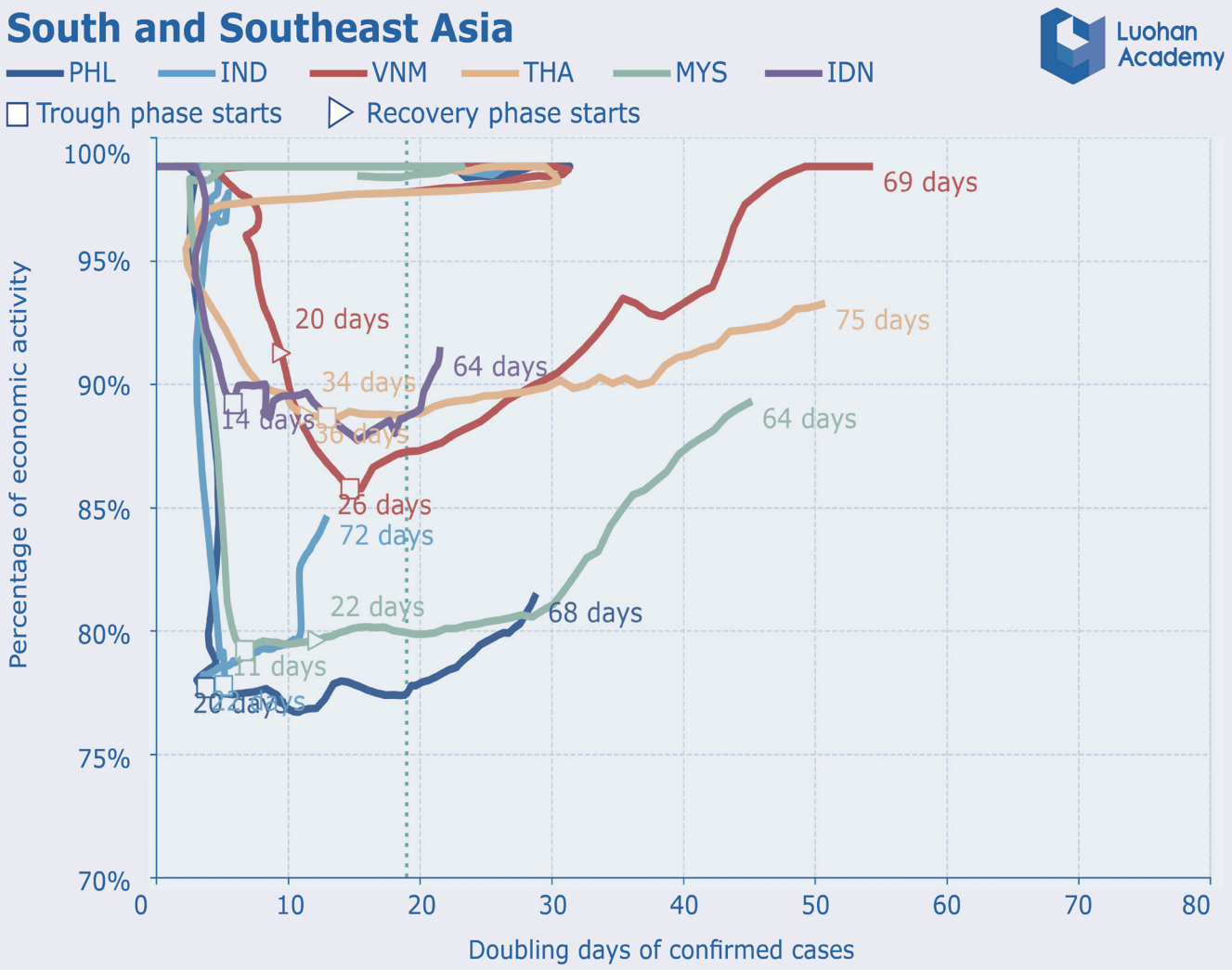
5.2 Different responses and their consequences in the third-wave economies

Due to distinct policy and social conditions, developing economies in the third wave of the pandemic have shown greater diversity in epidemic control policies and their effects, compared to those in the first and second waves. This resulted in varying different pandemic paths.

