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Michael Funke and Andrew Tsang

The People's Bank of China's response to the coronavirus pandemic – A quantitative assessment

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Abstract

The People's Bank of China (PBoC) has taken numerous measures to cushion the impacts of the COVID-19 health crisis on the Chinese economy. As the current monetary policy framework features a multi-instrument mix of liquidity tools and pricing signals, we employ a dynamic-factor modeling approach to derive an indicator of China's monetary policy stance. Our approach assumes that comovements of several monetary policy instruments share a common element that can be captured by an underlying unobserved component. We use the derived indicator to trace the response of the PBoC to the coronavirus pandemic. The estimates reveal that the PBoC has implement novel policy measures to ensure that commercial banks maintain liquidity access and credit provision during the COVID-19 crisis.

Keywords: corona pandemic, COVID-19, China, monetary policy, dynamic factor model
JEL Classification: C54, E32, E52, I15

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1 Introduction

In December 2019, respiratory illness clusters due to a novel coronavirus (SARS-COV-2) emerged in Wuhan, the capital of Hubei Province. The World Health Organization (WHO) named the disease caused by the virus Coronavirus Disease 2019 (COVID-19). Although doctors in Wuhan concluded in December 2019 that human-to-human transmission was occurring, provincial and local authorities suppressed information about the virus for weeks. On 31 December 2019, the WHO China Country Office was informed of pneumonia cases of unknown etiology. China provided the WHO with a map of the virus genome on 12 January 2020, enabling test kit building.

Eventually, the central government imposed aggressive containment measures in Wuhan and other cities in Hubei province, the outbreak's epicenter. As things got worse, flights were suspended and trains canceled. Wuhan transport links were fully shut down on 23 January 2020 in an attempt to stem the spread of the virus. At the height of the outbreak in China, many mainland cities enforced strict curfews on their citizens. City-wide lockdowns were augmented with extensive public monitoring of citizens, along various punishments and rewards to encourage adherence to official measures. Smartphone apps were released to help administer quarantines and social distancing, as well as certify active cases of COVID-19, identify those had recovered and those who had been exposed.[1]

The pandemic quickly sprawled out from Wuhan to the rest of mainland China. As of 16 April 2020, the official statistics indicate that COVID-19 has led to a cumulative number of 82,692 infections and 4,632 fatalities in China.[2] Figure 1 illustrates China's COVID-19 outbreak and slowdown. It illustrates the erroneous initial impression that the curve would be linear and the subsequent fear that it would be exponential.[3] Instead, it might be better to say that the epidemiological curve passes through stages of investigation, recognition, initiation, acceleration, and deceleration. Overall, this looks like a sigmoidal function. The fact that COVID-19 has touched nearly every corner of the globe implies that curve-flattening policies may need to be kept in place for a long time as

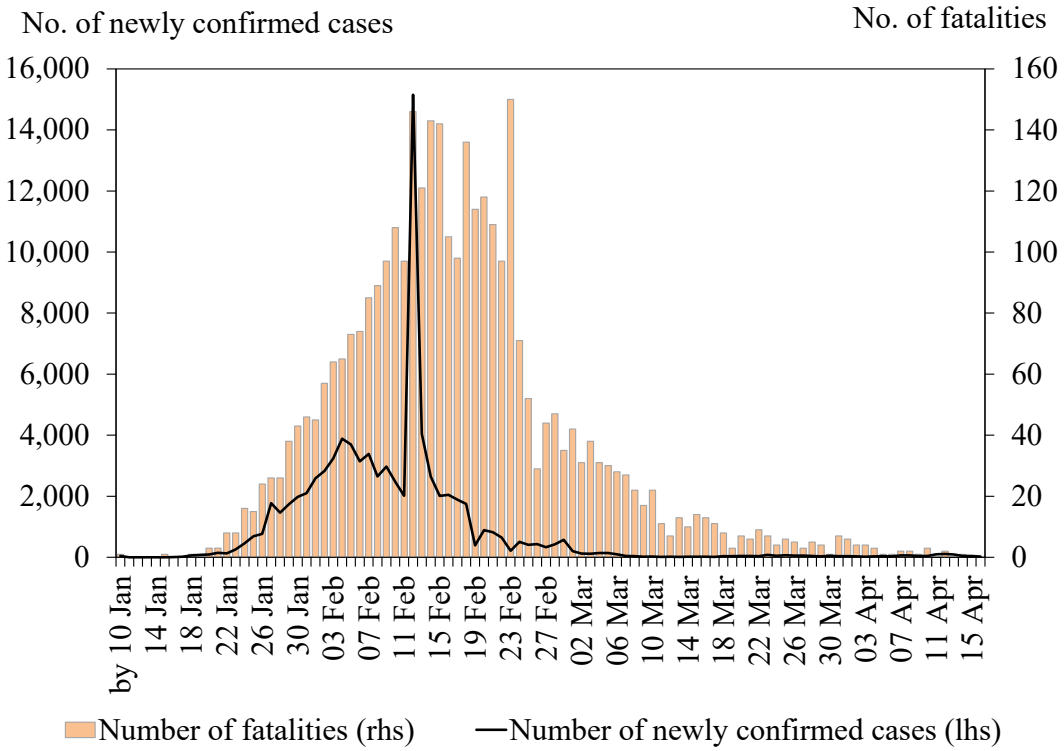
[1] For the classic epidemiological model of epidemic dynamics and its domestic and international spread, see Allen (2017), Balcan et al. (2010) and Wu et al. (2020). It is applied in Chinazzi et al. (2020) to study the effect of a travel ban in China and the world.

[2] There is reason to suspect that the Chinese downplayed the number of cases within China. China changed the definition of what constitutes a COVID-19 infection several times since the outbreak began in late December 2019. Another reason for skepticism about the initial number is that China raised its COVID-19 death toll for Wuhan by 50 percent in April 2020 in response to accusations that the government concealed the extent of the epidemic. See https://www.nytimes.com/2020/04/03/world/asia/coronavirus-china-grief-deaths.html. and https://www.bloomberg.com/news/articles/2020-04-18/china-tests-thousands-to-calculate-true-spread-of-coronavirus.

[3] The steep initial increase is largely determined by the reproduction rate R_0 of the COVID-19 virus which has been estimated to be $R_0 \approx 2.5$ (Riou and Althaus, 2020).

the pathogen can be repeatedly introduced into a susceptible population until such time as the general population is vaccinated or herd immunity is otherwise achieved. In other words, the COVID-19 epidemiological curve could look like a sine wave for years into the future (Anderson et al., 2020).

Figure 1 COVID-19 outbreak in mainland China
(number of newly confirmed cases and fatalities, 10 January–16 April 2020)



Notes: On 11 January 2020, the Wuhan Health Commission officially reported the number of confirmed COVID-19 infections up to 10 January 2020. The National Health Commission of the People's Republic of China (NHC) started to report the number of confirmed daily cases from 21 January 2020 onwards. Since 12 February 2020, the number of cases in Hubei have included both clinically and lab-confirmed cases (i.e. not just lab-confirmed cases), while the number in other provinces has only included lab-confirmed cases. The Chinese Center for Disease Control and Prevention (China CDC) reckons that at least 104 people were already infected in Wuhan as of 31 December 2019. These cases were reported in January 2020. The chart does not include the latest upward revision of the number of cases which was released by the NHC on 17 April 2020. This raised the death toll by 50% to 3,869. The reason is that their daily mapping is unknown. Data Source: NHC.

