Routledge
Taylor & Francis Group

Economic Research-Ekonomska Istraživanja

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rero20

Will digital financial development affect the effectiveness of monetary policy in emerging market countries?

Song Jiang, Shuang Qiu & Hong Zhou

To cite this article: Song Jiang, Shuang Qiu & Hong Zhou (2022) Will digital financial development affect the effectiveness of monetary policy in emerging market countries?, Economic Research-Ekonomska Istraživanja, 35:1, 3437-3472, DOI: 10.1080/1331677X.2021.1997619

To link to this article: https://doi.org/10.1080/1331677X.2021.1997619

Published online: 08 Nov 2021.

ECONOMIC RESEARCH-EKONOMSKA ISTRAŽIVANJA
2022, VOL. 35, NO. 1, 3437–3472
https://doi.org/10.1080/1331677X.2021.1997619

Will digital financial development affect the effectiveness of monetary policy in emerging market countries?

Song Jiang[a,b], Shuang Qiu[a] and Hong Zhou[c]

[a]School of Economics and Finance, Chongqing University of Technology, Chongqing, China;
[b]Chongqing Research Center of Labor Economics and Human Resources, Chongqing, China;
[c]Chongqing Geology and Minerals Exploration Group Co., Ltd, Chongqing, China

ABSTRACT

Whether digital finance should be included in the quantitative framework of monetary policy in emerging market countries has been widely discussed by scholars. However, the current research just focused on a single format of digital finance, lacking comprehensive analysis at the overall level and the refinement of general rules. Therefore, this paper constructed a spatial econometric model to empirically analyze the impact of digital finance on the effectiveness of monetary policy and its heterogeneity, taking China as the representative of emerging market countries. The empirical test showed that (1) Although the total index of digital finance had a negative impact on economic growth, the interaction between digital finance and monetary policy was significantly positive. This indicated that the "moderating effect" of monetary policy was beneficial to digital finance in promoting economic growth, which was confirmed from the subindexes level as well. (2) The development of digital finance had obvious characteristics of the "polarization effect" and the "spatial spillover effect". Meanwhile, there was a significant regional difference in the "moderating effect" of monetary policy. (3) In terms of control variables, consumption level, fixed capital formation level, and fiscal policy all had a significant positive impact on economic growth, with a positive "spatial spillover effect". Whereas, the impacts of COVID-19 and export level on economic growth were both negative. Hence, coping with the challenges of COVID-19 and revitalizing exports were important breakthroughs for emerging market countries to recover the domestic economy. Finally, based on the empirical conclusions, this paper proposed three suggestions. First, monetary policy should be strengthened to intervene in the development of digital finance. Second, digital financial development should be integrated into the quantitative framework of monetary policy. Third, it is essential to build a "double pillar" policy framework to compensate for the shortage of monetary policy.

ARTICLE HISTORY
Received 9 November 2020
Accepted 20 October 2021

KEYWORDS
Digital financial development; spatial effect; effectiveness of monetary policy; dynamic spatial panel model; COVID-19

JEL CLASSIFICATIONS
C58; E52; G29

CONTACT Song Jiang jiangsong@cqut.edu.cn

1. Introduction

Digital finance is financial services delivered through mobile phones, personal computers, the internet, or cards linked to a reliable digital payment system. From the perspective of innovation practice in emerging market countries, digital finance includes a large number of new financial products, financial businesses, financial related software, as well as new forms of customer communication and interaction provided by FinTech companies and innovative financial service providers (Gomber et al., 2017; Manyika et al., 2016; Ozili, 2018). As a consequence, the appearance of digital finance largely moderated the financial repression and provided convenient financial services for the poor in emerging market countries. That is to say, digital finance actively promoted the effective interconnection of participants in economic activities and boosted the gross domestic product (GDP) by providing convenient access to a diverse range of financial products and credit facilities for individuals as well as small, medium, and large companies (David-West et al., 2018; Ozili, 2018). According to the research of McKinsey Global Institute (MGI), digital financial services have created 95 million job opportunities and boosted the GDP of emerging economies by 6%. Meanwhile, the outbreak of the COVID-19 pandemic has brought unprecedented challenges to the global economy, accelerating the growth of digital finance irrevocably. Besides, as digital finance plays a growing role in social safety nets and economic relief, it has been becoming a key to addressing our most pressing needs, rendering policymakers and scholars to pay more attention to the prominence of digital finance. In a word, digital finance has reshaped the financial development theory and changed the organizational model of financial institutions, gradually becoming a sharp tool for emerging market countries to solve the problem of financial exclusion.

