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The impact of COVID-19 pandemic on transmission of monetary policy to financial markets

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ABSTRACT

This study uses event-study methodology to estimate the impact of the COVID-19 pandemic on the transmission of monetary policy to financial markets, based on a sample of 37 countries with severe pandemics. Financial markets include government bond, stock, exchange rate and credit default swap markets. The results suggest that the emergence of pandemic has weakened the transmission of monetary policy to financial markets to a more significant degree. During our sample period following the outbreak of pandemic, neither conventional nor unconventional monetary policies have significant effects on all four of the financial markets. Of course, the unconventional monetary policies are slightly more effective as they can affect the stock and exchange rate markets to some extent. Therefore, in the post-pandemic period, if the monetary policy is used to stimulate financial markets, stronger policy adjustments, or other macro policies such as fiscal policies, may be needed to achieve the desired effect

1. Introduction

In 2020, all economies around the world suffered from the unexpected "coronavirus disease 2019" (COVID-19). The damage of the COVID-19 pandemic to people and economy has already exceeded what the global financial crisis of 2008 did, which is regarded as the "Great Compression" (Harvey, 2020). Its spread has created great systematic risk (Sharif, Aloui, & Yarovaya, 2020), making it difficult for investors to find a safe haven. In response, almost all major economies have adjusted their monetary policies by lowering policy rates (e.g., Argentina, Australia, Brazil, Canada, Chile, India, Mexico, United Kingdom), introducing new targeted long-term refinancing operations (Eurozone), implementing unlimited and open-ended quantitative easing (United States), or reducing the reserve requirement ratio (e.g., Brazil, China) to provide monetary stimuli for their damaged economies (Ozili & Arun, 2020). For this destructive pandemic lasting more than one year and the frequent adjustments of monetary policy, it provides a unique scenario occasion for us to survey the effectiveness of monetary policy transmission.

As a general understanding, financial markets are often called the "barometer" of the national economy and react to monetary policy first before economic activities. For this reason, it is necessary to explore the effects of monetary policy on financial markets to assess the monetary policy effect on economy in advance. However, through 2020, almost all industries suffered suddenly severe losses during the COVID-19 pandemic period, and it was hard for investors to find a safe haven. Consequently, most investors did lose their directions for investment (Ozili & Arun, 2020), which could make the transmission of monetary policy to financial markets weaken as the usual pattern. But, in reality, looking through major economies in 2020 pandemic, can the monetary policy be effectively transmitted to financial markets? Will the emergence and increasing severity of the pandemic strengthen or weaken this transmission? Are the results different for the different types of monetary policies?

In order to shed light on the above questions, this paper aims to explore the impact of the COVID-19 pandemic on the transmission of monetary policy to financial markets. We seek to assess the impact of both the emergence and the severity of the pandemic. And we especially focus on comparison between the conventional and unconventional monetary policies, implementing survey comprehensively on financial markets covering the stock, the bond, the exchange rate and the CDS markets, making the conclusions more reliable. As policy rates usually

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remain unchanged in many countries for a long time, the data on policy rate changes contain several zero values. Therefore, we use the event-study method, consistent with a rich body of recent literature (Chortareas & Noikokyris, 2017; Kuttner, 2001; Sun, 2020). The event-analysis method makes it possible to test the transmission of monetary policy adjustments to financial markets separately, reducing interference from other information.

The analysis in this study proceeds via three steps. First, we start by exploring the immediate effects of monetary policy on daily financial market indicators in Section 3.1 as a benchmark model. The results show that, for the full sample period, conventional monetary policy has significant effects on all four financial market indicators considered in this study, including changes in 10-year government bond yields, stock index returns, changes in exchange rates, and growth rates in CDS spreads. However, during the pandemic period, conventional monetary policy has no significant effect on any of indicators. Unconventional monetary policies have effects only on stock index returns and changes in exchange rates to some extent. In other words, neither conventional nor unconventional monetary policies have significant effects on all four of financial market indicators. These results can be regarded as a primary indication that monetary policy has been less effective since the coronavirus outbreak. Of course, unconventional monetary policies are slightly more effective than conventional policy during the pandemic period.

Second, in Section 3.2, the benchmark model is extended to assess the impact of the emergence and severity of the pandemic. We introduce the interaction terms of monetary policy and pandemic variables to exploit and compare the influence of heterogeneous monetary policy coefficients on financial markets, on both pandemic and non-pandemic days. The results show that the emergence of pandemic has weakened the transmission of monetary policy to financial markets to a more significant degree, while its severity has weakened the transmission only partially.

Finally, we investigate whether these results are robust across sample countries that share similar economic or financial circumstances. Specifically, we examine the impact of circumstance variables, including a country's degree of trade openness, level of financial development, level of industrialization and fiscal policy. The results show that the weakening impact of pandemic emergence on monetary policy transmission is robust, even with circumstance variables are considered. Furthermore, the higher the degree of trade openness, the lower the weakening effect of the pandemic on the transmission of monetary policy to 10-year government bond yields. In addition, fiscal policies implemented during the pandemic have some effects on financial markets to some extent. However, the severity of pandemic has only partially weakened the transmission of monetary policy, and the results are insufficiently robust.

Our study builds on two types of literature: research on the transmission of monetary policy to financial markets; and research on the impact of the COVID-19 pandemic on financial markets or the transmission of monetary policy to financial markets.

There is a rich body of literature on the transmission of monetary policy to financial markets, based on event-study methodology. Most studies have investigated the transmission of monetary policy to single financial market indicators, such as government bond yields (Kuttner, 2001; Sun, 2020), stock index returns (Bayraci, Demiralay, & Gencer, 2018; Ferrer, Bolós, & Benítez, 2016), exchange rates (Bouakez & Normandin, 2010; Inoue & Rossi, 2019), and CDS spreads (Alexander & Kaeck, 2008; Chung & Chan, 2010; Eser & Schwaab, 2016; Hammoudeh & Sari, 2011; Hull, Predescu, & White, 2004). Other research has investigated the transmission of monetary policy to multiple financial market indicators, instead of a single indicator. For example, Claus, Claus, and Krippner (2018) estimate the effects of both conventional and unconventional monetary policy shocks on 10-year government bond yields, corporate bond rates, gold fixing prices, the stock price index, the real estate market index, and exchange rates in the United States.

Post the COVID-19 pandemic, several finance and economics researchers responded quickly to the urgent need to assess the impact of the pandemic on financial markets. For example, Yarovaya, Brzeszczynski, Goodell, Lucey, and Lau (2020) summarize the information transmission mechanism of the pandemic to financial markets, helping scholars conduct further studies on the impact of the pandemic on financial markets. Goodell (2020) provides a comprehensive agenda for future research on the COVID-19 pandemic and finance. Some empirical evidence of the impact of the pandemic on financial markets has also emerged. Using a sample of Nigeria's major stock market indices, Ozili and Arun (2020) has shown that the pandemic caused the stock market indices to plunge, as investors moved their money to safer assets, such as government bonds. Corbet, Larkin, & Lucey (2020), based on a sample of gold and crypto-currencies, find the evidence of a "flight to safety" during the COVID-19 pandemic period. Further, Sharif et al. (2020) have studied the relationship between the pandemic, oil prices, the stock market, geopolitical risk, and economic policy uncertainty in the United States. The results show that the pandemic has a stronger effect on geopolitical instability than on the economic instability of the United States. Ashraf (2020) finds that the increase in confirmed cases of COVID-19 has negatively affected stock markets in 64 countries. Izzeldin, Muradoglu, Pappas, & Sivaprasad (2021) examine the impact of COVID-19 on stock markets in G7 countries and show that almost all business sectors have suffered from crisis during COVID-19 pandemic period, particularly the U.S. and the U.K.

The studies most relevant to this study are those that estimate the effects of monetary policy on financial markets during the COVID-19 pandemic period. For example, Ozili and Arun (2020) find that policy rates had a significant negative impact on stock index prices during the pandemic period, based on data from leading stock markets in North America, Africa, Asia, and Europe between March 23 and April 23, 2020. Yilmazkuday (2020) investigates the effects of U.S. monetary policy (policy rates) on exchange rates during the pandemic period in 21 emerging-market countries. The results show that a negative U.S. monetary policy shock led to currency depreciation in emerging markets. Bhar & Malliaris (2020) find the Fed's unconventional monetary policies, implemented after 2008 financial crisis, could help reduce longer-term interest rates and point out their results could provide lessons for the central bank to calm financial and economic impacts of the COVID-19. However, they do not empirically test the effects of unconventional monetary policies during the COVID-19 pandemic period. In summary, some of the above studies are on the single country or single financial market, some are based solely on the data during the COVID-19 pandemic period, and the others only discuss a single monetary policy. Given that the COVID-19 pandemic has spread to almost all countries, a general study involving a wider range of sample is needed.