The need for social distancing and lockdowns has caused substantial economic collateral damage. COVID-19 initially caused a negative supply shock by forcing factories to shut down and disrupting global supply chains. Moreover, the pandemic, through its negative impact on agent expectations of future income growth, induced a demand-driven recession. Weak aggregate demand, in turn, depresses the incentive of firms to invest. The massive spike in uncertainty also injected wait-and-see responses of consumers and firms into a shaky world economy, and valuations in global financial markets imploded. These reactions reflect profound uncertainties over the path of the COVID-19

virus and the length of time the global economy could remain shuttered, or even induce a supply-demand doom loop.[4]

Which policy interventions can prevent a stagnation trap from taking place? How has monetary and fiscal policy respond to the coronavirus-led disruptions? As the global recession gains force, almost all governments around the world have implemented measures ranging from monetary easing to keep financial markets operating and lower interest rates. They have boosted fiscal spending to counteract the sharp drop-off in economic activity.[5]

Against the background of this challenging economic situation, this paper analyzes and quantifies the monetary policy response of the People's Bank of China (PBoC) to the COVID-19 crisis by dynamic factor modeling framework. Our modeling approach represents a refinement of the approach laid out by Funke and Tsang (2019). It includes the PBoC's numerous, earmarked (and sometimes arcane) monetary stimulus tools. China, which has become the main engine of the world economy in recent decades, plays an important role in both traditional global trade and global supply chains, processing intermediate goods and re-exporting them to other regions. Given China's pivotal role in the world economy, the economic policy course pursued in Beijing is watched by all with the greatest interest.

This paper proceeds as follows. The economic impact of COVID-19 on the Chinese economy is described in section 2. Section 3 deals with the chronological sequence of Chinese monetary policy responses. In section 4, we present our dynamic factor modeling framework and evaluate the monetary policy response. Section 5 ends with conclusions and a discussion of the policy implications.

2 The impact of COVID-19 on the Chinese economy

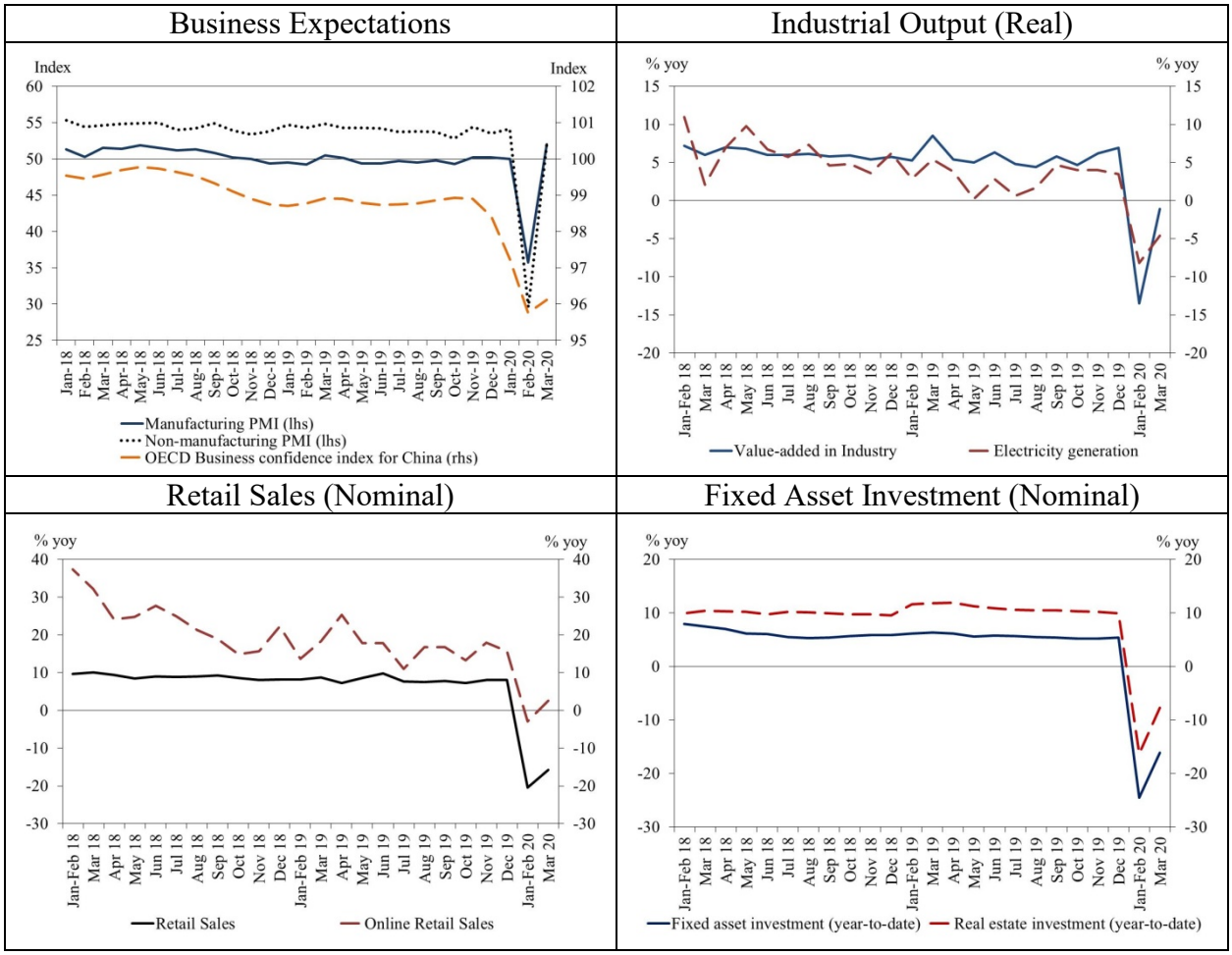
The Chinese government's distancing policies aimed at containing infections and saving lives prevented firms from operating (triggering a supply-side recession) and consumers from consuming

[4] See https://voxeu.org/article/covid-induced-economic-uncertainty-and-its-consequences. The catalog of papers on the macroeconomic aspects of the COVID-19 pandemic is rapidly expanding. For the various facets of the COVID-19 shock and possible policy responses, see Baldwin and Weder di Mauro (2020a, 2020b). Alvarez et al. (2020), Atkeson (2020), Baker et al. (2020), Berger et al. (2020), Caballero and Simsek (2020), Coibion et al. (2020), Eichenbaum et al. (2020a, 2020b), Fornaro and Wolf (2020), Guerrieri et al. (2020), Krueger et al. (2020) and Lewis et al. (2020). Maliszewska et al. (2020), Pindyck (2020) and Stock (2020) study the macroeconomic and trade effects and shock transmission of the COVID-19 pandemic. For historical lessons from previous pandemics, see Barro et al. (2020), Greenwood et al. (2019) and Jordà et al. (2020). Leiva-Leon et al. (2020) have developed a nowcasting COVID-19 global recession risk indicator. None of these papers focus on China.