However, a coin has two sides. After rapid development and fission, digital finance has accumulated multitudinous risks to traditional financial institutions (Buchak et al., 2018). Generally speaking, digital financial risks mainly include legal policy risk, business management risk, network technology risk, monetary policy risk, and money laundering risk (Yan, 2013). However, from the international development experience, the biggest impact of digital finance is the 'monetary policy risk', containing the problems of financial stability and monetary policy. Monetary policy risk measures a series of negative effects of digital finance on money supply and demand, as well as the monetary policy transmission mechanism, which further weakens its role in promoting the real economy and the effectiveness of macro-control. So, some formats of digital finance may attenuate, or at least slow, the impact of a monetary policy tightening (Settlements, 2008). Take digital currency as an example. Berentsen (1998) found that digital currency had the potential to replace currency in retail transactions, which aroused the alarm of central bank officials. What's more, central banks have lost control of the monetary aggregate. At the same time, the digital currency may change the foreign exchange rate, disrupt the money supply, and form a comprehensive financial crisis (Tanaka et al., 2010). Anyway, the development of digital finance will affect the money supply and demand, make the effect of monetary policy encounter many uncertainties, and directly affect the effectiveness of the monetary policy.

Moreover, given that digital financial technology is continuously developing, the uncertainty of the monetary transmission mechanism might be further heightened (Bordo & Levin, 2017). In this irreversible trend, can traditional monetary policy transmission play an indicative role in digital finance? Should emerging markets take digital finance into the framework of a new quantitative currency system? Under such conditions, it is urgent to evaluate the impact of digital finance on the ultimate goal of monetary policy and explore the effectiveness of the monetary policy. At the structural level, digital finance regards information technology as the link to realize transnational operation. In the meantime, digital finance achieves a low-cost and efficient allocation of financial elements resources in remote areas. Consequently, financial elements between regions are more closely linked, and the market integration is more thorough, making significant spatial correlation and spillover effects in the development of digital finance.

In other words, there is a certain regional agglomeration effect (Feng et al., 2020). So, will this kind of spatial interaction and linkage strengthen the impact of digital finance on monetary policy? As a comprehensive adjustment policy, will the monetary policy continue to be effective in the context of spatial interaction and interdependence of digital financial development? These are the main problems to be explored and solved in this paper. Actually, no matter in the overall level or the structural level, the foundation, mechanism, and acting path of the traditional monetary policy framework are all faced with the severe challenges brought by the rapid development of digital finance. In addition, we need to face the challenges of adjusting the core indicators and reconstructing the monetary policy framework. Therefore, this paper constructed a spatial econometric model to evaluate the effect of digital finance on the effectiveness of monetary policy and its heterogeneity. Meanwhile, it aimed to provide theoretical support and empirical evidence for emerging market countries' monetary policy to intervene in digital finance and promote the steady development of digital finance.

The main contributions of this paper are as follows. First, this paper used the total index of digital finance to explore the overall impact of digital finance on the effectiveness of the monetary policy. Compared with the research discussing the influence of digital finance on monetary policy from the perspective of digital currency, electronic payment, and P2P, the results of this paper are more general, which reveal the basic law of this influence and ensure the consistency of research caliber. Second, this paper revealed the 'spatial spillover effect' of digital finance on the effectiveness of the monetary policy. Digital finance takes the Internet as a link to break through geographical restrictions, causing the development of digital finance in various regions to interact with each other. But in existing research, it is rare to fully consider the influence of this "spatial spillover effect" on the effectiveness of the monetary policy. What's more, the spatial heterogeneity of monetary policy adjustment effects can be observed through the interaction results between digital finance and monetary policy. This is a breakthrough that can highly enrich the conclusions of the study. Third, COVID-19, the most uncertain factor, was included in the econometric model, which was also the main characteristic and contribution of this paper. The global pandemic of COVID-19 has become the most obstructing reason for economic growth.

Therefore, setting COVID-19 as the control variable will improve the interpretation ability of the model and enrich the existing research. Fourth, the applications of panel data and frontier measurement methods were also major contributions to the study. By contrast, the current research was mostly carried out with the time series data and traditional measurement methods, so the credibility of the research conclusions was supposed to be further improved. However, this paper utilized panel data, direct effect, and indirect effect decomposition method, as well as dynamic spatial measurement model to describe the research problems profoundly and obtain scientific research conclusions.

The following chapters are organized as follows. Section 2 presents the literature review; Section 3 details theoretical analysis; Section 4 describes variables and explains the empirical model; Section 5 presents our research results followed by discussions; Finally, Section 6 summarizes our research findings and suggests future research directions.

2. Literature review

With the development of the Internet, informational technologies have become universal, and their influence is felt strongly in all spheres (Tristram, 2001). Relying on Internet technology, digital finance has realized the integration with the financial industry, formed the scale of information, enhanced the availability of finance, and entered the public's view as an innovative form of traditional finance (Zavolokina et al., 2016). Digital finance was born in the USA, which can be traced back to the 1970s when the creation of NASDAQ marked the transformation of the digital financial model from conception to reality. Besides, as the first pure network bank without any branch in the world, the Security First Network Bank (SFNB) provided financial services through the Internet. Hence, information-based financial institutions have gradually evolved into the main mode of digital finance. For decades, the financial industry has experienced a continuous evolution in service delivery due to digitalization (Gomber et al., 2017). Over the last few years, technological-based financial innovations have increased significantly in most countries to simplify financial services and to improve the quality of financial activities. Meanwhile, the growing penetration level of the internet and smartphones inspired the potential of digital transformation in many aspects, including the financial sector (Santoso et al., 2019). Nowadays, the rise of Internet-based financial enterprises has had an immense impact on traditional financial institutions. Therefore, financial institutions should not only rely on IT (Internet Technology) to promote management informatization and business digitalization but take advantage of IT to vigorously innovate financial businesses and service modes (Zhu et al., 2016). Notably, even if digital financial development originated from developed countries, systematic and consistent research results have not been concluded at the academic level.