Asia

Across South Asia and Southeast Asia, both Vietnam and Thailand have made good progress. Their doubling days have exceeded 50 days, and their economy has recovered close to or more than 95%. In contrast, Philippine's economic activity has contracted much more and is still lower than 85% after 68 days in the contraction mode. The situations in India and Pakistan are much worse. These countries have stayed in the contraction mode no shorter than other countries. But their doubling days are stuck at around 10 days, and the curves are going upward, suggesting that they are being forced to restart the economy without effective epidemic control.

Figure 15. PET Graphs of selected economies of selected South and Southeast Asian countries in the third wave of the COVID-19

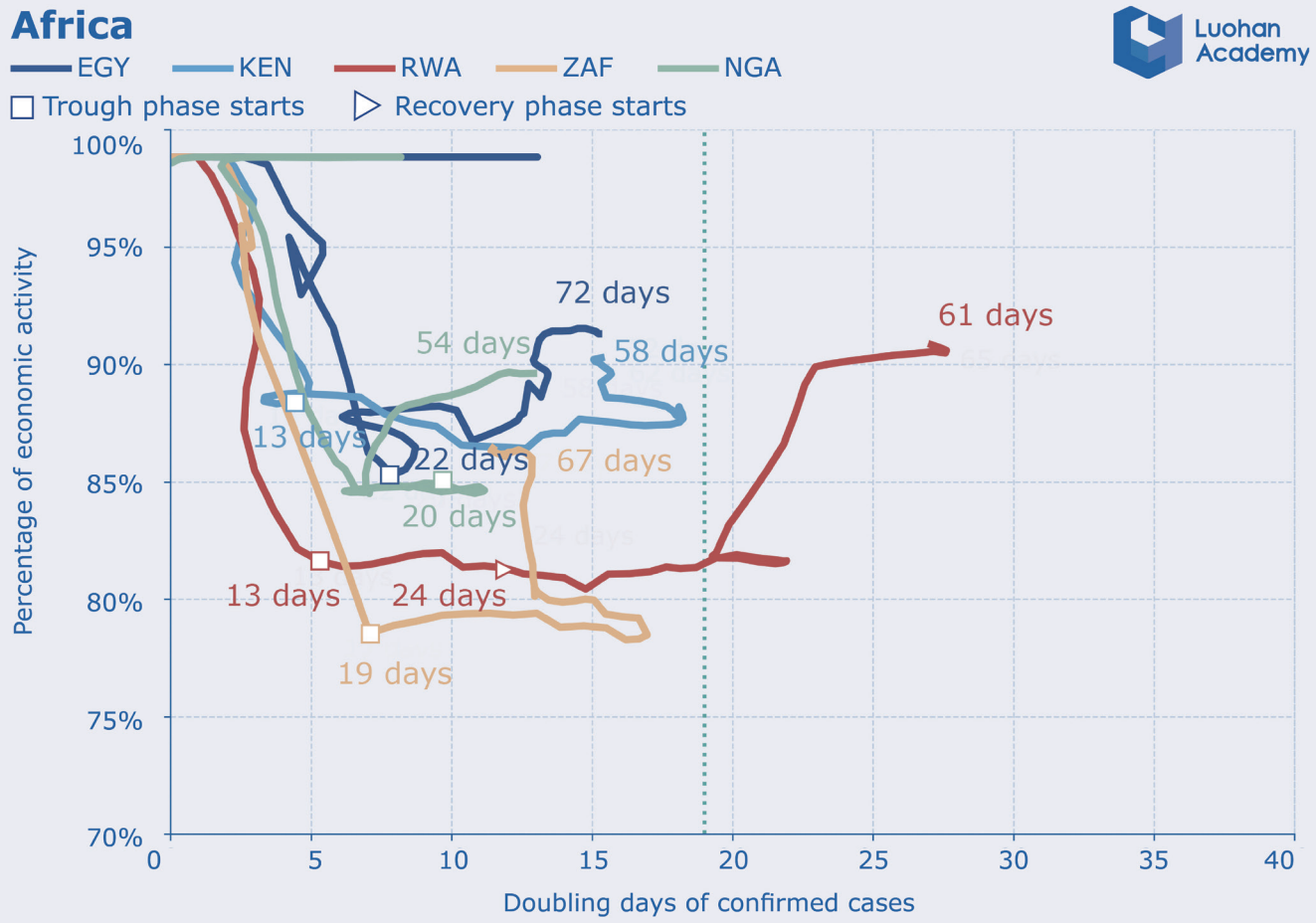


Source: PET project, using data (by May 20th 2020) from the Google COVID-19 Community Mobility Reports, the Apple Mobility Trends Reports, and the Wind Economic Database, the European Centre for Disease Prevention and Control, National Health Commission of the People's Republic of China, and the Johns Hopkins University.

Africa

In African, Rwanda fared better than many countries. Notably, there was no death resulting from COVID-19 in Rwanda, though it has not exceeded the threshold of 30 doubling days. The trajectories of PET of Egypt, Kenya, Nigeria, and South Africa, several of the African's largest economies, tend to be stuck on the left, and go upward or even backflip, suggesting that they all have difficulty balancing epidemic control and economic recovery. What is worrisome is that though many of these countries have experienced contraction for close to or more than two months, it is unclear the paths have found their ways going right and upward.

Figure 16. PET Graphs of selected economies of selected African countries in the third wave of the COVID-19