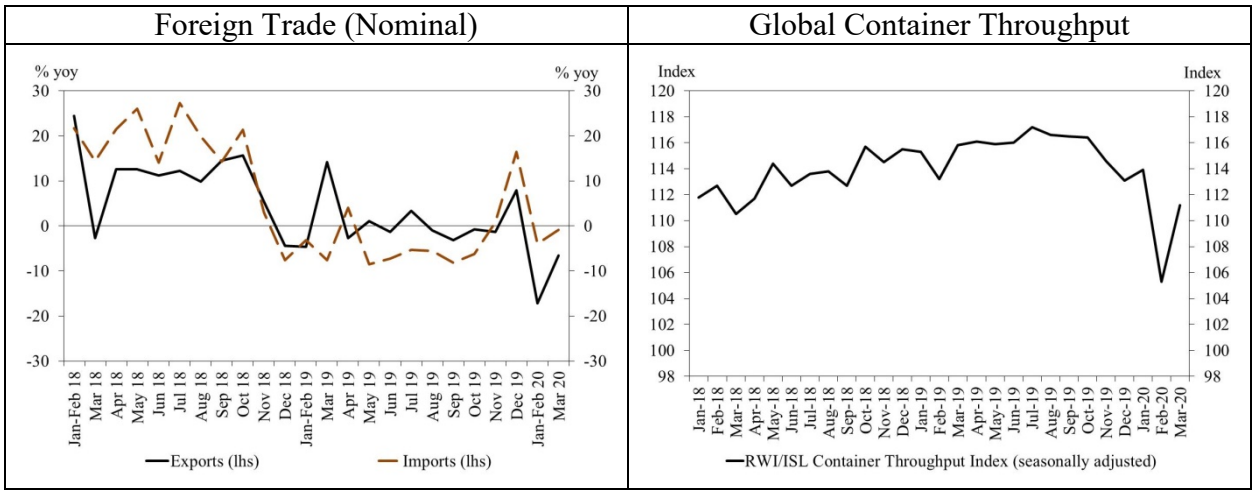
[5] For cross-national, cross-temporal government response trackers aiming to monitor and compare government responses to the coronavirus outbreak worldwide, see the IMF COVID-19 economic response tracker at https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19 and the Oxford COVID-19 Government Response Tracker (OxCGRT) at https://www.bsg.ox.ac.uk/research/research-projects/oxford-covid-19-government-response-tracker measuring the stringency of the responses.

(triggering a demand-side recession). In other words, the flattening of the infection curve inevitably steepened the *macroeconomic recession curve*. While this collateral damage was quite predictable, the extreme speed at which the crisis unfolded was unforeseen. Carmen Reinhart and Kenneth Rogoff asserted in their 2009 book on the Great Recession, *This Time Is Different: Eight Centuries of Financial Folly*, that we had encountered a situation without historical precedent. Only a decade later, we see the basis for assessing yet another paradigm-breaking economic upheaval. Perhaps the sequel, *The COVID-19 Crisis is Different: Global Recession in the Wake of a Pandemic*, is already in the works.[6] In any case, the knock-on effects of the pandemic on the Chinese economy are illustrated by the various indicators in Figures 2 and 3.

Figure 2 The mainland Chinese economy halts and begins to recover

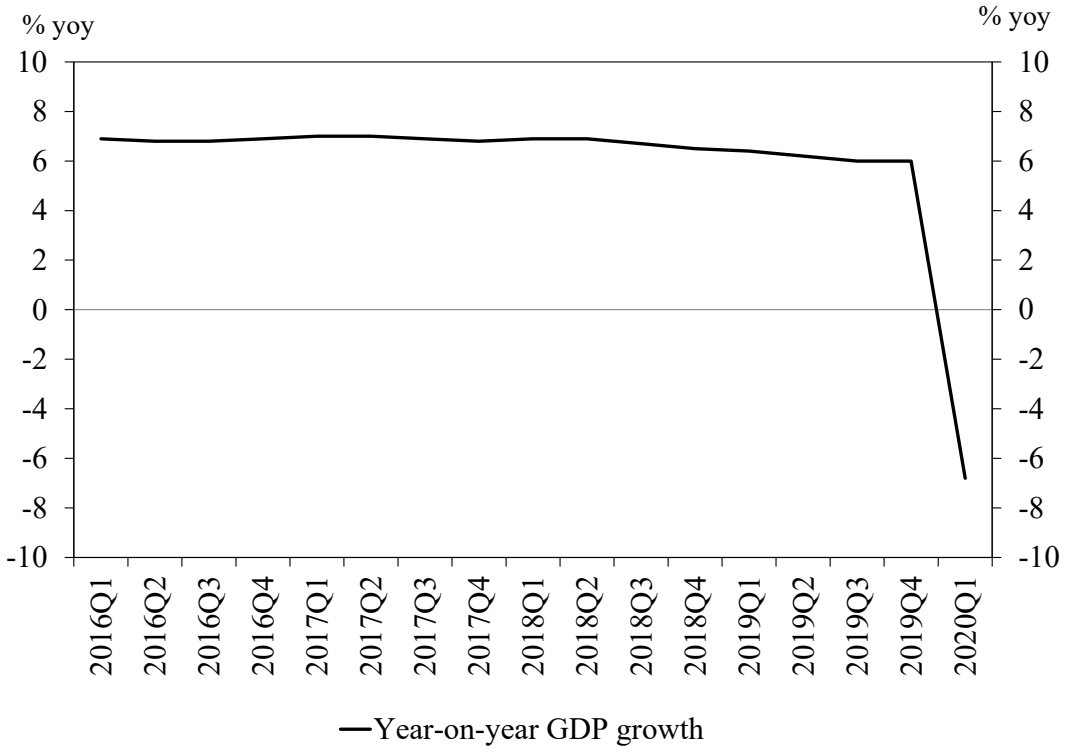


[6] Also see https://www.project-syndicate.org/commentary/covid19-crisis-has-no-economic-precedent-by-carmen-reinhart-2020-03.



Notes: The OECD business confidence indicator for China provides information on future expectations. It is based on opinion surveys on expected production, booked orders, and stocks of finished goods in the industry sector. The series is amplitude adjusted and 100 means the long-term average. (https://data.oecd.org/leadind/business-confidence-index-bci.htm#indicator-chart). The RWI/ISL Container Throughput Index includes the information on container throughput in 91 international ports and accounts for about 60 percent of the global container throughput (https://www.isl.org/en/containerindex/march-2020). Foreign trade figures are in US dollars. The dates of the Chinese Lunar New Year falls at different times depending on the year. Considering the year-on-year growth rate of some macroeconomic series (industrial output, retail sales, fixed asset investment and trade) are distorted by the this New Year holiday effect, National Bureau of Statistics of China only reported the aggregate figures for first two months. Data sources: National Bureau of Statistics of China (NBS), Chinese Customs, Shanghai Stock Exchange, OECD, and the Institute for Shipping Economics and Logistics (ISL).

Figure 3 China's quarterly real GDP growth rates (%)



Data source: China National Bureau of Statistics (NBS).

Figures 2 and 3 reveal that the COVID-19 shock quickly cascaded through the economy, morphing into an unparalleled downturn simultaneously impeding demand and supply (slumps of industrial production, retail sales, the purchasing manager indices, the business confidence indices, fixed asset investment and foreign trade in first three months of 2020). The same pattern is evident in the real GDP growth rate for the first quarter of 2020. The only bright spot is online retail.

For policymakers, the biggest surprise has been the depth of slump. The data for January and February 2020 show that real industrial output and nominal retail sales were down by 13.5% and 20.5%, respectively. The official seasonally adjusted purchasing manager index (PMI) and the OECD business confidence index for China fell to its lowest level since the global financial crisis of 2008–2009. Within the survey indices, the non-manufacturing sectors suffered the greatest losses. These three expectation-driven indicators suggest extreme stress and illustrate that market participants were increasingly worried that the public health crisis would become a broad-reaching financial crisis. Meanwhile, the seasonally adjusted RWI/ISL Container Throughput Index dropped by 8.6 points in February – the largest monthly decline ever recorded. The driving force was the decline in sharp declines in container handling at Chinese ports and ports on the US west coast, a textbook illustration of how trade is the conduit through which a pandemic-induced slowdown passes from one country to another.