Over the past decades, the pace of digital financial transformation has been accelerating across developed and emerging markets. Major developments in digital finance have increasingly influenced a broad range of global participants, encompassing developing countries with China, India, and Kenya leading. However, there is no

axiomatic or widely accepted definition for this term. Scholars have divergent opinions on the identification of digital finance. Similar concepts used by foreign scholars were Online Alternative Finance, Internet Finance, FinTech, and other terms (Funk & Hirschman, 2014; Ross, 2002; Zetzsche et al., 2017), which were consistent with the inherent implication of digital finance. As for the formats of digital finance, Hu and Zheng (2016) concluded that digital finance has acted as a kind of technological support for the financial industry, which further gave the birth of numerous emerging digital financial products and changed its role in the industry. Products such as third-party payment, P2P loans, crowdfunding and Yu'ebao, have been facilitating digital finance to become an independent force, which rivaled the traditional financial industry and attracted considerable attention from various circles. However, judging from the types of research results, scholars paid more attention to the function of digital finance, tending to regard digital finance as an 'alternative channel' that provided a source of funding in developed and developing countries. Lyons and Hanna (2019) found that the economically vulnerable populations were less likely to be financially included, and there was a difference in digital financial levels between developing and developed countries. Therefore, as the dominating capital source for enterprises in fast-growing economies, digital finance should increase the financial services availability and financial inclusiveness by serving the most vulnerable groups (Allen, 2012; Gandja et al., 2015). Meanwhile, policymakers in developing countries should develop digital finance and payment systems to narrow the wide gap in digital finance adoption (Ozili, 2020).

In addition to discussing the practical impact of digital finance at the micro-level, the impact of digital finance at the macro level has also attracted the extensive attention of scholars. As the cornerstone of macroeconomic policy, monetary policy has naturally attracted widespread attention (Binder et al., 2017; Castells, 2017; Mishkin, 2007). Scholars began to study the impact of digital finance on monetary policy and its effectiveness. If we refined our views, it can be found that most scholars believed that digital finance would harm the effectiveness of the monetary policy. For instance, Muli (2019) declared that the development of digital finance would negatively influence money demand, and further change the monetary policy landscape in Kenya with a decrease in the overall proportion of the unbanked. This opinion was verified by Funk and Hirschman (2014) as well. In the financial innovation activities, digital finance lacked appropriate and effective supervision, resulting in negative effects on monetary policy, that is, the uncertainty of monetary policy increased (Ali et al., 2014; Plassaras, 2013). At the same time, Obinne et al. (2020) examined the impact of digital finance on money supply in Nigeria with the Auto Regressive Distributed Lag (ARDL) model. They found that digital finance had a positive impact on the money supply in Nigeria within the period under review. Moreover, most studies on developing countries have shown that as financial markets improve, people will actively participate in financial markets and respond to monetary policy shocks, and the interest rate transmission mechanism of monetary policy will be more open so that the effect of monetary policy will be strengthened (Mishra et al., 2014). Therefore, the development of digital finance will enhance the effectiveness of the monetary policy.

It is worth noting that the research was mostly carried out from the internal formats of digital finance. Most research was implemented from the perspective of electronic payment, digital currency, or P2P lending. Whereas, it was found that the opinions were significantly different, or completely opposite. Some scholars declared that the development of digital finance would weaken the effectiveness of the monetary policy. Berentsen (1998) and Durgun and Timur (2015) argued that digital currency was likely to replace the central bank's currency, and further affect the M1 money stock. While M2 and M3 money stock were less affected because central bank currency accounted for a tiny proportion of these aggregates. Especially, global digital currencies, such as Libra or the Chinese Digital Yuan, will challenge existing financial and monetary policies, with a significant impact on digital economies (Mitha et al., 2020; Scheau, 2020). Moreover, as an important type of digital finance, electronic payment also derives many formats, such as credit cards, debit cards, and ATM networks, etc. Duca and Whitesell (1995), Humphrey et al. (1996) examined the effect of credit cards on money demand, concluding that expansion of credit cards has reduced demand for money in the United States. Wasiaturrahma et al. (2019) analyzed the effect of non-cash payments on real money demand in Indonesia based on the Error Correction Model (ECM), with the conclusion that credit cards have a significant negative effect on cash circulation in the long run, while debit cards have a significant positive effect. Furthermore, as Tehranchian et al. (2012) proved in the Rinaldi model, the most important effects of expanding the use of electronic money will be manifested on the money supply, money demand, monetary policy, and central bank. This change is quite important. For one thing, fluctuations in the money market will cause fluctuations in other macro markets. For another thing, considering the money demand reduction under circumstances similar to Keynes's liquidity trap, the influence of monetary policy will be questioned. In addition, the empirical evidence from developed countries held that the improvement of financial markets provided better conditions for smoothing monetary policy shocks in sectors such as businesses and households, and monetary policy effectiveness will therefore be weakened (Mishra & Montiel, 2013). Al-Laham et al. (2009), Tule and Oduh (2016) agreed that the increase in the proportion of electronic money would directly affect the accuracy of monetary statistics and the effectiveness of the monetary policy. Besides, the emergence of a decentralized P2P platform, which matches lending and borrowing without collateral requirement, has weakened the bank lending and balance sheet channels of monetary policy, calling monetary policy effectiveness into question (Wong & Eng, 2020).