This paper extends the existing literature on three main dimensions. First, this study explores the impact of the COVID-19 pandemic on the effects of monetary policy transmission to financial markets from an international perspective, helping to assess the impact of the pandemic worldwide. Second, we discuss not only the impact of the emergence of the pandemic on the effects of conventional and unconventional policy transmission, but also the impact of the severity of the pandemic, analyzing the impact of pandemic more comprehensively. Finally, the results provide a better understanding of the changes in the effects of monetary policy transmission to financial markets in response to the outbreak of pandemic and a more specific consideration for future monetary policy adjustments in the post-pandemic period.

The rest of the paper is organized as follows. Section 2 outlines the data and their sources. Section 3.1 sets up the benchmark event-study models to assess the transmission of monetary policy to financial markets. Section 3.2 investigates the impact of the COVID-19 pandemic on the transmission. Section 3.3 considers the influence of the economic or financial circumstance on the robustness of results. Section 4 concludes the paper.

2. Data

This study draws on the panel data for 37 countries between January 1, 2011 and April 30, 2020. The sample countries are selected based on the severity of the pandemic and the importance of their position in the world economy. Of the countries in our sample, 34 have severe COVID-19 pandemics (more than 10,000 confirmed cases as of April 30, 2020). Three G20 countries, Argentina, Australia, and South Africa, are not included among these 34 countries. Given the importance of the G20 countries and their influence on the world economy, we include these three countries in our sample. Their confirmed cases, as of April 30, 2020, were 4428, 6766, and 5647, respectively. Precisely, we consider the following countries: Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, France, Germany, India, Indonesia, Ireland, Israel, Italy, Japan, Mexico, Netherlands, Pakistan, Peru, Poland, Portugal, Qatar, Romania, Russia, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Turkey, Ukraine, United Arab Emirates, United Kingdom and United States. The number of confirmed cases in 37 sample countries is shown in Fig. 1.

We seek to assess the impact of both the emergence and the severity of the COVID-19 pandemic. Thus there are two key independent variables in the experiment. One measures whether the COVID-19 pandemic has occurred and is denoted by a 0–1 dummy variable. The other measures the severity of the pandemic, which is defined as the ratio of confirmed cases to aggregate population in a country.

For monetary policy, the policy rate changes are taken as the conventional monetary policy variable. And a dummy variable, developed by the announcements of the unconventional monetary policies, is taken as unconventional monetary policy variable. The dummy variable takes the value of 1 on days of unconventional monetary policy announcements and zero otherwise. Unconventional monetary policies include the announcements of quantitative easing, large-scale purchases of long-term assets, targeted reduction in reserve requirement ratio, and so on, during the COVID-19 pandemic period. The investigation of conventional monetary policy is based on the full sample period—January 1, 2011 to April 30, 2020, while the investigation of unconventional monetary policies considers the pandemic period—January 22, 2020 to April 30, 2020,[1] when the monetary policy changes most frequently after the coronavirus outbreak.

Among the daily financial market indicators, we choose representative indicators that respond freely to changes in monetary policy and may be influenced by monetary policy. To test the transmission of monetary policy to yield curves, we include 10-year zero-coupon government bond yields. To estimate the transmission of monetary policy to equity markets, we include stock index returns. The data also include changes to each country's currency exchange rate against the dollar to estimate the transmission of monetary policy to exchange rate markets (Claus et al., 2018). Finally, we include the growth rates of credit default swap (CDS) spreads to represent the credit market. A CDS seller provides credit protection against the risk of default for CDS buyers. In return, CDS buyers pay periodic fees to sellers, and these are called CDS spreads. CDS spreads are, therefore, used as a direct measure of credit risk in economies and financial markets (Alexander & Kaeck, 2008).

The daily policy rate data are sourced from DataStream, while data related to unconventional monetary policy announcements are collected manually by the authors from the central bank websites and the various monetary policy reports for each country. The detailed data concerning the unconventional monetary policy announcements are shown in Table A1 in Appendix. All daily data about dependent variables, including 10-year government bond yields, stock index returns, exchange rates, and 10-year CDS spreads, are sourced from DataStream. The annual data for trade openness, financial development, and industrialization are sourced from the World Bank Database. Fiscal policy data are collected by the authors from the website of governments and the reports of fiscal policies. The U.S. exchange rate is represented by the U.S. dollar index, while other exchange rates are calculated using spot rates for each country's currency against the dollar. The daily number of confirmed cases of COVID-19 is sourced from data collected by Johns Hopkins University.[2]

3. Empirical results

3.1. The transmission of monetary policy to financial markets

We seek to identify the impact of the COVID-19 pandemic on the transmission of monetary policy to financial markets. As a starting point, this analysis estimates the effects of monetary policy on financial market indicators. It draws on the broadest range of literature (Alexander & Kaeck, 2008; Chortareas & Noikokyris, 2017; Kuttner, 2001; Sun, 2020) to regress the changes in financial markets on policy rate changes (conventional monetary policy) and the unconventional monetary policy announcement variable.

$$y_{i,t} = c + \alpha_1 r_{i,t} + \varepsilon_{i,t} \tag{1}$$

$$y_{i,t} = c + \beta_1 r_{i,t} + \beta_2 u_{i,t} + \varepsilon_{i,t} \tag{2}$$

where $y_{i,\ t}$ can represents daily changes in country i's 10-year government bond yields (GOV), the daily (log) returns of stock market price indices (STO), changes in exchange rates (EXC) and the growth rates of CDS spreads (CDS) on the day when monetary policy changed[3]; $r_{i,\ t}$ can denote policy rate changes that stand for adjustments of conventional monetary policy. $u_{i,\ t}$ is a dummy variable that takes the value of 1 on days with unconventional monetary policy announcements and zero otherwise. In model (1), t refers to the full sample period—from January 1, 2011 to April 30, 2020. However, in model (2), t refers only to the COVID-19 pandemic period—from January 22 to April 30, 2020.

Following the existing literature (e.g., Chortareas & Noikokyris, 2017), we estimate models (1) and (2) based on the least square method. The estimated results for models (1) and (2) are reported in Tables 2 and 3, respectively.

The coefficient estimates α_1, capturing the responses of financial markets to changes in policy rates, are statistically significant in all Eqs. [1]–[4] in Table 1. Specifically, the coefficient of changes in 10-year government bond yields (Eq. [1] in Table 1) on policy rate changes has the expected positive sign, suggesting that the transmission of conventional monetary policy along the yield curves is relatively smooth, in line with the results of most studies. For example, Kuttner (2001) estimates the responses of bond yields to the changes in target Federal funds rate and finds that the unanticipated changes in target rate have more significant positive effect on the bond yields than the anticipated changes. Sun (2020) finds that the government bond yields are positively correlated with the benchmark lending rate in China. Compared to the above studies, our result covers a wider sample of countries and the result is more general. The first sub-graph of Fig. 2 also displays the positive relationship between the changes in policy rates and 10-year government bond yields.

The response of stock index returns (Eq. [2] in Table 1) to policy rate changes is positive and significant. This result appears to contradict the empirical theory that when the policy rates rise, the bond yields rise and the stock index returns will fall. But it's consistent with a lot of recent research that the rise in bond yields or interest rates is accompanied by

[1] In practice, the COVID-19 pandemic began before January 22, 2020, but these are the earliest data available on the number of confirmed cases.

[2] See the webpage:https://www.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6

[3] A non-zero change in the policy rates is considered a change of conventional monetary policy, while an announcement of unconventional monetary policy is considered a change of unconventional monetary policy.