The latest March figures give a somewhat mixed picture. Real industrial output fell 1.1% in March, nominal retail sales slid 15.8%, and nominal investment decreased 16.1% in the first three months of the year. Exports also fell less in March as production capacity was gradually restored. Nevertheless, the continued spread of COVID-19 globally adds fresh downward pressure on China's exporters in a feedback loop. While the marked improvement in industrial output, which had suffered a double-digit fall in the first two months of the year, should be noted, regaining consumer confidence as the lockdowns are lifted is increasingly as become the Achilles heel of the rebound. The continuing uncertainty and restrained demand bode a difficult recovery ahead.

The latest published real GDP growth rate for 2020Q1 in Figure 3 shows an unprecedented decline of 6.8%, the worst performance since 1992 when official releases of quarterly GDP started. This first GDP contraction in China in decades dims the global outlook. Seasonally adjusted quarterly real GDP growth was even worse (-9.8%).

What are the current forecasts for Chinese economic growth? The latest IMF baseline forecasts for 2020 and 2021 released on 14 April 2020 see GDP growth of 1.2% and 9.2%, respectively (https://www.imf.org/en/Publications/WEO/Issues/2020/04/14/weo.April-2020). The World Bank GDP growth forecasts for 2020 and 2021, which were published almost concurrently, are 2.3% and 7.7%, respectively (https://openknowledge.worldbank.org/bitstream/handle/10986/33477/211565-ch01.pdf).

We offer four comments on these assessments. First, the sudden stop in economic activity should be worse than during the Great Recession.[7] Second, both the IMF and World Bank expect China's economic growth will rebound in 2021 to levels well above trend, reflecting the normalization of economic activity from very low levels. Third, the forecasts illustrate China's dwindling effect on global growth. Finally, the timing and shape of the rebound remain highly uncertain.[8] In total, this is a dramatic deterioration in outlook from the forecasts at the end of 2019. For example, the IMF's semi-annual *World Economic Outlook*, released in October 2019, predicted a real GDP growth rate of 6.1% for China in 2020 (https://www.imf.org/external/pubs/ft/weo/2019/02/weo-data/index.aspx).

This highlights the challenges for policymakers posed by the pandemic. While the immediate impact of the public health crisis can be observed, the medium and longer-term effects are difficult to predict. Will China experience a short-lockdown, quick-snapback V-shaped recovery, or will the coronavirus lead to an anemic rebound that looks like a U or reverse J? While the V-shaped recession has a pointed trough, troughs are more elevated and prolonged in U-shaped recoveries. How much of the economic damage wrought by the temporary shutdown will last even after Chinese firms reopen?

There is also potential second and third waves of infection to consider. While the reported number of newly infected people appears to be contained in China and its epicenter in Hubei province has been free of new cases for days at a time, global infection poses a threat that could well trigger a second wave of infection in China that obviates containment measures and further lowers demand for China's exports. This would cause a double-dip, or W-shaped recession and recovery. An ex-ante estimate of the severity and length of this second slump in growth is challenging to say the least.

Amidst the considerable uncertainties, China has abandoned its usual practice of setting a numerical target for economic growth in 2020. Shifting away from a hard target for GDP growth breaks with decades of Communist Party planning habits and is an admission of the deep rupture that the COVID-19 virus has caused in the world's second-largest economy.

[7] The implications of this unexpected GDP growth slowdown for financial stability are difficult to assess. In 2019,the PBoC stress-tested the resilience of 30 banks under a variety of scenarios. In the then-presumed most extreme hit to the economy envisaged (growth slowing to 4.15%), 17 of the 30 commercial banks modeled would need additional capital (http://www.pbc.gov.cn/en/3688235/3688414/3710021/3830459/3950366/index.html). Also see PBoC answers to journalist questions (http://www.pbc.gov.cn/en/3688110/3688172/4005082/index.html).

[8] This presupposes that new pharmaceuticals, vaccines, or other interventions such as aggressive contact tracing and quarantine would alleviate the need for stringent social distancing to maintain control of the epidemic. Otherwise, sustained distancing may need to be maintained in the postpandemic period into 2022 to curb the outbreak. See Kissler et al. (2020).

3 China's emergency monetary measures to combat corona risks

The long-term effects from putting the Chinese economy into a brief induced coma was a key question in the PBoC's response. The shutdown created an immediate risk of a wave of bankruptcies and layoffs could deepen the induced recession and undermine the recovery. The PBoC took a number of policy measures designed to combat the economic repercussions of the pandemic. The monetary policy measures imposed from 31 January to 20 April are summarized in Table 1.

Table 1 Monetary policy measures implemented from 31 January to 20 April

Date	Decision/action	Source (link)
31.1	PBoC announces that it was implementing a mix of monetary policy tools (e.g. open market operations, standing lending facility, central bank lending, and central bank discount) to provide sufficient liquidity to the market.	PBoC, "Notice of PBC, MOF, CBIRC, CSRC and SAFE on Further Strengthening Financial Support for Containing Novel Coronavirus Outbreak" http://www.pbc.gov.cn/en/3688110/3688172/4001601/index.html
3.2	PBoC injects RMB 1.2 trillion in liquidity into the banking sector through reverse repo operations, (lowering repo rates by 10 basis points).	PBoC, "Announcement of Open Market Operations No. 18 [2020]" http://www.pbc.gov.cn/en/3688110/3688181/3966448/index.html
4.2	PBoC injects RMB 500 billion in liquidity into the banking sector through reverse repo operations.	PBoC, "Announcement of Open Market Operations No. 19 [2020]" http://www.pbc.gov.cn/en/3688110/3688181/3967540/index.html
7.2	PBoC announces plans to support bond issuance by financial institutions for epidemic prevention and control.	PBoC, "PBC Takes Measures to Facilitate Bond Issuance by Financial Institutions in Support of Epidemic Control" http://www.pbc.gov.cn/en/3688110/3688172/3969153/index.html
7.2	PBoC announces plans to set up RMB 300 billion in special central bank lending (relending) to provide low-cost funds for banking lending supporting epidemic prevention and control. The central government commits to subsidizing 50% of business interest payments to ensure actual financing costs below 1.6%.	PBoC, "PBC Holds Tele-Video Conference on Arrangements for Special Central Bank Lending in Support of Epidemic Prevention and Control" http://www.pbc.gov.cn/en/3688110/3688172/3969490/index.html
10.2	PBoC injects RMB 900 billion in liquidity into the banking sector through reverse repo operations.	PBoC, "Announcement of Open Market Operations No. 23 [2020]" http://www.pbc.gov.cn/en/3688110/3688181/3969221/index.html
11.2	PBoC injects RMB 100 billion in liquidity into the banking sector through reverse repo operations.	PBoC, "Announcement of Open Market Operations No. 24 [2020]" http://www.pbc.gov.cn/en/3688110/3688181/3969719/index.html
17.2	PBoC injects RMB 100 billion in liquidity into the banking sector through reverse repo operations, as well as RMB 200 billion in medium-term (1-year) liquidity through MLF operations (with 10-bp cut in MLF rate).	PBoC, "Announcement of Open Market Operations No. 29 [2020]" http://www.pbc.gov.cn/en/3688110/3688181/3971901/index.html