Some scholars claimed that digital financial development seldom adversely affected the effectiveness of the monetary policy, such as Snellman et al. (2001) and Rahman (2018). However, digital finance may have positive effects on the effectiveness of monetary policy as well. At present, digital finance is increasingly implemented in many countries as a means of preventing fraud and fostering economic growth (Igoni et al., 2020). As claimed by Bordo and Levin (2017), digital currency can be an instrument for promoting monetary policy. Meanwhile, Ely (1996), Woodford (2001) explored whether digital currency threatened central banks. They believed that monetary policy remained effective even if digital currency completely replaced the local

currency. Besides, Meaning et al. (2018) also believed that the monetary policy can operate better in terms of price and volume through digital currency transactions, which has also strengthened the policy instruments. Nowadays, central banks around the world are exploring, in some cases, even piloting Central Bank Digital Currencies (CBDCs) that promise to realize a broad range of new capabilities, including direct government disbursements to citizens, frictionless consumer payment and money-transfer systems, and a range of new financial instruments and monetary policy levers (Allen et al., 2020). Based on the reality that many central banks have been considering the issuance of digital currency, Keister and Sanches (2019) have built a coexistent model about digital currency and cash of central banks, believing that digital currency enhanced the flexibility and social welfare effect of monetary policy. But it should be noted that the optimal inflation rate is strictly positive when cash and digital currency of central banks are at the highest ratio. Moreover, Hasan et al. (2020) demonstrated that, on the basis of the Interacted Panel VAR model, FinTech adoption generally enhanced monetary policy transmission to real GDP, bank loans, and housing prices.

Researches on digital finance and the effectiveness of monetary policy have laid a solid theoretical foundation for this study. To make it more explicit, this paper potted a table with brief presentations about these researches. Details are manifested in Table 1. However, there are also the following problems. First, the impacts of digital

Table 1. The key research on digital finance.

Authors	Methodology	Conclusion	Type
Snellman et al. (2001)	OLS and learning curve analysis	The expansion of electronic payment creates a lowering effect on the demand for money.	Electronic payment
Tehranchian et al. (2012)	The Rinaldi Model	The influence of monetary policy will be questioned.	Electronic money
Wong and Eng (2020)	New Keynesian Model	P2P calls monetary policy effectiveness into question.	P2P
Muli (2019)	Friedman's Quantity Demand Theory and Keynes Model	Digital finance negatively influenced money demand.	Digital finance
Wasiaturrahma et al. (2019)	The Error Correction Model (ECM)	Credit cards have a significant negative effect on cash circulation in the long run, while debit cards have a significant positive effect.	Credit cards and debit cards
Obinne et al. (2020)	The ARDL Model	Digital finance had a positive impact on the money supply in Nigeria.	Digital finance
Hasan et al. (2020)	The Interacted Panel VAR model	FinTech adoption generally enhanced monetary policy transmission to real GDP, bank loans, and housing prices.	FinTech

Source: summarized from the above literature.

finance on the effectiveness of monetary policy were mostly discussed from the perspective of digital currency, electronic payment, P2P, and other digital financial types. Digital finance is a pedigree concept, and little research explores the impact of digital finance on the effectiveness of monetary policy from an overall perspective. Second, the existing studies have no consideration for the 'spatial spillover effect' of digital financial development. Digital finance strengthens financial links among different regions with the Internet. Therefore, when constructing the econometric model, it is quite important to take the 'spatial spillover effect' into consideration, otherwise, conclusions may be unreliable. Third, the global pandemic of COVID-19 has caused the external environment of global economic development to face many external uncertainties, as well as the transmission process and mechanism of monetary policy. It can be seen that if we ignore the influence of COVID-19, the empirical model may be unfair. Fourth, according to the monetary and financial theory, the development of digital finance has a significant time-lag effect on the transmission mechanism of monetary policy. Therefore, a dynamic model is demanding to be established to reveal this effect. Finally, in terms of data and methods, most of the existing studies focus on time series, but the use of panel data is much rare. Besides, the frontier spatial measurement method is seldom used. These research gaps are the starting points and the main theoretical contributions of this article.