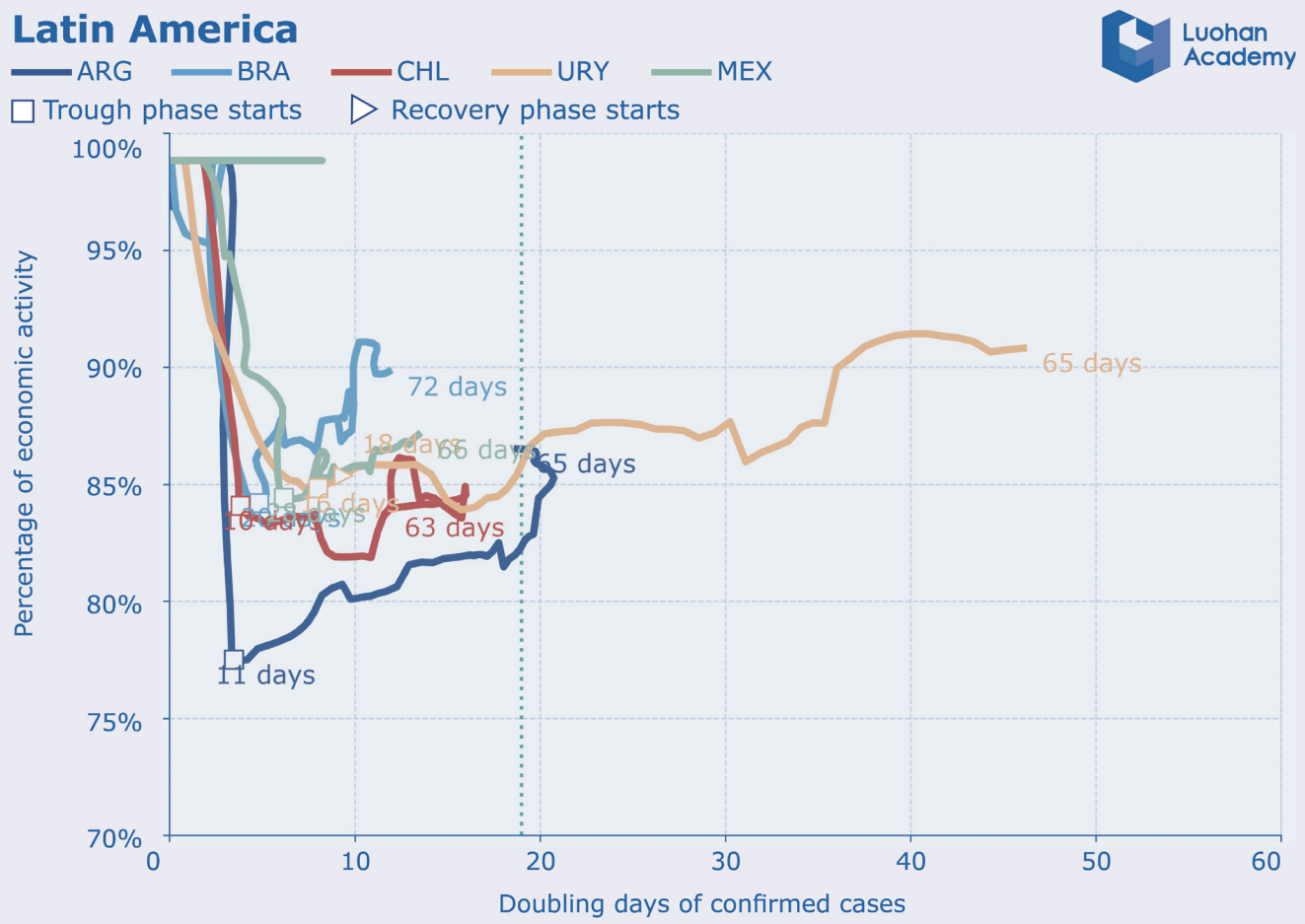


Source: PET project, using data (by May 20th 2020) from the Google COVID-19 Community Mobility Reports, the Apple Mobility Trends Reports, and the Wind Economic Database, the European Centre for Disease Prevention and Control, National Health Commission of the People's Republic of China, and the Johns Hopkins University.

Latin America

Most Latin American countries (Figure 17) have adopted epidemic control policies and a strategy of early mitigation, except for Brazil. Yet, the implementation has not been very effective. Brazil has already been in the contraction mode for 72 days, but its doubling day is still around 10, which means the virus is still spreading. The curve is squeezed on the left side, reflecting the fact the country has not found an effective way to combat the epidemic while initiate economic recovery. Mexico is a similar situation. Uruguay, a higher income country than its neighbors, did better than most South American neighbors with the doubling days much further along, paving the way for sustainable recovery. At present, Latin American countries have a large infected population and high mortality rate, they are likely to become the new global epicenter of the pandemic and stay subdued for a long time.

Figure 17. PET Graphs of selected economies in Latin America, many risking large outbreaks by not effectively implementing distancing measures



Source: PET project, using data (by May 20th 2020) from the Google COVID-19 Community Mobility Reports, the Apple Mobility Trends Reports, and the Wind Economic Database, the European Centre for Disease Prevention and Control, National Health Commission of the People's Republic of China, and the Johns Hopkins University.

What Should We Expect from The Third Wave?

The ability of the developing economies in the third wave of the pandemic to handle the crisis is much lower than that of most higher-income economies in the first and second waves. The pandemic is expected to spread widely in these economies in the second and third quarters of 2020, and a big outbreak in some economies is almost inevitable.

When winter returns to the northern hemisphere later in 2020, the pandemic may follow the path as well, and some developing economies who successfully handled the early outbreaks might face a new round of pressure. In a pessimistic scenario, many will have difficulties in quickly containing the epidemic, and they will vacillate between implementing strict lockdown measures to reduce virus transmission and brief re-openings to temporarily relieve social and economic pressure.

The global recession and the corresponding breakdowns in global supply chains will have a large impact on many emerging economies, including Brazil, India, Indonesia, Russia and Mexico, which heavily depend on trade. It will also cause significant difficulties to many commodity-exporting economies, such as Nigeria and Angola whose main pillar of economy is oil export.