Date	Decision/action	Source (link)
20.2	PBoC lowered 1-year loan prime rate by 10 bps and 5-year loan prime rate by 5 bps.	China Banking News, "China's One-year Loan Prime Rate Falls 10 Basis Points" http://www.chinabankingnews.com/2020/02/20/chinas-one-year-loan-prime-rate-falls-10-basis-points/
25.2	State Council decides to increase the PBoC's relending and rediscount quota by RMB 500 billion for bank lending to support SMEs, as well as lower relending rate by 25 bps to 2.5%.	China State Council, "China to introduce strong financial measures to help smaller firms tide over difficulties" http://english.www.gov.cn/premier/news/202002/25/content_WS5e5534dac6d0c201c2cbce84.html
28.2	State Council decides to guide financial institutions to issue extra-low-interest loans with a quota of RMB 300 billion for self-employed businesses.	China State Council, "China's targeted support for SMEs during epidemic" http://english.www.gov.cn/news/topnews/202003/03/content_WS5e5e0d1ac6d0c201c2cbd732.html
1.3	China Banking and Insurance Regulatory Commission urges financial institutions to defer loan principal and interest repayments.	China State Council, "China's targeted support for SMEs during epidemic" http://english.www.gov.cn/news/topnews/202003/03/content_WS5e5e0d1ac6d0c201c2cbd732.html
3.3	State Council orders policy banks to add a RMB 350 billion special credit quota for loans issuing to SMEs at preferential rates.	China State Council, "China's targeted support for SMEs during epidemic" http://english.www.gov.cn/news/topnews/202003/03/content_WS5e5e0d1ac6d0c201c2cbd732.html
13.3	PBoC announces earmarked required reserve ratio (RRR) cuts of 50 to 100 basis for loans to SMEs on 16 March, subject to banks' performance. Cuts set to release RMB 550 billion in long-term funds.	PBoC, "PBC Scheduled to Conduct Targeted RRR Cuts on March 16, Releasing RMB550 Billion Long-term Funds" http://www.pbc.gov.cn/en/3688110/3688172/3989478/index.html
16.3	PBoC injects RMB 100 billion in medium-term liquidity through MLF operations.	PBoC, "Announcement of Open Market Operations No. 49 [2020]" http://www.pbc.gov.cn/en/3688110/3688181/3989689/index.html
30.3	PBoC injects RMB 50 billion in liquidity into the banking sector through reverse repo operations, including a lowering of repo rates by 20 basis points.	PBoC, "Announcement of Open Market Operations No. 60 [2020]" http://www.pbc.gov.cn/en/3688110/3688181/3998498/index.html
31.3	PBoC injects RMB 20 billion in liquidity into the banking sector through reverse repo operations.	PBoC, "Announcement of Open Market Operations No. 61 [2020]" http://www.pbc.gov.cn/en/3688110/3688181/4000518/index.html
31.3	State Council decides to (i) increase the PBoC's relending and rediscount quota for small and medium-sized banks by RMB 1 trillion to support SMEs; (ii) order PBoC impose RRR cuts for small and medium-sized banks; and (iii) reinforce the PBoC's support for bond financing.	PBoC, "Deputy Governor Liu Guoqiang Attends the Press Conference on Expanding Local Government Special Bonds and Enhancing Support for MSMEs with Inclusive Finance" http://www.pbc.gov.cn/en/3688110/3688172/4005082/index.html

Date	Decision/action	Source (link)
3.4	PBoC announces cut in RRR for small and medium banks, effective 15 April and 15 May, by 5 basis points each time. Release of RMB 400 billion to the market expected. PBoC also announces a cut in the excess deposit reserve interest rate of financial institutions in the central bank (the lower bound of the interest rate corridor) from 0.72% to 0.35%, effective 7 April.	PBoC, "PBC Scheduled to Cut RRR for Small and Medium-sized Banks and IOER for Financial Institutions in April" http://www.pbc.gov.cn/en/3688110/3688172/4002931/index.html
15.4	PBoC injects RMB 100 billion in medium-term liquidity through MLF operations (with 20 bp cut in MLF rate).	PBoC, "Announcement of Open Market Operations No. 71 [2020]" http://www.pbc.gov.cn/en/3688110/3688181/4007901/index.html
20.4	PBoC lower 1-year loan prime rate by 20 bps and 5-year loan prime rate by 10 bps.	China Banking News, "China's One Year Loan Prime Rate Drops to 3.85%" http://www.chinabankingnews.com/2020/04/20/chinas-one-year-loan-prime-rate-drops-to-3-85/

Notes: The calculated indicator reflects monetary policy decisions taken through 20 April 2020. The dates are based on PBoC announcements in Beijing time.

At first glance, we see the PBoC has unveiled an unprecedented set of measures intended to ensure China's commercial banks maintain liquidity access and credit provision during the COVID-19 crisis. The chronological sequence in Table 1 further shows that the Chinese monetary policy response was not a one-off reaction, but a successive series of easing actions. Since some of the listed open market policy measures are regular and limited in duration, it is interesting to determine the extra liquidity triggered by the pandemic crisis. The COVID-19 excess liquidity injection of all operations appears to be on the order of RMB 3.6 trillion for the February-March period.[9]

Ultimately, all measures are aimed at safeguarding financial stability and prevent liquidity shortages and market disruptions amplifying and perpetuating the COVID-19 shock. Larger firms, including state-owned enterprises, enjoyed relatively stable credit access throughout (largely because China's large state banks continued to lend generously to them). For small and medium-sized firms, commercial banks were required to roll over debt contingencies. The following section provides a quantitative assessment of the monetary policy measures taken.

[9] An excess liquidity injection is estimated by the gross liquidity injection through various loan facilities (without deduction of the amount of matured facilities) exceeding the amount in the same period of 2019, which includes (i) the short-term liquidities (maturing in 7 or 14 days) of RMB 2.39 trillion through PBoC's reverse repo operations and SLF; (ii) RMB 170 billion in medium-term funding (maturing in 1 year or longer) through MLF and PSL; (iii) RMB 505.7 billion in rediscount and relending loans actually granted by 30 March (see PBoC, "Deputy Governor Liu Guoqiang Attends the Press Conference on Expanding Local Government Special Bonds and Enhancing Support for MSMEs with Inclusive Finance" http://www.pbc.gov.cn/en/3688110/3688172/4005082/index.html); and (iv) RMB 550 billion in long-term funds released from the earmarked required reserve ratio (RRR) cuts of 50 to 100 basis points for loans to SME firms since 16 March (see Table 1).

4 The proposed dynamic factor model and estimation results

Before diving into the factor modelling approach, we briefly review China's monetary policy reforms in recent years.

After wrapping up its decades-long process of interest rate liberalization in late 2015, the PBoC upgraded its monetary policy framework to include a corridor system of interest rates. The basic principle of the corridor system is as follows: the central bank provides a lending facility tool (upper bound of the corridor) and a deposit facility tool (lower bound of the corridor) to form an interbank interest rate corridor. The PBoC's interest rate target is somewhere within the corridor. The new policy target is the pledged 7-day interbank market rate applied to all financial institutions.

The rates for the Standing Lending Facility (SLF) constitute the upper bound of the corridor, while the interest rate on excess reserves form the lower bound of the interest rate corridor. In addition, several other lending facilities exist. The Medium-term Lending Facility (MLF) allows the PBoC to provide funds with longer maturities from three months to a year, and the Pledged Supplementary Lending (PSL) program aims at the nation's three policy banks (China Development Bank, Agricultural Development Bank of China and the Export-Import Bank of China). In practice, the PBoC steers a wide interest rate corridor, anchored by the seven-day reverse-repurchase rate DR007 (rate at which banks lend to each other) and the medium-term lending facility MLF (part of the open.3ket facility). Meanwhile the one-year loan prime rate LPR, the rate for lending to prime customers, became the new standard for all loans.[10]

The reserve requirement ratio is a quantity-based monetary policy instrument used actively by the PBoC. The adjustment of the reserve requirement ratio can unleash or lock up huge amounts of liquidity. In particular, the authorities resort to the reserve requirement ratio tool in times of market stress to give clear, strong policy signals to the market.