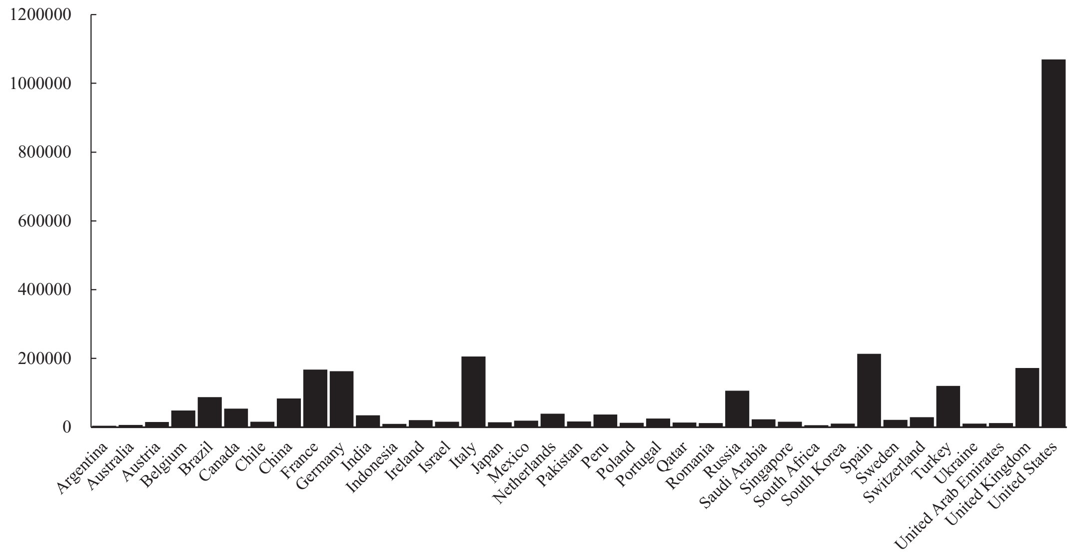

Fig. 1. Confirmed cases in 37 countries, as of April 30, 2020.

Table 1
Effects of monetary policy on financial markets: full sample period.

Dependent variables	[1]	[2]	[3]	[4]
	GOV	STO	EXC	CDS
$r_{i,\,t}$	0.454***	0.030***	−0.025***	0.072***
	(58.202)	(10.456)	(−24.477)	(41.153)
c	0.010	−0.001	0.001	0.005
	(1.496)	(−0.320)	(0.964)	(0.242)
Observations	4868	4895	4895	4893
R^2	0.412	0.022	0.110	0.257
Number of countries	37	37	37	37

Notes: This table reports the benchmark results from the regressions of the model (1), that is, the effects of the changes in policy rates ($r_{i,\,t}$) on the changes in 10-year government bond yields (GOV), stock index returns (STO), changes in exchange rates (EXC) and growth rates of CDS spreads (CDS). The estimation is based on the full sample period. The coefficient estimates are obtained by the OLS method. t-statistics are reported in parentheses and ***/ **/* denote the significance at 99%, 95% and 90% confidence levels, respectively.

an increase in stock index returns.[4] For example, Ferrer et al. (2016) find that 10-year government bond yields (the proxy of interest rates) and stock returns move in the same direction in European countries, despite it varies over time and across time horizons. Bayraci et al. (2018) have observed the co-movement between the 10-year Treasury yields and stock returns based on a sample of G7 countries. In our case, the coefficient of interest rates is 0.030, meaning that the stocks index returns and interest rates move also in the same direction. This positive sign may reflect the fact that policy rates (or market interest rates) and stock indices follow the same macroeconomic indicators, such as inflationary expectations and economic prospects (Ferrer et al., 2016). For example, a fall in the policy rates means an expansionary monetary policy, and investors expect inflation. Inflation expectations lead investors to expect higher raw material prices, which can lead to higher financing costs and lower corporate profits. Consequently, corporate valuations fall and investment returns decline in the short term. For another example, when the central bank reduces policy rates, investors view the economic prospects as gloomy and reduce their stock holdings. Thus, lowering interest rates can make stock returns decline. A typical case occurred on March 3, 2020, when the Federal Reserve announced that the standard range of the federal funds rate would be lowered by 50 basis points to deal with the economic impact of the COVID-19 pandemic. Market investors sold off the stocks on that day, and the S&P 500 index fell by more than 2.81% in a day. The VIX fear index rose by 12.54%, showing that monetary policy will affect the stock market by influencing the views of market participants in relation to economic prospects. The second sub-graph of Fig. 2 shows the positive relationship between policy rate changes and stock index returns.

The exchange rate and policy rate changes are significantly negatively correlated (see also the third sub-graph of Fig. 2). This means that a contractionary monetary policy (an increase in policy rates) will lead to a depreciation of exchange rates. Many studies have reached the similar result. For example, Hellwig, Mukherji, and Tsyvinski (2006) develop a model of currency crises and conclude that an increase in domestic interest rates may cause a depreciation of the domestic currency. Bouakez and Normandin (2010) find that the nominal exchange rates in G7 countries depreciate within roughly then months in response to the expansionary U.S. monetary policy shocks. There are two possible reasons for this result. On the one hand, an increase in policy rates reduces demand for borrowing in the domestic currency and leads to a capital outflow, which causes domestic currency depreciation (Hellwig et al., 2006). On the other hand, an increase in policy rates reflects the increase in the expected inflation rate, which further causes the demand for domestic currency to fall (Frankel, 1979). Therefore, when policy rates increase, the local currency exchange rate depreciates.

The policy rates have significant positive effect on CDS spreads (see also the fourth sub-graph of Fig. 2). On the one hand, higher CDS spreads mean higher credit risk in the market. Therefore, the positive effect of monetary policy on CDS spreads can indicate that investors are worried about the adverse selection and moral hazard caused by higher interest rates. Therefore, an increase in policy rates can cause CDS spreads to rise. On the other hand, an increase in policy rates can cause a booming economy to depress. The bond issuers' repayment burden increases rapidly and creates a risk of default. Then the demand for protecting against risk increases, and the CDS spreads rise.

In summary, as Table 1 shows, changes in conventional monetary policy (policy rates) can transmit significantly to the four financial markets in our sample. This suggests that governments need to consider

[4] Early studies provided evidence that the increase in policy rates negatively affected stock returns (e.g., Korkeamäki, 2011). They explain this result using the cash-flow hypothesis, which assumes that when interest rates rise, money flows from the stock market into the bond market in pursuit of higher yields. However, some studies verify the possible positive relationship between interest rates and stock returns, using the economic prospects hypothesis to explain this (Shahzad, Ferrer, Ballester, & Umar, 2017).