The pandemic economy in the developing world will enter and stay a long trough in the next two to three quarters. These economies need strong assistance from international institutions, including new aids and loans, as well as delay in current debt payments, and eventually debt forgiveness. In the meantime, the crisis also provides a small window for some economies to seize the opportunity and adopt innovative technologies, such as 5G and other digital technologies, and take new routes for more sustainable development.

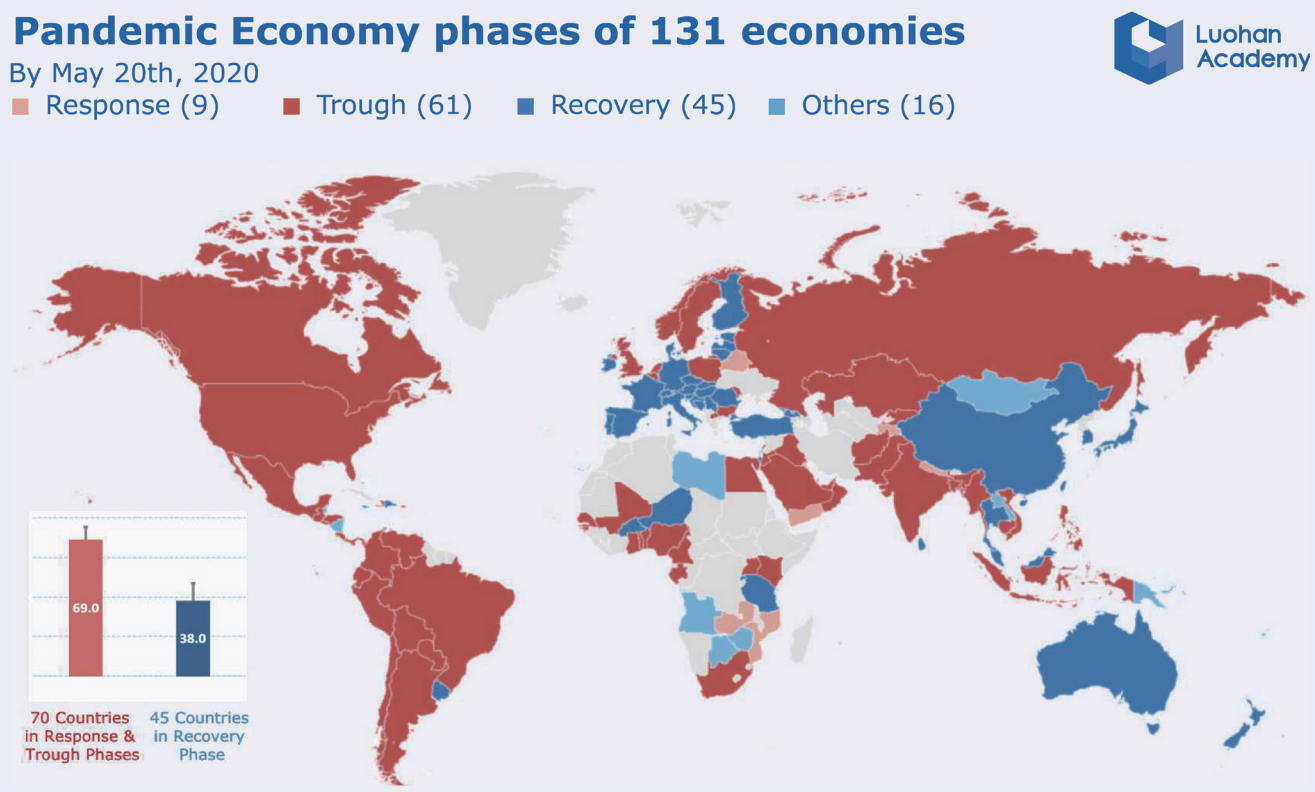
While the main donor countries are still mired in their own pandemic economy challenges, the need for help in many developing economies is real and urgent. In fact, the evolution of the pandemic economy in these economies in the next few quarters may have a large impact on the global economy. We must learn from the experiences of the world's first and second waves of the pandemic and be quick in fighting the third wave. A key lesson is that we need effective and timely global cooperation. International agencies and institutions have an important role to play in reducing the negative impact of the pandemic.