Against the background of this multitude of price-based and quantity-based monetary policy instruments, the following five variables summarize the monetary policy tools used by the PBoC: the 7-day pledged repo rate (DR007); the required reserve ratio (RRR); the PBoC's open market operations, including standing lending facility (SLF), relending and rediscount (e.g. actual amount of loans granted within the announced total of RMB 1.8 trillion in relending and rediscount quota since February); the medium-term lending facility (MLF); and pledged supplemental lending (PSL). The amount of the targeted MLF stimulus measures is included in the variable Net OMO withdrawal/total loans (t - 1). Table 2 summarizes these five variables.

[10] China has made good progress in recent years in liberalizing interest rates. Although the described policy shifts are still works in progress, the IMF (2017, p. 34) reach a tentative verdict already in 2017 that "the conduct of [China's] monetary policy increasingly resembles a standard interest-rate-based framework." Also see Fernald et al. (2014) and Chen et al. (2017).

Table 2 Variables included in the dynamic factor model

Variable	Data description
Change in the 7-day pledged repo rate	Change in the monthly average of the 7-day pledged repo rate for depository institutions in the interbank market (DR007).
Changes in required reserve ratio (RRR)	Changes in the required reserve ratio (RRR, within the month). Since a different RRR has been applied to different sizes of banks since September 2008, the overall RRR for the banking sector is estimated as 75%**RRR for large banks* + 25%**RRR for small and medium-sized banks*.
Net OMO withdrawal / total loans $(t-1)$	Net amount of funds reduced through the PBoC's open market operations (OMO) from the banking sector (net amount during the month). The net amount of funds withdrawn in other items in the central bank's claims on the banking sector, e.g. standing lending facility (SLF), rediscount, and relending, is included in this variable.
Net MLF withdrawal / total loans $(t-1)$	Net amount of funds withdrawn through the PBoC's medium-term lending facility (MLF) from the banking sector (net amount during the month).
Net PLS withdrawal / total loans $(t-1)$	Net amount of funds withdrawn through the PBoC's pledged supplemental lending (PSL) from the banking sector (net amount during the month).

Dynamic factor models are used in applied econometrics to quantify unobserved variables. Such models are particularly valuable in business-cycle analyses, forecasting, and nowcasting the state of an economy. As with many useful empirical modelling approaches, factor models are extrapolated from data rather than being deduced from theory.

A further development of the model in Funke and Tsang (2019) which includes the novel and specific and earmarked monetary policy measures in the COVID 19 pandemic is used below. The Chinese monetary policy stance indicator is based on the notion that different monetary policy instruments have a common element that can be captured by a single underlying, unobservable variable.[11] Our dynamic factor model in first differences is specified as follows:

$$\Delta I_{i,t} = \beta_i \Delta M_t + e_{i,t} \tag{1}$$

$$\Delta M_t = \varphi_1 \Delta M_{t-1} + \varphi_2 \Delta M_{t-2} + u_t \tag{2}$$

$$e_{i,t} = \rho_{i,1} e_{i,t-1} + \rho_{i,2} e_{i,t-2} + v_{i,t}, \tag{3}$$

where Δ is the first-difference operator, M_t is the unobserved common component at time t, I_i $(i = 1, \cdots, 5)$ are the five monetary policy instruments, β_i are the factor loadings, $u_t \sim$ i.i.d. $N(0, \sigma_u^2)$, and $v_{i,t} \sim$ i.i.d. $N(0, \sigma_i^2)$. The lag structure in equations (2) and (3) has been chosen to ensure the i.i.d. properties of the residuals. We suppose that every monetary policy indicator $I_{i,t}$ is

[11] The number of common factors must be given a priori when using the maximum-likelihood method. A popular test for the number of factors in approximate factor models can be found in Bai and Ng (2002). The empirical evidence suggests that a single factor exists.

a weakly stationary process that has at least finite second-order moments. If the null hypothesis of non-stationarity cannot be rejected, we take first-differences. Following the suggestion of Stock and Watson (1991), the series are also demeaned. In the state-space representation, the measurement equation is written as

$$\begin{bmatrix}\Delta I_{1,t}\\ \Delta I_{2,t}\\ \Delta I_{3,t}\\ \Delta I_{4,t}\\ \Delta I_{5,t}\end{bmatrix} = \begin{bmatrix}\beta_1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\ \beta_2 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0\\ \beta_3 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0\\ \beta_4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0\\ \beta_5 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0\end{bmatrix} \begin{bmatrix}\Delta M_t\\ \Delta M_{t-1}\\ e_{1,t}\\ e_{1,t-1}\\ e_{2,t}\\ e_{2,t-1}\\ e_{3,t}\\ e_{3,t-1}\\ e_{4,t}\\ e_{4,t-1}\\ e_{5,t}\\ e_{5,t-1}\end{bmatrix}, \tag{4}$$

and the state equation is

$$\begin{bmatrix}\Delta M_t\\ \Delta M_{t-1}\\ e_{1,t}\\ e_{1,t-1}\\ e_{2,t}\\ e_{2,t-1}\\ e_{3,t}\\ e_{3,t-1}\\ e_{4,t}\\ e_{4,t-1}\\ e_{5,t}\\ e_{5,t-1}\end{bmatrix} = \begin{bmatrix}\varphi_1 & \varphi_2 & 0 & 0 & & 0 & 0\\ 1 & 0 & 0 & 0 & \cdots & 0 & 0\\ 0 & 0 & \rho_{1,1} & \rho_{1,2} & & 0 & 0\\ 0 & 0 & 1 & 0 & & 0 & 0\\ & & \vdots & & \ddots & \vdots & \\ 0 & 0 & 0 & 0 & & \rho_{5,1} & \rho_{5,2}\\ 0 & 0 & 0 & 0 & \cdots & 1 & 0\end{bmatrix} \begin{bmatrix}\Delta M_{t-1}\\ \Delta M_{t-2}\\ e_{1,t-1}\\ e_{1,t-2}\\ e_{2,t-1}\\ e_{2,t-2}\\ e_{3,t-1}\\ e_{3,t-2}\\ e_{4,t-1}\\ e_{4,t-2}\\ e_{5,t-1}\\ e_{5,t-2}\end{bmatrix} + \begin{bmatrix}u_t\\ 0\\ v_{1,t}\\ 0\\ v_{2,t}\\ 0\\ v_{3,t}\\ 0\\ v_{4,t}\\ 0\\ v_{5,t}\\ 0\end{bmatrix} \tag{5}$$

The versatile estimation procedure involves four steps.[12] First, the parameters of the dynamic factor model in equations (4) and (5) are estimated using the maximum likelihood estimation method based on the predicted error decomposition. Second, the current state of the unobserved common factors is obtained by applying a Kalman filter to the estimated dynamic factor model. Third, the monetary policy stance (M_t) is calculated by accumulating the estimated series of ΔM_t, assuming the initial value of M_t is 0 at $t = 0$. Finally, the monetary policy stance is normalized to a range between -2 and 2.

[12] This article is not the venue for a complete review of the factor modelling approach. See Harvey (1989) and Durbin and Koopman (2012) for thorough treatments.