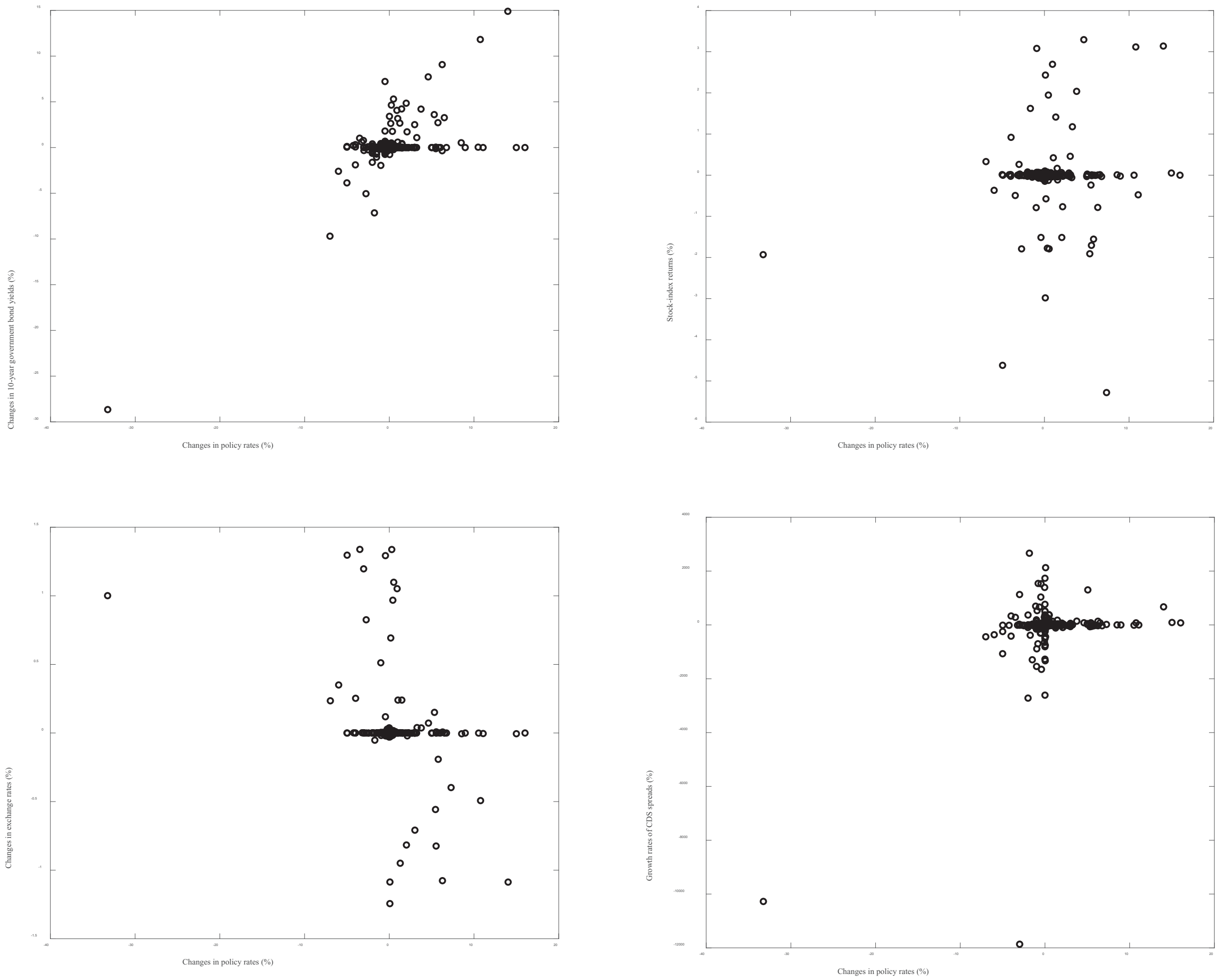

Fig. 2. Policy rate changes and changes in financial market indicators.

these significant effects of monetary policy on financial markets when adjusting monetary policy in response to economic targets, such as output and inflation or when the monetary policy is used to stimulate the financial markets.

Table 2 presents the estimation results for the transmission of monetary policy to financial markets during the pandemic period. The effects of the policy rates on all of four financial indicators are not significant. This is a preliminary indication that the pandemic has weakened the transmission of conventional monetary policy to financial markets.

Table 2
Effects of monetary policy on financial markets: COVID-19 pandemic period.

	[1]	[2]	[3]	[4]
Dependent variables	GOV	STO	EXC	CDS
$r_{i,\ t}$	0.021	−0.003	−0.000	0.006
	(0.609)	(−0.845)	(−0.130)	(0.818)
$u_{i,\ t}$	0.055	−0.033***	−0.007***	0.011
	(0.677)	(−2.790)	(−3.335)	(0.657)
c	−0.043	−0.001	0.000	0.008
	(−1.123)	(−0.323)	(0.000)	(0.909)
R^2	0.0210	0.0613	0.0781	0.0512
Obs.	136	136	136	136
Number of countries	24	24	24	24

Notes: This table reports the benchmark results from the regressions of the model (2), that is, the effects of changes in policy rates ($r_{i,\ t}$) and unconventional monetary policy announcements ($u_{i,\ t}$) on the changes in 10-year government bond yields (GOV), stock index returns (STO), changes in exchange rates (EXC) and the growth rates of CDS spreads (CDS). The estimation is based on the sample of COVID-19 pandemic period, i.e., January 22, 2020 - April 30, 2020. The coefficient estimates are obtained by the OLS method. t-statistics are reported in parentheses and ***/ **/* denote the significance at 99%, 95% and 90% confidence levels, respectively.

In the case of unconventional monetary policies, the policy has significant negative effects on stock index returns and exchange rates (as shown in Eqs. [2] and [3] in Table 2) but no significant effects on government bond yields or CDS spreads. As we know, both conventional and unconventional monetary policies are primarily expansionary during the pandemic period. The negative coefficients above indicate that expansionary unconventional monetary policies make stock index returns and exchange rate changes fall. The effect of unconventional monetary policies on stock index returns is similar to that of conventional monetary policy in Table 1. Perhaps the expansionary unconventional monetary policies make market participants more pessimistic about the economy, thus causing the stock index returns decline.

The effect of unconventional monetary policies on exchange rates is different from that of conventional monetary policy in Table 1. An expansionary unconventional monetary policy leads to a depreciation of the local currency, consistent with the results obtained by Inoue and Rossi (2019). Of course, Inoue and Rossi (2019) focus only on the effects of U.S. monetary policy on the U.S. dollar exchange rate during the unconventional monetary policy period and don't distinguish between the conventional and the unconventional monetary policies. We examine the effects of the announcements of unconventional monetary policies on the exchange rates separately and obtain a coefficient of

−0.007. The reason for this negative relationship may be that unconventional monetary policies affect exchange rates by influencing the current account. When the central bank announces an unconventional monetary policy, credit is loosened, loans increase, and investment and consumption rise. Subsequently, the demand for imports increases, causing household demand for foreign currencies to rise and the local currency to depreciate.

In short, we can conclude from Table 2 that neither conventional nor unconventional monetary policies have significant effects on all four financial market indicators during the COVID-19 pandemic period. This further demonstrates that the pandemic has weakened the transmission of monetary policy to financial markets. Of course, the effects of unconventional monetary policies on financial markets are slightly more significant than those of conventional monetary policy.

3.2. The role of the COVID-19 pandemic

To identify the impact of the COVID-19 pandemic on the transmission of monetary policy to financial markets, we include variables of the emergence and severity of the pandemic in this section. We estimate the following two models.

$$y_{i,t} = c + \alpha_1 r_{i,t} + \alpha_2 dum_{i,t} + \alpha_3 dum_{i,t} \times r_{i,t} + \varepsilon_{i,t} \tag{3}$$

$$y_{i,t} = c + \beta_1 r_{i,t} + \beta_2 u_{i,t} + \beta_3 s_{i,t} + \beta_4 s_{i,t} \times r_{i,t} + \beta_5 s_{i,t} \times u_{i,t} + \varepsilon_{i,t} \tag{4}$$

where dum_{it} is a 0–1 dummy variable taking the value of 1 during the pandemic period and zero otherwise. $s_{i,\ t}$ denotes the severity of pandemic in country i on day t during the pandemic period, defined as the daily growth rate of confirmed cases. The interaction term $dum_{i,\ t} \times r_{i,\ t}$ represents the impact of the emergence of pandemic on the effects of policy rates on financial markets. $s_{i,\ t} \times r_{i,\ t}$ and $s_{i,\ t} \times u_{i,\ t}$ represent the impact of the severity of pandemic on the effects of policy rates and unconventional monetary policies on financial markets, respectively. Similarly, t refers to the full sample period in model (3). In model (4), t refers only to the COVID-19 pandemic period.

As Table 2 clarifies, policy rates have no significant effect on any of the four financial market indicators, while unconventional monetary policies have significant effects only on stock index returns and exchange rates during the COVID-19 pandemic period. For this reason, we examine the impact of the pandemic's severity on these two effects only. In other words, when model (4) is estimated, $s_{i,\ t} \times u_{i,\ t}$ is introduced into the equation, where the dependent variables are stock index returns and exchange rate changes.[5] However, in the four estimation equations in Table 1, the effects of policy rates on all four dependent variables are significant. Therefore, we include all four financial market indicators as dependent variables when estimating model (3) in this section.

Table 3 shows the impact of the emergence of pandemic on the transmission of monetary policy to financial markets. The effects of the policy rates on the four dependent variables are consistent with those in Table 1; they are all still significant and consistent with the signs of the response coefficients in Table 1. This confirms that, to some extent, the effects of policy rates on the four financial market indicators are robust.

The coefficient α_3 of $dum_{i,\ t} \times r_{i,\ t}$ is the main focus of this section. Table 3 shows that α_3 in Eqs. [1], [3] and [4] are significant, with signs that are the reverse of the policy rate coefficients. This indicates that the emergence of COVID-19 pandemic has weakened the effects of policy rate changes on 10-year government bond yields, exchange rate changes, and the growth rates of CDS spreads. Although the coefficient of the interaction term $dum_{i,\ t} \times r_{i,\ t}$ on stock index returns is not significant enough, it is negative, and the t-statistic value is −1.301, which

Table 3
Impact of the emergence of COVID-19 pandemic on the transmission of monetary policy to financial markets: full sample period.