6. Summary

COVID-19 presents a great challenge to humanity. As a whole, we have failed thus far in tackling it. At the national level, many economies are repeating the same mistakes over and over again. Most of them have missed the best time to contain the pandemic. Unfortunately, some economies considered to be equipped with the best medical resources have been among the least successful in dealing with the pandemic. In many lower-income economies where medical care and ability to provide economic stimulus are in inadequate supply, a major storm may be looming in the horizon.

As of May 20th, of the 131 economies tracked by PET, 45 have entered the Recovery phase. Prior to this, they stayed on average 38 days in the Response and Trough phases. At least 70 economies had spent on average 69 days in Response & Trough phases and still there (Figure 18). That is to say, more than half of the countries and regions have not been able to rebound effectively after spending more than two months coping with the epidemic.

Figure 18. Countries and regions currently in Recovery phase acted faster and stayed shorter in Response and Trough phases (by May 20th 2020)



Note: Sixteen economies with few COVID-19 cases (<150) and without clear trends in pandemic economy are temporarily classified as Others.

Due to often inconsistent policies, lack of capability in some economies and missing international coordination, the virus may live with us for a long time to come, waging further waves of attacks on public health and economic growth. Therefore, tackling the pandemic economy challenge urgently demands clarity in defining, measuring and monitoring its evolution. A pandemic economy is not simply an economy with pandemic. The pandemic, the economy and the policy responses have strongly coupled into complex dynamics. Every misjudgment and delayed responses, even small ones, may bring huge costs to human life and to the global economy, potentially transforming a short-lived crisis into a long-term disaster.

In this report, based on patterns of the pandemic economy uncovered in various economies, we propose an analytical framework and the Global Pandemic Economy Tracker platform. We will continue to track and update the global pandemic economy on a daily basis, and will soon add interactive features and elements to facilitate more interested parties and professionals to track and compare the diverse trajectories of the pandemic economy worldwide on this platform. We aim to build an active open community to continually developing and tracking system, and updating the situations in various economies, and co-generate key knowledge and evidence to inform better coordination and decision making, so that we will walk together out of the pandemic economy in a more equitable and sustainable way.

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Appendix

Table 1. Regression results of mobility and epidemic containment policies.

	(1) OLS	(2) FE	(3) FE	(4) FE	(5) FE	(6) FE	(7) FE
School							
	−0.226***	−0.234***	−0.210***	−0.189***	−0.187***	−0.188***	−0.201**
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Workplace							
	−0.082***	−0.118***	−0.107***	−0.104***	−0.103***	−0.103***	−0.105***
	(0.006)	(0.007)	(0.008)	(0.006)	(0.006)	(0.006)	(0.007)
Public							
	−0.103***	−0.143***	−0.140***	−0.142***	−0.133***	−0.132***	−0.127***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)	(0.009)
Gathering							
	−0.113***	−0.138***	−0.109***	−0.098***	−0.097***	−0.100***	−0.104***
	(0.007)	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Pub transport							
	0.051***		−0.103***	−0.074**	−0.073***	−0.077***	−0.090***
	(0.007)		(0.007)	(0.008)	(0.008)	(0.008)	(0.008)
Staying home							
	−0.042***			−0.057**	−0.053***	−0.061***	
	(0.008)			(0.006)	(0.006)	(0.007)	
Dom mobility							
	−0.035**				−0.016*	−0.019**	−0.025***
	(0.006)				(0.007)	(0.007)	(0.007)
Inter mobility							
	0.033***					0.017*	−0.015*
	(0.009)					(0.008)	(0.007)
Constant							
	0.940***	0.974***	1.014***	1.017***	1.016***	1.016***	1.015***
	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Country							
	130	130	130	130	130	130	130
Observations							
	8896	8896	8896	8896	8896	8896	8896
R^2							
	0.601	0.694	0.771	0.719	0.719	0.720	0.717