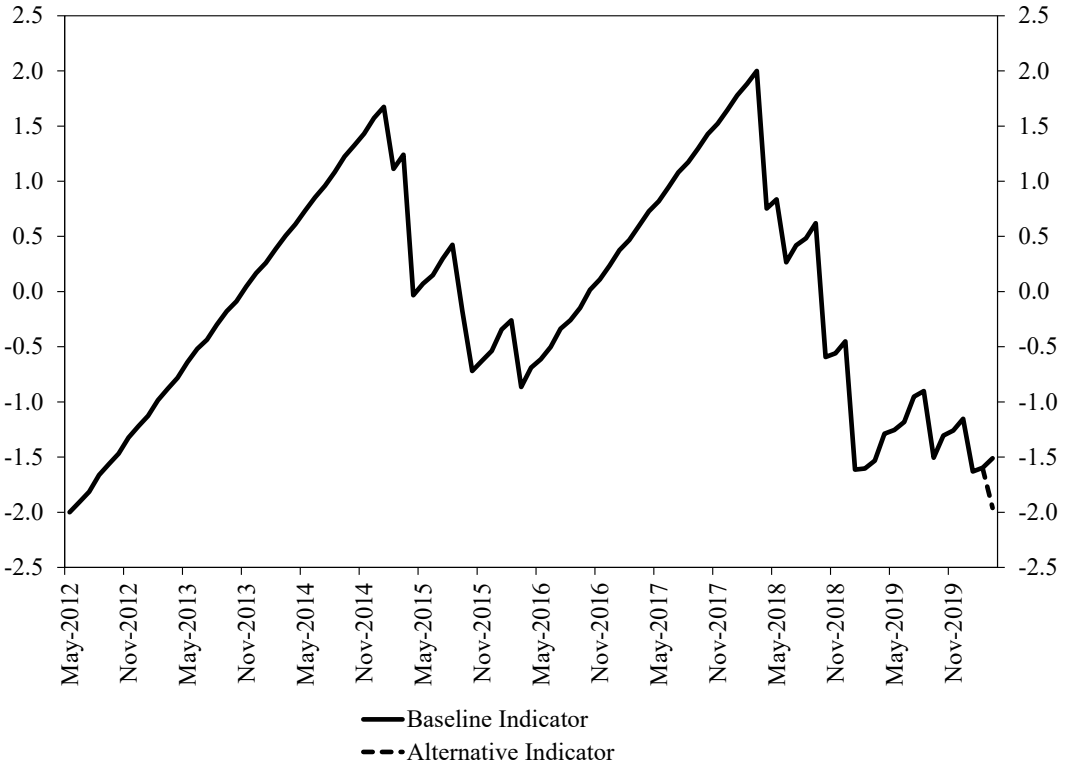
For understanding the calculated index, three explanatory notes must be given. (i) The fact that the index is "0" in a given month does not imply necessarily that the PBoC has assumed a neutral policy stance; (ii) an index value of "+2" ("-2") does not mean that further monetary policy tightening (loosening) is no longer possible. Rather, values of "+2" ("-2") mark the most tightened (eased) monetary policy impulses stance observed during the sample period; and (iii) the calculated index does not include measures that have been announced but will only be effective beyond the end of the sample period. This concerns, for example, the prospective loan quota for rediscounting and relending (only the actual amount of loans granted is included in the calculation) and the announced future RRR cuts. The corollary of this is that the index calculated for May-June 2020 will display a more expansionary monetary policy stance than in mid-2012.

Figure 4 shows the resulting two indicators.[13] Higher (lower) values of the indicator represent a monetary policy tightening (easing). The baseline indicator only takes into account measures encompassing all banks and the whole economy. The alternative indicator additionally takes into account the earmarked RRR cuts for loans to small and medium-sized enterprises (SMEs) announced on 13 March 2020 (effective 16 March 2020, see Table 1). These loans are intended to help SMEs bear fixed costs such as rent, interest payments, and tax bills. The PBoC estimates that the earmarked RRR cut of 16 March 2020 led to a liquidity increase in the banking sector of approximately RMB 550 billion. This is equivalent to a 0.34 percentage-point cut in the standard RRR (for every 0.5 percentage-point cut, RMB 800 billion is released).[14] The indicators only differ in March 2020.

[13] The factor model estimation results are provided in the Appendix. For a comprehensive comparison of the monthly factor model indicator and the two quarterly narrative indicators of McMahon et al. (2018) and Sun (2018), see Funke and Tsang (2019).

[14] The informal and difficult-to-quantify window guidance policy is not included for either indicator. For a thorough DSGE-based analysis of China's window guidance policy, see Chen et al. (2020).

Figure 4 DFM-based indicators of Chinese monetary policy stance



Notes**:** The calculated indicator reflects monetary policy decisions taken through 31 March 2020. Higher (lower) values of the indicator represent a monetary policy tightening (easing). The baseline indicator (solid black line) and the alternative indicator (dashed black line) only differ in March 2020. The calculated indices of the Chinese monetary policy stance are available online at https://www.bofit.fi/en/publications/discussion-papers/.

In retrospect, China's central bank has been highly interventionist. So what was the reaction to the COVID-19 shock? How expansionary has this multi-instrument monetary policy cocktail performed in softening the COVID-19 blow? What does the composite monetary policy stance indicator reveal about the economic outlook of the PBoC?

From Figure 4, we can comfortably divide China's monetary policy stance into four sub-periods, two tightening periods (May 2012–January 2015 and April 2016–March 2018) and two easing periods (February 2015–March 2016, April 2018–March 2020). How pronounced is the monetary policy boost to counteract a possible COVID-19 meltdown? The first impression is that China's post-COVID-19 monetary policy is as expansionary as it was after in the years following the global financial crisis.[15]

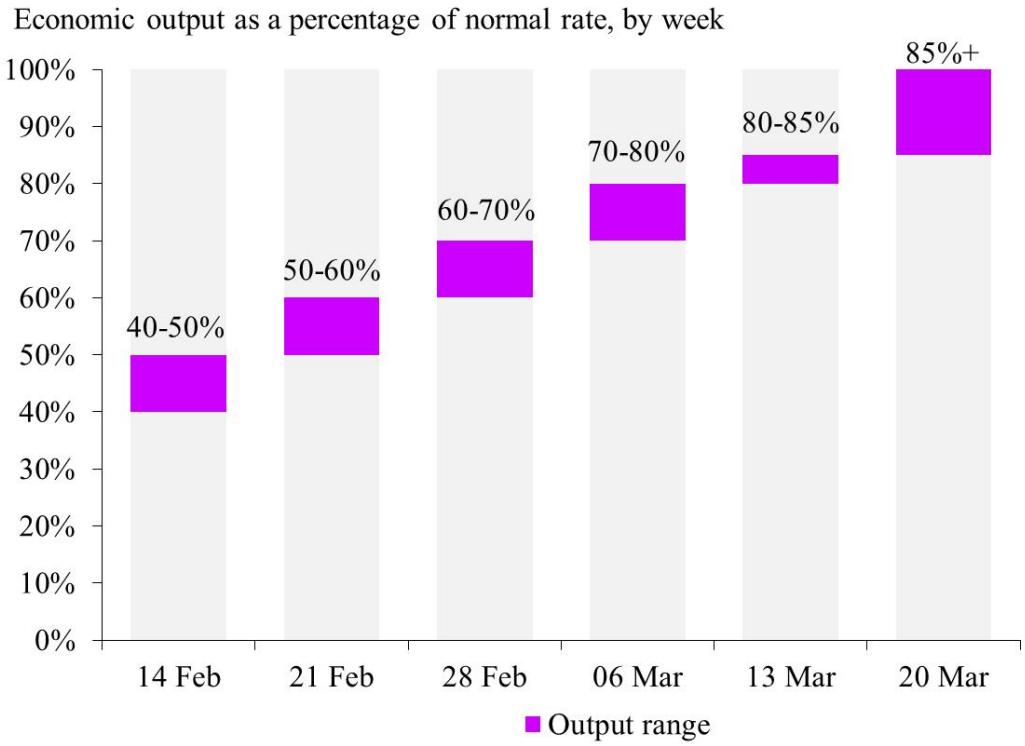
Compared with the global financial crisis, the PBoC has this time used a different policy mix. While the focus in 2008 was on reducing the benchmark interest rates and the RRR, this time liquidity injections play a major role. One reason for this is the lower interest rate level that has