	[1]	[2]	[3]	[4]
Dependent variables	GOV	STO	EXC	CDS
$r_{i,\ t}$	0.462***	0.031***	−0.026***	0.073***
	(58.941)	(10.564)	(−24.709)	(41.725)
$dum_{i,\ t}$	−0.011	0.004	−0.003	0.010
	(−0.252)	(0.238)	(−0.562)	(1.032)
$dum_{i,\ t} \times r_{i,\ t}$	−0.414***	−0.030	0.023***	−0.070***
	(−6.803)	(−1.301)	(2.781)	(−5.125)
c	0.007	−0.001	0.001	0.002
	(1.026)	(−0.455)	(1.260)	(0.100)
Obs.	4868	4895	4895	4893
R^2	0.419	0.022	0.112	0.262
Number of countries	37	37	37	37

Notes: This table reports the results from the regressions of the model (3), that is, the effects of changes in policy rates ($r_{i,\ t}$), the emergence of COVID-19 ($dum_{i,\ t}$) and their interaction terms ($dum_{i,\ t} \times r_{i,\ t}$) on the four financial market indicators. The estimation is based on the full sample period. The coefficient estimates are obtained by the OLS method. t-statistics are reported in parentheses and ***/**/* denote the significance at 99%, 95% and 90% confidence levels, respectively.

is close to significant (Eq. [3] in Table 3). This indicates that the pandemic has weakened the effect of policy rates on stock index returns to some extent.

Combining the estimates of the four equations in Table 3, we conclude that the emergence of COVID-19 pandemic has weakened the transmission of conventional monetary policy to financial markets to a significant degree. The reasons for this weakening effect will be explained later. Of course, the results in Yilmazkuday (2020) suggest that, during the COVID-19 pandemic period, the negative shock on the U.S. policy rates still leads to spillover currency depreciation of 10 advanced and 21 emerging economies, which appears inconsistent with our results. However, they are essentially not contradictory. Due to the important position of the dollar, the U.S. monetary policy will naturally cause the fluctuations of exchange rates against the U.S. dollar in many countries. Instead, we explore the impact of the pandemic on the transmission of a country's own monetary policy to its financial markets. Without examining the data, Ozili and Arun (2020) put forward a view that, during the COVID-19 pandemic period, monetary policy may help to calm financial markets but it can't cure the economic recession. In practice, our empirical results suggest that monetary policy becomes less effective even in regulating financial markets during the COVID-19 period. Therefore, our results confirm the view in Ozili and Arun (2020) to some extent and provide more convincing evidence for the effectiveness of monetary policy transmission to financial markets during the pandemic period.

Table 4 lists the impact of the severity of pandemic on the transmission of monetary policy to financial markets. The coefficients β_5 of $s_{i,\ t} \times u_{i,\ t}$ in Eqs. [1] and [2] in Table 4 are the main focus of this section.

The coefficient of interaction term $s_{i,\ t} \times u_{i,\ t}$ in Eq. [1] in Table 4 is almost significant, and its sign is the reverse of the coefficient of $u_{i,\ t}$, indicating that the increased severity of the COVID-19 pandemic has partially weakened the transmission of unconventional monetary policies to stock index returns. The coefficient of $s_{i,\ t} \times u_{i,\ t}$ in Eq. [2] in Table 4 is significant, and its sign is the reverse of the coefficient of $u_{i,\ t}$, meaning that the increased severity of the pandemic has weakened the transmission of unconventional monetary policies to exchange rates.

Table 2 shows that monetary policy has no significant effects on all financial market indicators during the COVID-19 pandemic. However, as Table 4 shows, as long as there is an effect, that effect will weaken or remain largely the same, as the pandemic becomes more severe. This suggests that an increase in the severity of COVID-19 pandemic hasn't significantly affected the effectiveness of the monetary policy transmission to financial markets.

[5] If a variable itself has no significant effect on the dependent variable, it is meaningless to study the interaction or moderating effect of other variables with this variable on the dependent variable.

Table 4
Impact of the severity of COVID-19 pandemic on the transmission of monetary policy to financial markets: COVID-19 pandemic period.

Dependent variables	[1]	[2]
	STO	EXC
$r_{i,\ t}$	−0.017**	−0.001
	(−2.022)	(−0.495)
$u_{i,\ t}$	0.005	0.004
	(0.187)	(0.847)
$s_{i,\ t}$	−0.004	0.001
	(−0.214)	(0.335)
$s_{i,\ t} \times u_{i,\ t}$	−0.220	−0.063**
	(−1.518)	(−2.454)
c	−0.006	−0.001
	(−0.834)	(−0.788)
R^2	0.104	0.132
Obs.	111	111
Number of countries	24	24

Notes: This table reports the results from the regressions of the model (4), that is, the effects of changes in policy rates($r_{i,\ t}$), unconventional monetary policy announcements ($u_{i,\ t}$), the severity of COVID-19 ($s_{i,\ t}$) and their interaction terms ($s_{i,\ t} \times u_{i,\ t}$ and $s_{i,\ t} \times r_{i,\ t}$) on stock index returns (STO) and changes in exchange rates (EXC). The estimation is based on the sample of only COVID-19 pandemic period, i.e., January 22, 2020 - April 30, 2020. The coefficient estimates are obtained by the OLS method. t-statistics are reported in parentheses and ***/**/* denote the significance at 99%, 95% and 90% confidence levels, respectively.

In summary, we can conclude from Tables 3–5 that the transmission of monetary policy to financial market variables has wakened during the COVID-19 period, in comparison to the non-COVID-19 period. Furthermore, both the emergence and severity of the pandemic have somewhat weakened the transmission of monetary policy. Although policymakers set out to enhance public confidence in financial markets and the economy during the pandemic period, these fast monetary policy responses were insufficient.

We can explain why the COVID-19 pandemic has weakened the transmission of monetary policy to financial markets in three ways. First, investors did not expect the nascent, inadequate, and uncertain monetary policies introduced during the pandemic period. This lack of experience made market participants less responsive to monetary policies than they would have been in normal times. To a greater extent than usual, less risk tolerant market participants stayed on the sidelines in the short run.

Second, although the expansionary monetary policies were designed to encourage market participants to engage in financial and economic activities, the social distancing restrictions and lockdowns imposed by several governments hindered financial activity (Sharif et al., 2020). For example, the World Health Organization advises people to stay at least one meter apart. Meetings, conferences, and dinners are not allowed. All of these measures limit financial and economic transactions.

Third, investors in financial markets generally react quickly to monetary policy announcements by moving assets into safe or higher-yielding assets. However, some studies show that most assets are relatively ineffective in providing a safe haven for investors (Ji, Zhang, & Zhao, 2020). Investors are less likely to transfer liquidity or shift to safe assets by replacing financial assets when COVID-19 is spreading worldwide and creating systematic risk. Therefore, they react less after monetary policy announcements.

3.3. The role of economic circumstances

The previous section shows that the emergence and severity of the COVID-19 pandemic have nonnegligible impact on the transmission of monetary policy to financial markets. This section assesses whether the above results are robust, when considering a country's domestic economic circumstances, including trade openness, financial development, industrialization and fiscal policy.[6] In particular, we investigate whether domestic economic circumstances can explain why the impact of the pandemic on the transmission of monetary policy has been reduced (or increased) in countries with similar domestic economic circumstances.