3. Theoretical analysis

The development of digital finance has revolutionized existing business models. In 1999, Friedman pointed out that the central bank would become a signaled army without any active regulatory intervention to prevent digital financial development (Woodford, 2001). This showed the impact of digital financial development on the status of central banks, as well as their ability to regulate the economy, which may directly affect the effectiveness of the monetary policy. Therefore, we are supposed to explore and comprehend the impact of digital financial development on the effectiveness of monetary policy from the transmission mechanism. Generally speaking, emerging market countries often consider the money supply as an intermediate target for monetary policy. According to the money supply formula, money supply (M_s) can generally be regarded as the product of money multiplier (m) and the base currency (B) (Mishkin, 2007). That is, $M_s = m \times B$. After transformation, the money multiplier can be expressed as:

$$m = \frac{M_s}{B} \tag{1}$$

In general, the money supply has generalized and narrow meanings. The narrow money supply (M_s^N) is the sum of cash in circulation and demand deposits. If we regard C as the cash in circulation, D as the demand deposit, S as the time deposit (Banking), then M_s^N can be represented as $M_s^N = C + D$, and generalized money supply (M_s^G) can be expressed as $M_s^G = C + D + S$. In addition, the base currency is the sum of the cash in circulation (C) and the reserve (R) deposited by commercial banks in the central bank account, and the reserve can be divided into statutory deposit

reserve (R_L) and excess deposit reserve (R_E) (Mishkin, 2007). Hence, the base currency can be further expressed as $B = C + R_L + R_E$, then equation (1) can be transformed into equation (2) and equation (3).

$$m_S^N = \frac{M_S^N}{B} = \frac{C+D}{C+R_L+R_E} = \frac{1+c}{c+(r_L+r_E)\times(1+s)} \tag{2}$$

$$m_S^G = \frac{M_S^G}{B} = \frac{C+D+S}{C+R_L+R_E} = \frac{1+c+s}{c+(r_L+r_E)\times(1+s)} \tag{3}$$

In equation (2) and equation (3), c, r_L, r_E and s represent the currency leakage ratio, the required reserve ratio, the excess reserve ratio, and the time deposit(Banking) ratio, respectively. The money multiplier will bear the brunt of the development of digital finance. To be specific, the development of e-commerce has become increasingly frequent under the guidance of digital finance, and payment methods have gradually shifted from traditional cash payments to electronic ones. Besides, c keeps getting smaller. Due to the development of digital finance, the entry threshold for money market funds has fallen sharply, so people's financial concepts have been effectively improved in emerging market countries, which will lead to the decline of D and increase of s. Actually, emerging market countries could make full use of digital finance to accelerate the process of interest rate liberalization, reduce social financing costs, and eliminate information asymmetry. As a consequence, r_L can be seen as a constant in the short term, and r_E will drop as well. Take partial derivatives of c, r_E and s in equation (2) respectively, then we can obtain the following equations.

$$\frac{\partial m_S^N}{\partial c} = \frac{(r_L+r_E)\times(1+s)-1}{\left[c+(r_L+r_E)\times(1+s)\right]^2} \tag{4}$$

$$\frac{\partial m_S^N}{\partial r_E} = -\frac{(1+c)\times(1+s)}{\left[c+(r_L+r_E)\times(1+s)\right]^2} \tag{5}$$

$$\frac{\partial m_S^N}{\partial s} = -\frac{(1+c)\times(r_L+r_E)}{\left[c+(r_L+r_E)\times(1+s)\right]^2} \tag{6}$$

Correspondingly, if we take partial derivatives of c, r_E, s in equation (3) separately, then we can get the following equations.

$$\frac{\partial m_S^G}{\partial c} = \frac{(r_L+r_E-1)\times(1+s)}{\left[c+(r_L+r_E)\times(1+s)\right]^2} \tag{7}$$

$$\frac{\partial m_S^G}{\partial r_E} = -\frac{(1+s+c)\times(1+s)}{\left[c+(r_L+r_E)\times(1+s)\right]^2} \tag{8}$$

Table 2. The variation of m_S^N and m_S^G.

Narrow money multiplier (m_S^N)	Generalized money multiplier (m_S^G)
$\partial m_S^N/\partial c$, uncertain	$\partial m_S^G/\partial c < 0$
$\partial m_S^N/\partial r_E < 0$	$\partial m_S^G/\partial r_E < 0$
$\partial m_S^N/\partial s < 0$	$\partial m_S^G/\partial s > 0$

Source: Author's calculation and analysis.

$$\frac{\partial m_S^G}{\partial s} = \frac{c \times [1 - (r_L + r_E)]}{[c + (r_L + r_E) \times (1 + s)]^2} \tag{9}$$

From equation (4) to equation (6), it can be seen that inconsistency exists in the impact of digital financial development on the m_S^N. The impact of c on m_S^N is uncertain, primarily depending on $r_L + r_E$ and s. Whereas, the effect of r_E on m_S^N is negative, hence, the bigger r_E is, the smaller m_S^N will be. There also exists a negative correlation relationship between s and m_S^N. Therefore, on the whole, the uncertain influence of digital financial development on m_S^N will affect the measurability, controllability, and relevance of M_S^N, further influencing the effectiveness of monetary policy regulation. According to equation (7) to equation (9), digital financial development will enlarge m_S^G, and there is a negative relationship among c, r_E and m_S^G, but s is positively related to m_S^G (Table 2).