[15] 2012 marked a monetary policy turning point. High growth rates and rising inflation prompted the PBoC to tighten monetary policy. The Chinese authorities also pivoted towards economic reform. In particular, they sought to rein in galloping credit growth in the wake of the global financial crisis.

already been achieved. In the period September to December 2008, the 1-year benchmark lending rate dropped from 7.47% to 5.31% (215-bp cut), while the 1-year loan prime rate was reduced by 30-bp from 4.15% to 3.85% during first four months in 2020. In both crises the RRR was lowered. In the period September to December 2008, the reserve ratios for small and medium-sized banks (large banks) were reduced by 4 (2) percentage points. The RRR cut released about RMB 1,000 billion. In spring 2020, the the overall RRR cut in March released long-term funding of about RMB 550 billion. Furthermore, two more targeted 0.5-percentage-point RRR cuts for the small and medium banks released about RMB 400 billion liquidity. With regard to open market operations (repos and reverse repos), the gross injections were RMB 982.5 billion in the period September to December 2008, and RMB 2,870 billion in February - March 2020. Finally, in spring 2020 liquidity in the amount of RMB 675.7 billion was provided by means of MLF, relending and rediscounting injections. This monetary policy instrument did not yet exist in 2008.

Another feature is the sequential step-by-step approach since the beginning of 2020. This incremental approach may be due to the declining number of new domestic COVID-19 infections. Although concerns about a second wave of infection persist, the initial assessment is that the economic impact of the pandemic has been a sharp, but short, recession. It will be followed by a V-shaped recovery with a return to normal in the second half of 2020 and growth accelerating in 2021. The supply-side recovery shown in Figure 5 points towards such a swift rebound as happened with China's SARS outbreak in 2003. This assessment is supported by readings of the Manufacturing Purchasing Managers Index (PMI), which surged to 52.0 in March 2020 after hitting a record low of 35.7 in the previous month and solidly beating market expectations of 45. The seasonally adjusted month-on-month growth rates of industrial production, retail sales, and fixed asset investment also recorded rebounds of 32.1%, 0.2% and 6.1% respectively. This improvement contrasts with the contraction in the first two month of the year.

Figure 5 China gets back to wor



Source: Bloomberg Economics

There is another explanation for the initial restrained monetary policy response, however. The perception could have been that traditional monetary policy slashing interest rates and providing liquidity is not the solution to a virus outbreak and thus ill-advised. In a nutshell, severe viral outbreaks are not "typical recessions" due to the peculiarity of the shock the economy faces, i.e. a shock that involves both supply-side and demand-side channels. It follows that more targeted interventions show more promise in the event of a severe viral outbreak. An example of this is the earmarked measure for loans to SMEs included in the alternative indicator. From this angle, the PBoC's swift monetary policy easing propping up the coronavirus-hit Chinese economy reflects the well-understood unorthodox nature of the shock. This also explains why many measures target specific industries, avoiding a "flood-like" easing to lift all boats as in previous slowdowns. This assessment is corroborated by comparison with other countries.[16] Despite the adopted counter-cyclical monetary policy stance aimed at creating confidence and limiting the amplification of the shock, the PBoC's course of action appears remarkably relaxed and restrained compared with the exceptional array of

[16] For a timeline displaying the actions taken by the central banks of the five largest economies, see https://www.piie.com/blogs/realtime-economic-issues-watch/timeline-central-bank-responses-covid-19-pandemic.

pandemic-fighting measures deployed around the world to prevent cascading defaults and market panic.[17]

5 Conclusions

For many years, GDP growth held a special preeminence in China. During the early 2000s, double-digit GDP growth became shorthand for China's success. On 17 April, China reported the country's first quarterly GDP contraction since the publication of quarterly GDP figures in 1992. When the novel COVID-19 infection first emerged late last year, with the number of infections in the epicenter of Wuhan growing exponentially in early January, few yet imagined the disease would morph into a raging global pandemic. The world is exposed to the virus and the virus is exposing how our world works.

Three observations are in order. First, the dynamic factor model allows estimation of the monetary policy stance hammered out from China's unorthodox and earmarked mix of monetary policy instruments. The advantages of the dynamic factor model approach are its intuitiveness and the incorporation of dimension reduction and variable selection into a single model. Moreover, the framework can indicate the respective weights of the input variables, thereby enabling an understanding of the algorithmically determined input-output relationship. Second, the established monthly indicators reveal in concise form the response of the PBoC to the outbreak of the COVID epidemic over time. Third, the current easing period is noticeable and illustrates the need to counter the calamitous downturn and the possibility of a self-reinforcing downward spiral that could contaminate future economic growth in China. For several years, the question has lingered over China's market-roiling crackdown on financial leverage. The index shows that the Chinese authorities have shifted their focus from containing the nation's debt pile to supporting the slowing economy. The years ahead will show the soundness of this judgement and establish that the course of action was adequate to meet these exceptional challenges.

[17] To cushion the economic blow, China also unveiled a range of fiscal measures, although not on the scale of other nations. The cumulative fiscal stimulus announced to date is estimated to be 1.2% of GDP (http://economy.caixin.com/2020-03-17/101529682.html). In contrast, many advanced economies have implemented substantial fiscal measures according to the principle "there is no time to lose". Corporate bailouts have been a core element. However, it must be borne in mind that China may not need such unprecedented fiscal parachutes as they are already built into the system. The predominant share of corporate loans go to state-owned firms and hence already enjoy implicit government guarantees. See the IMF policy action tracker at https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19.

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Appendix

Parameter estimates of the baseline Dynamic Factor Model

Variables	Parameters	Estimates
ΔM_t	φ_1	-0.0387 (0.3)
	φ_2	0.1103 (1.0)
$\Delta I_{1,t}$	β_1	0.0926 (1.7)
	$\rho_{1,1}$	-0.3230 (2.9)
	$\rho_{1,2}$	-0.0947 (0.9)
	σ_1^2	0.2728 (7.8)
$\Delta I_{2,t}$	β_2	0.2265 (12.7)
	$\rho_{2,1}$	-0.9686 (11.7)
	$\rho_{2,2}$	-0.9645 (14.1)
	σ_2^2	0.0002 (0.4)
$\Delta I_{3,t}$	β_3	-0.0382 (1.0)
	$\rho_{3,1}$	-0.2495 (2.5)
	$\rho_{3,2}$	-0.1488 (1.4)
	σ_3^2	0.1324 (7.4)
$\Delta I_{4,t}$	β_4	-0.0750 (4.3)
	$\rho_{4,1}$	0.4197 (3.9)
	$\rho_{4,2}$	-0.1749 (1.7)
	σ_4^2	0.0296 (7.1)
$\Delta I_{5,t}$	β_5	-0.0038 (1.2)
	$\rho_{5,1}$	0.4087 (4.3)
	$\rho_{5,2}$	0.2307 (2.5)
	σ_5^2	0.0011 (7.0)
Log likelihood		112.47

Note: t-values given in parentheses.

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