Following Ma and Lin (2016), we use the ratio of domestic credit to GDP as the measure of financial development. The ratio of trade (export + import) to GDP is used to measure the degree of trade openness (Chortareas & Noikokyris, 2017). The ratio of industrial added value to GDP measures the level of industrialization. The ratio of fiscal stimulus amount during the COVID-19 pandemic period to GDP in 2019 measures the degree of fiscal policy. Specifically, following the existing literature (e.g., Chortareas & Noikokyris, 2017; Ehrmann & Fratzscher, 2009; Ma & Lin, 2016), we include the interaction terms of trade openness, financial development, industrialization and fiscal policy with the interaction terms in models (3) and (4) to obtain models (5) and (6).

$$y_{i,t} = c + \alpha_1 r_{i,t} + \alpha_2 dum_{i,t} + \alpha_3 dum_{i,t} \times r_{i,t} + \sum_{k=1}^{4} \alpha_4^k X_{i,t}^k + \sum_{k=1}^{4} \alpha_5^k X_{i,t} \times dum_{i,t} \times r_{i,t} + \varepsilon_{i,t} \quad (5)$$

$$y_{i,t} = c + \beta_1 r_{i,t} + \beta_2 u_{i,t} + \beta_3 s_{i,t} + \beta_4 s_{i,t} \times r_{i,t} + \beta_5 s_{i,t} \times u_{i,t} + \sum_{k=1}^{4} \beta_6^k X_{i,t}^k + \sum_{k=1}^{4} \beta_7^k X_{i,t} \times s_{i,t} \times r_{i,t} + \sum_{k=1}^{4} \beta_8^k X_{i,t} \times s_{i,t} \times u_{i,t} + \varepsilon_{i,t} \quad (6)$$

where $X_{i,t}^k$ is a 0–1 dummy variable and denotes the economic circumstances. $X_{i,t}^1$,$X_{i,t}^2$, $X_{i,t}^3$ and $X_{i,t}^4$ represent the level of trade openness, financial development, industrialization and fiscal policy, respectively. $X_{i,t}^k$ takes the value of 1 if a country's economic circumstance variable is in the top half of the sample of 37 countries, and zero otherwise. $X_{i,t}^1 \times dum_{i,t} \times r_{i,t}$ is the interaction term for the economic circumstance variable. It denotes differences in the impact of the emergence of COVID-19 pandemic on the transmission of policy rates (conventional monetary policy) to financial markets in different economic settings. $X_{i,\ t} \times s_{i,\ t} \times r_{i,\ t}$ denotes differences in the impact of the severity of pandemic on the transmission of policy rates to financial markets in different economic settings. $X_{i,\ t} \times s_{i,\ t} \times u_{i,\ t}$ denotes differences in the impact of the severity of pandemic on the transmission of unconventional monetary policies to financial markets in different economic settings. Other variables in models (5) and (6) are as previously defined.

Here, the estimation is based on the estimation results of models (3) and (4). Eq. [2] in Table 3 shows that the emergence of COVID-19 pandemic does not significantly impact the effect of policy rates on stock index returns. Therefore, when the regression model (5) is estimated, it no longer includes the equation in which the dependent variable is "stock index returns". Instead, the dependent variables are 10-year government bond yields, changes in exchange rates, and growth rates of CDS spreads.

The Eq. [2] in Table 4 shows that the severity of COVID-19 pandemic only has a significant impact on the effect of policy rates on exchange rates. Therefore, we estimate model (6) by including equations in which exchange rates are the dependent variable. Moreover, in the equations with exchange rates as the dependent variables, the interaction term includes only $X_{i,t}^k \times s_{i,\ t} \times r_{i,\ t}$.

Table 5 reports the results of the estimation of model (5) with government bond yields and exchange rates as dependent variables; Table 6 reports the results using CDS spreads as dependent variables. The coefficients of $X_{i,\ t}^k \times dum_{i,\ t} \times r_{i,\ t}$ (k= 1,2,3,4) are the main focus of this section. As shown in Tables 6 and 7, apart from trade openness, the other three circumstance variables have no significant effects on the results, suggesting that the circumstance variables have little influence on the

[6] It is worth noting that that we do not assess the impact of time series data of fiscal policy. We view fiscal policy as a circumstance variable. It allows us to identify the impact of different fiscal circumstances on the results in Section 3.2.

Table 5
Role of economic circumstances: full sample period.

Dependent variables	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
	GOV	GOV	GOV	GOV	EXC	EXC	EXC	EXC
$r_{i,\ t}$	0.465***	0.465***	0.465***	0.465***	−0.026***	−0.026***	−0.026***	−0.026***
	(59.416)	(59.381)	(59.425)	(59.380)	(−24.741)	(−24.727)	(−24.702)	(−24.799)
$dum_{i,\ t}$	−0.010	−0.018	−0.013	−0.019	−0.004	−0.002	−0.005	−0.003
	(−0.221)	(−0.418)	(−0.300)	(−0.429)	(−0.630)	(−0.387)	(−0.884)	(−0.565)
$dum_{i,\ t} \times r_{i,\ t}$	−0.462***	−0.412***	−0.398***	−0.411***	0.023**	0.022***	0.025***	0.023***
	(−6.946)	(−6.707)	(−6.330)	(−6.604)	(2.568)	(2.612)	(2.943)	(2.673)
$X^1_{i,\ t}$	−0.042				−0.059***			
	(−0.662)				(−4.263)			
$X^1_{i,\ t} \times dum_{i,\ t} \times r_{i,\ t}$	0.241*				0.001			
	(1.790)				(0.068)			
$X^2_{i,\ t}$		0.001				0.002		
		(0.020)				(0.386)		
$X^2_{i,\ t} \times dum_{i,\ t} \times r_{i,\ t}$		−0.049				0.034		
		(−0.194)				(0.991)		
$X^3_{i,\ t}$			−0.052**				0.003	
			(−2.038)				(0.775)	
$X^3_{i,\ t} \times dum_{i,\ t} \times r_{i,\ t}$			−0.102				−0.026	
			(−0.600)				(−1.114)	
$X^4_{i,\ t}$				0.022				−0.095***
				(0.291)				(−3.422)
$X^4_{i,\ t} \times dum_{i,\ t} \times r_{i,\ t}$				−0.043				−0.005
				(−0.227)				(−0.213)
c	0.095*	0.071*	0.094***	0.061	0.041**	0.010	0.009	0.057**
	(1.912)	(1.805)	(2.615)	(1.181)	(1.962)	(0.483)	(0.452)	(2.358)
R^2	0.427	0.427	0.426	0.426	0.0604	0.111	0.110	0.0387
Obs.	4868	4868	4868	4868	4895	4895	4895	4895
Number of countries	37	37	37	37	37	37	37	37

Notes: This table reports the results from the regressions of the model (5), that is, the effects of changes in policy rates ($r_{i,\ t}$), the emergence of COVID-19 ($dum_{i,\ t}$), the circumstance variables ($X^k_{i,\ t}$, k = 1,2,3,4) and their interaction terms ($dum_{i,\ t} \times r_{i,\ t}$ and $X^k_{i,\ t} \times dum_{i,\ t} \times r_{i,\ t}$) on the changes in 10-year government bond yields (GOV) and the changes in exchange rates (EXC). The estimation is based on the full sample period. The coefficient estimates are obtained by the OLS method. t-statistics are reported in parentheses and ***/ **/* denote the significance at 99%, 95% and 90% confidence levels, respectively.

impact of COVID-19 pandemic on the transmission of monetary policy. Of course, the coefficient of $X^1_{i,t} \times dum_{i,t} \times r_{i,t}$, indicating that the higher the degree of trade openness, the lower the weakening effect of the pandemic on the transmission of policy rates to 10-year government bond yields. This may reflect the fact that the higher the degree of trade openness, the more the economy and financial markets are affected by the foreign economy, and the less they are affected by the domestic economy. Therefore, if a country has a higher degree of trade openness, the domestic COVID-19 pandemic will have less impact on its overall economy, and the effect of policy rates on 10-year government bond yields will not be significantly weakened.

In addition, it is worth noting that Eq. [8] in Table 5 and Eq. [7] in Table 6 show that fiscal policy has negative effects on both exchange rates and CDS spreads. In other words, the looser the fiscal policy during the COVID-19 pandemic period, the lower the exchange rates and the lower the CDS spreads. Because the expansionary fiscal policy can increase domestic currency supply and thus increase the demand for foreign currency, which causes the domestic currency to depreciate. At the same time, looser fiscal policy helps to improve credit conditions, which lead to lower CDS spreads. These results indicate that the fiscal policies implemented during the COVID-19 pandemic period play an important role in regulating financial markets.

Table 7 reports the estimation results of model (6). The coefficients of $X^k_{i,\ t} \times s_{i,\ t} \times u_{i,\ t}$ in Eqs. [1]–[4] are the main focus of this section. The coefficients of $X^k_{i,\ t} \times s_{i,\ t} \times u_{i,\ t}$ in Eqs. [1]–[4] are not significant, indicating that, under different circumstances, there would be no significant difference in the impact of the severity of COVID-19 pandemic on the transmission of unconventional monetary policies to the exchange rate market.