Comprehensively, the impact of digital financial development on m_S^G is uncertain. However, digital financial development can increase m_S^N, which further makes money supply produce the 'expansion effect'. In fact, from whichever aspect, digital financial development will influence the effectiveness of monetary policy and affect the control ability of the central bank. Since digital financial development will affect the intermediate target of monetary policy, does this mean that monetary policy will be invalid with the development of digital finance? Based on the conclusions of theoretical analysis, this paper will establish an econometric model to empirically describe the impact of digital financial development on the effectiveness of the monetary policy.

4. Variable description and empirical model

4.1. Research objects and variable description

4.1.1. Research objects

The development of digital finance in emerging market countries has shown an exponential growth trend. So, it is a frontier topic to study the impact of digital finance on the effectiveness of monetary policy in emerging market countries where are rarely noticed in the existing research (Glocker & Piribauer, 2021). But the real dilemma is quite considerable, obstructing the process of research implementation. One of the most important reasons is the unavailability of digital financial data. Therefore, this paper only selected the representative countries as the research object, instead of

covering all the emerging market countries. Among them, we noticed that China was a quite suitable research object. The specific reasons are as follows:

First, although digital finance did not originate in China, China's achievements were most remarkable. Specifically, according to KPMG, digital financial services (mainly loans) have increased from 4.05 billion dollars to 12.21 billion dollars by 2014, which had reached 57.9 billion dollars by the first half of 2018, and China accounted for a quarter. What's more, China has obtained predominant achievements in digital finance, which is outstanding among emerging market countries.

Second, digital finance is still a newly sprouted thing for emerging market countries, so relevant statistical data cannot be obtained yet. In this regard, China has compiled a detailed digital financial development index, providing great convenience for research. Therefore, this paper mainly focused on China and revealed the impact of digital financial development on the effectiveness of the monetary policy.

4.1.2. Dependent variable

The dependent variable is economic growth (*EG*), expressed by GDP. According to the theory of monetary policy transmission mechanism, monetary policy influences the ultimate targets through intermediate ones. An essential step to unveil the impact of digital finance on the effectiveness of monetary policy is to analyze the effect of the interaction between digital financial development and intermediate targets on the ultimate targets. There was a wide agreement about the major goals of economic policy, namely high employment, stable prices, and rapid growth (Friedman, 1968). In emerging market countries, the welfare implied in these indicators is consistent, whereas the means to achieve the targets may be unavailable (Salvary, 2006). Therefore, economic growth is generally taken to be the ultimate target of monetary policy by most developing countries. According to Mathai (2009) and Chicheke (2009), most economists agreed that prices and wages would not make the corresponding adjustment immediately. That's why changes in the money supply can affect the actual production of goods and services, and monetary policy should serve to accommodate increases in real output. At last, The Law of the People's Bank of China, the benchmark law of the People's Bank of China for formulating monetary policy, stipulates in Article 3 that 'the objective of monetary policy is to maintain the stability of the value of money and thus promote economic growth'. Therefore, choosing economic growth as the ultimate goal of monetary policy has not only a theoretical basis but legal support, which is consistent with reality.

4.1.3. Core independent variables

Digital finance development (*DF*). Constant innovations in finance and technology and different levels of their development worldwide necessitate investigating universal integrated indexes (Pakhnenko et al., 2021). In this paper, the development level of digital finance is represented by complied digital financial development index. It's noteworthy that the index not only covers the total index of digital finance (*DF*) but also includes two structural indicators, namely the coverage index of digital finance (*CDF*) and the use depth index of digital finance (*UDF*). *CDF* was measured by transaction penetration rate, while *UDF* was appraised by the per capita transaction