Note: 1. OLS: Ordinary Least Square regression. FE: Fixed effect regression. 2. The numbers in parentheses are standard errors. 3. * p<0.1, ** p<0.05, *** p<0.01. 4. Each policy index has been standardized as a variable between [0, 1], thus the coefficient symbol is the impact of mobility when the each policy is at its highest level. The variance inflation factors (VIF) of school closure and suspension of public activities are between 5 and 10, while VIFs of all other variables are all less than or equal to 5.

Appendix Table 2. Basic data sources and construction methods of Luohan Academy's Global COVID-Economic Tracker

Tracking indicators	Sources of basic data	Data analyses methods
Doubling days of COVID-19 cases/death	Data from the European Centre for Disease Prevention and Control, National Health Commission of the People's Republic of China, and the Johns Hopkins University.	Gaussian filter is used to smooth intermittent jumps.
Real-time effective reproduction number (Rt)	Data from the European Centre for Disease Prevention and Control, National Health Commission of the People's Republic of China, and the Johns Hopkins University.	Based on the pandemic data and the parameters of the serial interval distribution of COVID-19 (Zhang et al. 2020), Rt is estimated by applying the Bayesian framework (Wallinga and Teunis, 2004).
Death per million population	Data from the European Centre for Disease Prevention and Control, National Health Commission of the People's Republic of China, and the Johns Hopkins University, and the Wind Economic Database.	Total deaths of a country or region divided by its total population
Daily economic activity indicator	Data the Google COVID-19 Community Mobility Reports, the Apple Mobility Trends Reports, the Baidu Mobility Index, the Gaode Traffic Index, and the Wind Economic Database.	The empirical relationship between mobility and GDP growth rate across economies in the first quarter of 2020 is used to convert a country's economic activity based on people's mobility levels.
Cumulative economic losses	Daily economic activity levels from the proceeding calculation.	Total losses of economic activities relative to normal condition is summed across a period of time, e.g., a quarter.

Appendix 3. Summary Description of the Pandemic Economy phases along the PET Graphs

Phases	Description and criteria for determining transition time
Preparation	WHO issues an early warning for outbreaks, and countries begin to prepare accordingly, mainly including restrictions on travel to and from known epidemic centers.
Emergency Response	The epidemic starts to emerge, with even community outbreaks. Countries adopts and implements non-pharmaceutical interventions, including closures of schools and workplaces, quarantines and social distancing. Societal level human mobility declines or even plummets. The starting time point is the day before people's mobility shows a clear downward trend.
Trough	The declining trend of mobility starts to slow down and turns into a prolonged period of fluctuating up and down around a low level, limiting the spread of virus in the population. The starting time is the end of the long continuous downward trend when people's mobility reaches a local minimum.
Recovery	Epidemic growth decelerates, transmissibility declines progressively, and human mobility gradually rises. The starting point is characterized by a pivotal change when the recovered individuals start to outnumber new cases in a consistent manner (i.e., a minimum of three consecutive days), which means that more capacity of the health system is released.
Vaccination	COVID-19 vaccine is successfully developed. Mass production is made possible, followed by equitable and speedy deployment worldwide. The starting point is when WHO announces the success of the development of a new COVID-19 vaccine.

AGENCY PRESENTATION

Luohan Academy was founded in Hangzhou, China on June 26th, 2018. It is an open research institute initiated by the Alibaba Group and launched by world-renowned social scientists, including seven Nobel Prize laureates in economics, who sit on the academy's academic committee. Luohan Academy will dedicate itself to collaborating with world-class social scientists and practitioners to collectively explore and shape the consensus regarding how to embrace the social and economic transformations brought by digital technology. The purpose of Luohan Academy is to serve the society at large, addressing the most important global challenges as well as having an eye for the humanity’s long-term future.

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