In addition, the coefficients of $dum_{i,\ t} \times r_{i,\ t}$ in Tables 6 and 7 are consistent with the sign and significance of the coefficients in Table 3, indicating that the results of Eqs. [1], [3] and [4] in Table 3 are robust. In other words, the emergence of COVID-19 pandemic has weakened the transmission of conventional monetary policy to 10-year government bond yields, exchange rates, and CDS spreads. Meanwhile, the weakening impact on the transmission of conventional monetary policy to stock market is close to significant. This indicates that the emergence of pandemic has weakened the transmission of conventional monetary policy to financial markets to a more significant degree so that the effects of conventional monetary policy on all four of financial markets are insignificant during the pandemic. The increased severity of pandemic has also mitigated the transmission of unconventional monetary policies to stock and exchange rate markets (Table 4). In Table 7, however, the coefficients of interaction term $s_{i,\ t} \times u_{i,\ t}$ are not as significant as those in Table 4, indicating that the impact of the severity of pandemic on the transmission of unconventional monetary policies to financial markets is not sufficiently robust.

4. Conclusions and policy implications

This study explores the impact of COVID-19 pandemic on the transmission of monetary policy to financial markets, which covers a sample of 37 countries with severe pandemics. We assess the impact of not only the emergence of COVID-19 pandemic on the transmission of monetary policy to financial markets but also the severity of it.

Our findings show that the emergence of pandemic has weakened the transmission of monetary policy to financial markets to a more significant degree; these results are robust, even when the circumstance variables are taken into account. However, an increase in severity of the pandemic hasn't significantly affected the effectiveness of the monetary policy transmission to financial markets. As a result, during the COVID-19 pandemic period, neither conventional nor unconventional monetary policies have significant effects on all four of the financial markets, including the government bond, stock, exchange rate and CDS markets. Of course, unconventional monetary policies are slightly more effective than conventional policies because they can affect the stock and

Table 6
Role of economic circumstances: full sample period.

Dependent variables	[1]	[2]	[3]	[4]
	CDS	CDS	CDS	CDS
$r_{i,\,t}$	0.074**	0.073***	0.073***	0.073***
	(2.229)	(41.734)	(41.704)	(41.753)
$dum_{i,\,t}$	0.004	0.008	0.009	0.009
	(1.560)	(0.799)	(0.904)	(0.881)
$dum_{i,\,t} \times r_{i,\,t}$	−0.064*	−0.069***	−0.068***	−0.069***
	(−1.787)	(−4.944)	(−4.753)	(−4.910)
$X^1_{i,\,t}$	−0.000			
	(−0.034)			
$X^1_{i,\,t} \times dum_{i,\,t} \times r_{i,\,t}$	−0.020			
	(−1.553)			
$X^2_{i,\,t}$		0.007		
		(1.065)		
$X^2_{i,\,t} \times dum_{i,\,t} \times r_{i,\,t}$		−0.057		
		(−0.983)		
$X^3_{i,\,t}$			−0.004	
			(−0.576)	
$X^3_{i,\,t} \times dum_{i,\,t} \times r_{i,\,t}$			−0.026	
			(−0.665)	
$X^4_{i,\,t}$				−0.079**
				(−2.187)
$X^4_{i,\,t} \times dum_{i,\,t} \times r_{i,\,t}$				−0.028
				(−0.648)
c	0.002	−0.002	0.003	0.040
	(0.064)	(−0.093)	(0.167)	(1.450)
R^2	0.261	0.261	0.262	0.219
Observations	4893	4893	4893	4893
Number of countries	37	37	37	37

Notes: This table reports the results from the regressions of the model (5), that is, the effects of changes in policy rates ($r_{i,\,t}$), the emergence of COVID-19 ($dum_{i,\,t}$), the circumstance variables ($X^k_{i,\,t}$, k = 1,2,3,4) and their interaction terms ($dum_{i,\,t} \times r_{i,\,t}$ and $X^k_{i,\,t} \times dum_{i,\,t} \times r_{i,\,t}$) on the growth rates of CDS spreads. The estimation is based on the full sample period. The coefficient estimates are obtained by the OLS method. t-statistics are reported in parentheses and ***/ **/* denote the significance at 99%, 95% and 90% confidence levels, respectively.

exchange rate markets to some extent.

Furthermore, the regression results of the circumstance variables show that, even with different levels of industrialization and financial development, there is no significant difference in the weakening impact of the pandemic on monetary policy transmission. This may be due to, even if a country has a higher level of industrialization or financial development in 2019, manufacturing industry has been disrupted and the demand for loans has fallen since the coronavirus outbreak, making it impossible to reflect the difference in impact of the pandemic on transmission of monetary policy due to different degrees in industrialization and financial development. However, a higher degree of trade openness could mitigate some of the weakening impact of the pandemic on monetary policy transmission. Because the higher the degree of trade openness, the less the economy and financial markets are affected by the domestic pandemic. In addition, the fiscal policies introduced during the pandemic have direct effects on exchange rate and CDS markets to some extent.

The above findings have three important policy implications. First, the central banks should implement more expansionary monetary policy or resort to the other macro-policies during the COVID-19 pandemic period since the transmission of monetary policy to financial markets is weakened. In fact, the central banks in many countries have started "printing money" pattern in response to the pandemic. For example, interest rates are already adjusted to be negative in Switzerland, Denmark and Hungary, while they are also close to negative territory in New Zealand, Norway and Australia. Although these unprecedentedly expansionary monetary policies do not have significant effects on financial markets in the short term (sample period of this paper), the panic in financial markets has eased somewhat by the end of 2020. For example, the S&P 500 has recovered by the end of 2020, and the stock indexes in major emerging markets, excluding Russia, have also largely

Table 7
Role of economic circumstances: COVID-19 pandemic period.

Dependent variables	[1]	[2]	[3]	[4]
	EXC	EXC	EXC	EXC
$r_{i,\,t}$	0.001	−0.000	−0.001	0.000
	(0.377)	(−0.092)	(−0.473)	(0.302)
$u_{i,\,t}$	−0.005*	−0.005*	−0.006	−0.006**
	(−1.798)	(−1.871)	(−1.244)	(−2.053)
$s_{i,\,t}$	−0.001	−0.001	−0.003	−0.001
	(−0.414)	(−0.173)	(−0.645)	(−0.347)
$s_{i,\,t} \times u_{i,\,t}$	−0.047	−0.040	−0.081*	0.079
	(−1.626)	(−1.325)	(−1.649)	(0.782)
$X^1_{i,\,t}$	−0.002			
	(−1.306)			
$X^1_{i,\,t} \times s_{i,\,t} \times u_{i,\,t}$	−0.101			
	(−1.242)			
$X^2_{i,\,t}$		−0.000		
		(−0.195)		
$X^2_{i,\,t} \times s_{i,\,t} \times u_{i,\,t}$		−0.124		
		(−1.489)		
$X^3_{i,\,t}$			−0.000	
			(−0.208)	
$X^3_{i,\,t} \times s_{i,\,t} \times u_{i,\,t}$			0.054	
			(0.463)	
$X^4_{i,\,t}$				−0.000
				(−0.920)
$X^4_{i,\,t} \times s_{i,\,t} \times u_{i,\,t}$				−0.015
				(−1.488)
c	−0.000	−0.000	−0.001	0.001
	(−0.491)	(−0.122)	(−0.654)	(0.558)
R^2	0.160	0.151	0.134	0.161
Obs.	111	111	111	111
Number of countries	24	24	24	24

Note: This table reports the results from the regressions of the model (6), that is, the effects of changes in policy rates ($r_{i,\,t}$), unconventional monetary policy announcements ($u_{i,\,t}$), the severity of COVID-19 ($s_{i,\,t}$), the circumstance variables ($X^k_{i,\,t}$, k=1,2,3) and their interaction terms ($s_{i,\,t} \times r_{i,\,t}$, $s_{i,\,t} \times u_{i,\,t}$, $X^k_{i,\,t} \times s_{i,\,t} \times r_{i,\,t}$ and $X^k_{i,\,t} \times s_{i,\,t} \times u_{i,\,t}$) on the changes in exchange rates (EXC) and the growth rates of CDS spreads (CDS). In Eqs. [1]–[3] with the changes in exchange rates as the dependent variables, multicollinearity exits between the severity of COVID-19 pandemic, unconventional monetary policy announcements and circumstance variables. For this reason, these variables are decentered. The estimation is based on the sample of only COVID-19 pandemic period, i.e., January 22, 2020 - April 30, 2020. Coefficient estimates are obtained by the OLS method. t-statistics in parentheses and ***/ **/* denote the significance at 99%, 95% and 90% confidence levels, respectively.

recovered. Therefore, higher monetary policy changes are necessary to regulate financial markets.