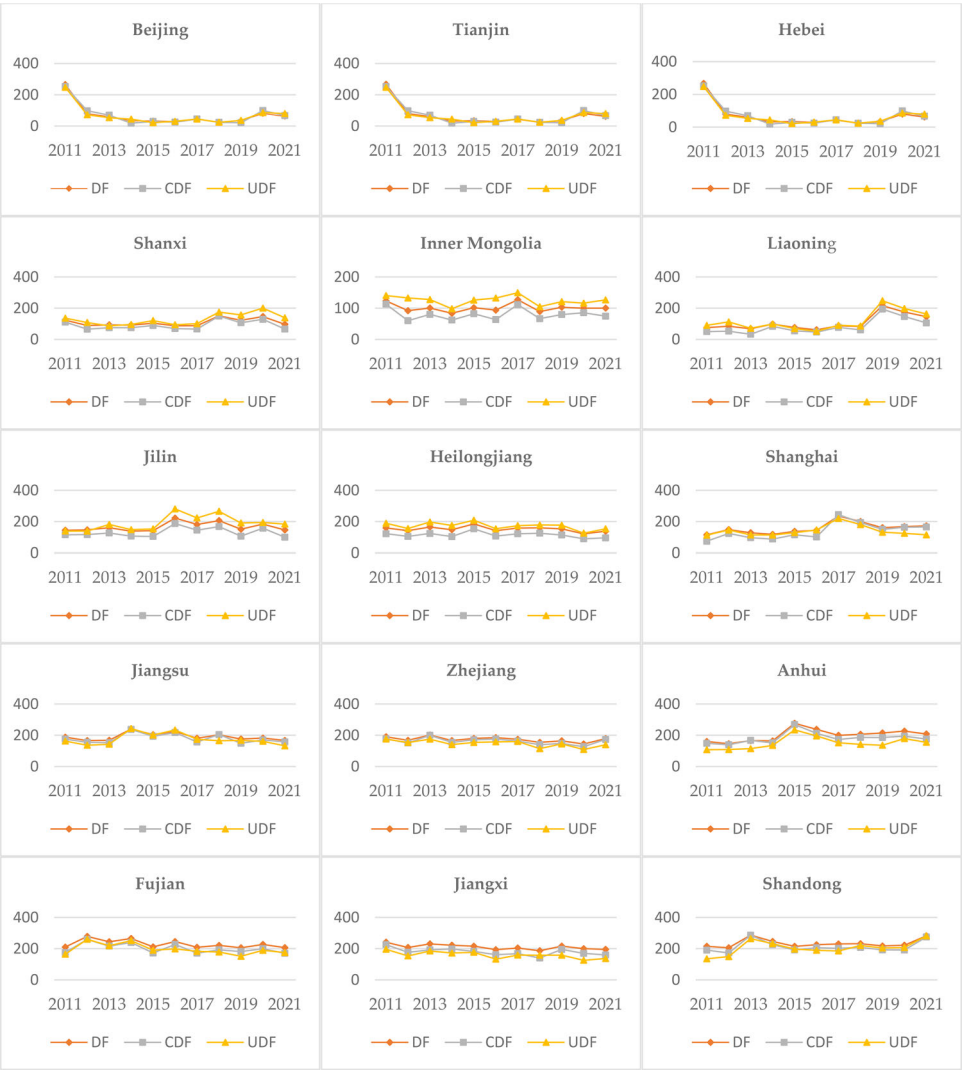

Figure 1. Evolution trend of China's digital finance indexes.
Source: Author's processing in Excel based on the data from the Digital Finance Research Center of Peking University.

amount and the per capita deal count. In terms of weight setting, this paper set the weights of the transaction penetration rate, the per capita transaction amount, and the per capita transaction number to 50%, 25%, and 25%, respectively. By weighting these structural indicators, we can get the total index of digital finance (*DF*), which were shown in Figure 1. It can be seen that the digital financial indexes of 31 provinces in mainland China showed a steady upward trend during the sample period. At the same time, *CDF* and *UDF* keep consistent with the overall index. Hence, we can gain an insight into the overall achievements of China's digital finance development.

Monetary policy (*MP*). The monetary policy mainly affects the overall target through an intermediary target, so monetary policy is supposed to be quantified from the intermediary target level. From the perspective of China's monetary policy