Second, the insignificant impact of the increased pandemic severity on monetary policy transmission suggests that, as long as the number of confirmed cases reaches a threshold, whether serious or not, financial markets will slow down their responses to monetary policy in the short term. The possible reasons are the financial market participants' overreaction to the pandemic information and the investors' behavior such as herding behavior. This leads to the consequence that a limited number of confirmed cases could cause a large number of investors to shift to the safe assets by replacing financial assets, which further reduces the stimulus effect of monetary policy on financial markets. For example, although the severity of the pandemic in China, the United States, Japan and Germany is different, the stimulation effects of their monetary policies introduced in March and April 2020 on stock markets are uniformly insignificant in the short term. All four stock indexes[7] did not begin to recover to the levels in early March until June 2020. As a result, the policy implications for central banks are that, even if a country is not at the highest level of pandemic severity, the short-term weakening effect of monetary policy on financial markets should be

[7] China's HS300, the S&P 500 in the U.S., Japan's Nikkei 225 and Germany's DAX.

fully considered in the policy implementation.

Finally, the unconventional monetary policy can be used to stimulate the financial markets and reverse the economic downturns in the post-pandemic period since it is slightly more effective than conventional monetary policy. And unlike interest rate policy, many unconventional monetary policies tend to be targeted to support certain types of enterprises such as those involved in fighting the epidemic of COVID-19 or small and micro enterprises. Obviously, the effects of such unconventional monetary policies on financial markets may not be significant, but their changes can be transmitted directly to the micro-economy and play a positive role in economic recovery. Therefore, in the future, the central banks can implement more flexible and diversified unconventional monetary policies and provide more targeted support to the real economy. Moreover, other macro policies may be needed to be implemented. For example, a combination of unconventional monetary policy and fiscal policy can be a better choice to regulate the financial markets and stimulate the economy in the post-pandemic period.

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Appendix A. Appendix

Table A1
Unconventional monetary policy announcements in 37 countries: January 22, 2020 - April 30, 2020.

Country	Announcements
Argentina	On March 19, the Central bank of Argentina announced that banks must reduce their LELIQ positions in order to lending more loans to the public.
Australia	On March 13, the reserve bank of Australia injected 8.8 billion AUDs into markets in its open-market operations. On March 19, the reserve bank of Australia announced to enter quantitative easing mode.
Euro area[a]	On March 10, the European commission said it would use all tools to maintain the economic stability. On March 12, the European central bank unveiled its latest comprehensive portfolio of monetary policy tools: increasing temporary and long-term refinancing operations; launching the new targeted longer-term refinancing operation (TLTRO-III); increasing bond purchases by 120 billion euros by the end of 2020; temporarily relaxing banking regulatory requirements on capital and liquidity ratios. On March 18, the European central bank announced an emergency purchase program in the amount of 750 billion euros.
Brazil	On March 23, Bank of Brazil reduced the reserve requirement ratio (RRR) from 25% to 17%.
Canada	–
Chile	On March 27, the central bank of Chile announced that it would relax its liquidity management rules for banks.
China	On February 3, the People's Bank of China (PBC) launched the reverse repo operation on the open market for 1.2 trillion yuan. On February 7, the PBC set up a special re-lending program in the amount of 300 billion yuan. On February 26, the PBC increased its quota for refinancing and rediscount by 500 billion yuan. On March 13, the PBC announced that it would implement a targeted reduction in the reserve requirement ratio for inclusive finance on March 16, 2020. On April 3, the PBC announced that it would reduce the required reserve ratio for small and medium-sized banks by 1 percentage point.
India	On March 16, the governor of the reserve bank of India announced a long-term refinancing operation in the amount of 1 trillion rupees. On March 27, India reduced its reverse repo rate by 90 basis points to 4.0%. On April 17, the reserve bank of India injected 500 billion rupees into the financial system.
Indonesia	Indonesia's central bank bought government bonds of 8 and 6 trillion rupiahs on March 12 and 13, respectively.
Israel	On April 21, the bank of Israel announced a relaxation of mortgage lending rules in the context of the COVID-19 pandemic.
Japan	On March 16, the Bank of Japan announced the quantitative and qualitative easing policy, increasing the annual purchase target of ETF to 12 trillion yen, adjusting the purchase scale of corporate bonds and commercial bonds, and increasing the purchase target of Japanese real estate investment trust to 180 billion yen. On March 19, the bank of Japan announced to purchase of JPY 1 trillion of Japanese public bonds. On April 27, the Bank of Japan decided to ease monetary policy, including expanding its purchases of commercial paper and corporate bonds. It also decided to cancel the limit of government bond purchases.
Mexico	—[b]
Pakistan	–
Peru	–
Poland	–
Qatar	–
Romania	–
Russia	On March 17, the central bank of Russia announced that it would use liquidity facilities and relax the banking and financial regulations to minimize the impact of the COVID-19 pandemic.
Saudi Arabia	On March 14, the central banks of United Arab Emirates (UAE) and Saudi Arabia jointly announced a stimulus plan in the amount of 40 billion dollars.
Singapore	On March 26, Singapore's monetary authority announced it would provide up to 60 billion dollars to the banking sector. On April 7, the monetary authority of Singapore announced the relaxation of some regulations to assist financial institutions to support their clients in the face of COVID-19 pandemic.
South Africa	–
South Korea	On March 19, the Bank of Korea bought KRW 1.5 trillion of government bonds. On March 26, the Bank of Korea announced it would pump unlimited amounts of cash into the market through repurchase operations.
Sweden	On March 13, the Riksbank announced it would offer loans of up to SEK 500 billion to the companies. On April 22, the Riksbank said it would buy municipal bonds.
Switzerland	–
Turkey	–
Ukraine	On March 16, Ukraine's President obliged the central bank, Ministry of Finance, state-owned commercial banks to provide loan support and tax changes for small and medium-sized enterprises to respond to COVID-19 pandemic.
United Arab Emirates	On March 14, the central banks of United Arab Emirates (UAE) and Saudi Arabia jointly announced a stimulus plan in the amount of 40 billion dollars. Regulators in United Arab Emirates planned to provide 100 billion dirhams to the country's banks and businesses.
United Kingdom	On March 19, the Bank of England decided to increase its holdings of the UK government bonds and corporate bonds by GBP 200 billion to GBP 645 billion, as well as expand its term funding facility.
United States	On March 17, the Federal Reserve reactivated its commercial-paper funding facility, restarted the primary dealer credit facility. On March 18, the U.S. Treasury secretary approved the creation of the money market investor financing facility. On March 19, the Federal Reserve reported that it would buy USD 68 billion of interest-bearing Treasury securities in the morning and afternoon of Thursday and Friday, and about USD 7 billion of Treasury inflation-protected securities (TIPS) each day.

(*continued on next page*)

Table A1 (*continued*)

Country	Announcements
	On March 23, the Federal Reserve announced that it would carry out unlimited and open-ended quantitative easing (QE). On March 26, the Federal Reserve decided to cut the reserve requirement ratio to zero. On March 31, the Federal Reserve announced the creation of a temporary repurchase agreement facility for foreign and international monetary authorities. On April 9, the Federal Reserve announced a credit-support program in the amount of 2.3 trillion dollars and some purchases of high-yield bonds. On April 23, the Federal Reserve announced the fourth bail-out program in the amount of 484 billion dollars.

Source: Author's compilation based on the website of central bank and various issues of monetary policy report of each country.

[a] The euro area countries in our sample contain Austria, Belgium, France, Germany, Ireland, Italy, Netherlands, Portugal and Spain.

[b] "—" means the unconventional monetary policy remains unchanged in the COVID-19 pandemic period (January 22, 2020 - April 30, 2020).

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