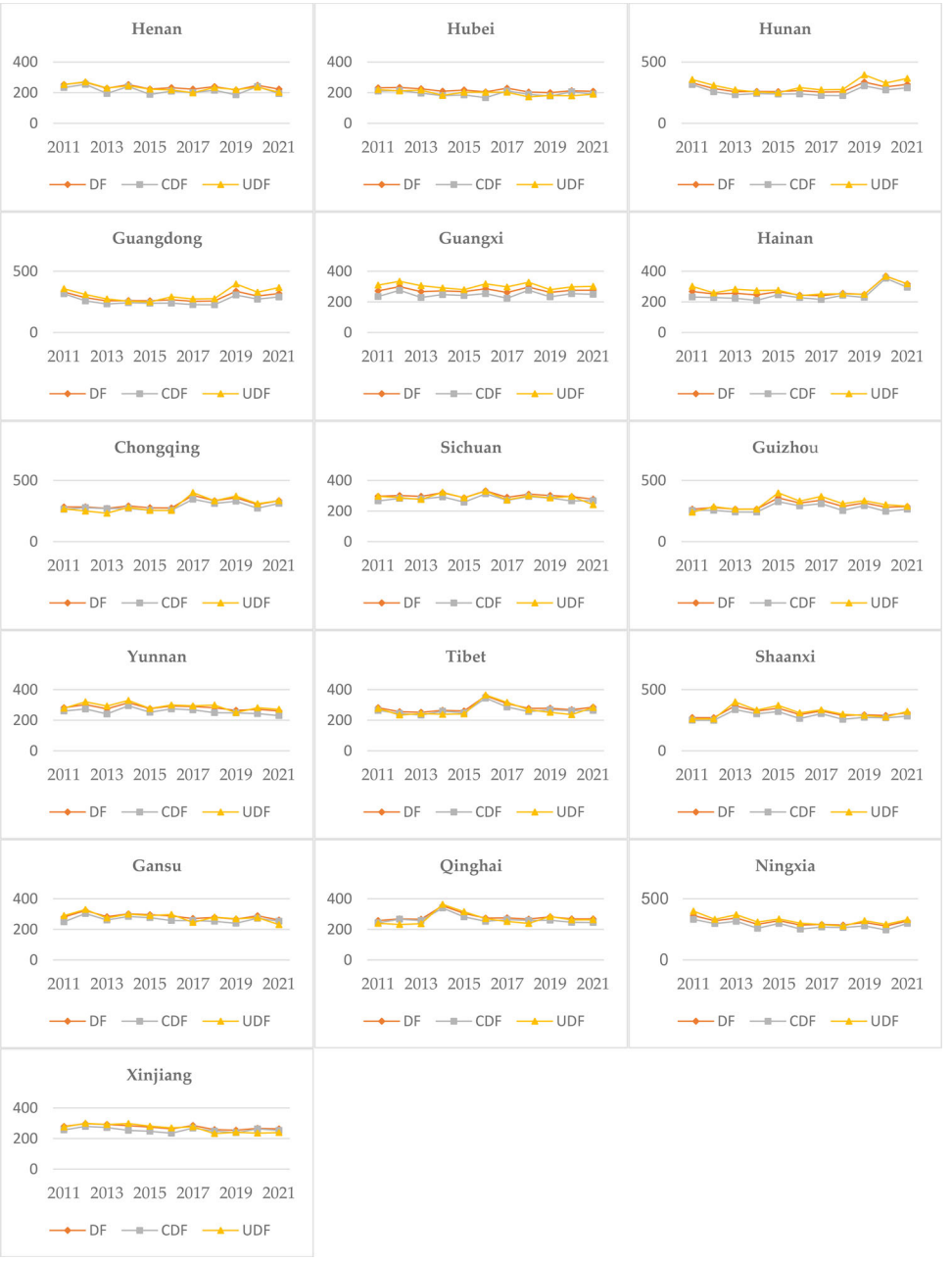

Figure 1. Contined.

operation, the money supply has long been selected as the intermediary target of monetary policy (Yin et al., 2020). However, the money supply data was mainly published from a macro perspective, this study aimed to use the provincial panel data of China. To this end, this study adopted a credit scale to substitute the money supply. The relationship between bank credit and the ultimate goal is similar to that between

money supply and ultimate goal. Generally speaking, the broad money supply includes cash and deposits, reflecting the liabilities of the banking system, and loans represent the assets of the banking system. If other assets and liabilities of a bank remain the same, then the increment of the loan equals the sum of the increase in cash and deposits. Therefore, taking money supply as an intermediary target and 'credit scale' as an incremental target are two sides of the same medal. Given the international experience, Britain, Japan, France, South Korea, India, and Indonesia all utilized 'credit scale' as an intermediary target. Besides, the United States employed the scale of bank credit as the intermediary target of monetary policy before the 1970s (McCallum, 1993). Therefore, it is reasonable to take the RMB loan balance of financial institutions as a quantitative indicator of monetary policy in this paper.

4.1.4. Control variables (*CV*)

Many other factors can influence the ultimate target of monetary policy besides the core variables. Therefore, it is necessary to select control variables to enhance the explanatory ability of the model.

First, in the traditional economic growth theory, consumption level (*CL*), fixed capital formation level (*FC*) and export level (*EL*) have the most significant impact on economic growth. When it comes to the consumption level, Carrier and Heyman (1997) believed that the economic growth driven by China and other emerging economies promoted the growth of consumer demand. As one of the troikas driving economic growth, consumption can promote economic growth. So, this paper used the total consumption of residents to quantify the consumption level. Fixed capital formation level refers to the proportion of present income that is saved and invested to augment future output and income. Generally speaking, fixed capital formation determined the national capacity to produce, which in turn affected economic growth (Bakare, 2011; Topcu et al., 2020). Meanwhile, economic theories have shown that fixed capital formation plays a crucial role in the models of economic growth. Thus, the total amount of fixed capital formation is used to measure the fixed capital formation level. Besides, the relationship between exports and economic growth has been extensively discussed in the literature. There are many reasons in trade theory to support export-led growth. For example, export growth can increase demand for a country's output, promote specialization, and allow general skill levels to increase real output (Giles & Williams, 2000). Thereby, the export level is expressed as net exports of goods and services in this article.

Second, fiscal policy (*FP*) is also a control variable that needs special attention. Nowadays, the role of public investment is emerging as a major policy issue for governments around the world. Whereas most developing countries are in the stage of market economy transformation, so the economic growth of emerging market countries mainly depends on the fiscal policy to allocate resources and achieve economic growth. In other words, the impact of fiscal policy, including the role of government capital, on long-term economic growth is an important policy issue (DeLong et al., 2012; Turnovsky, 1997). Thus, we utilize the general budget expenditure of local finance to measure the fiscal policy.

At last, as we all know, the COVID-19 has become a global issue. The COVID-19 outbreak has paralyzed major economies with both demand and supply shocks, on

Table 3. The measurement of variables.

Type	Variables		Measurement
Dependent variable	Economic growth (EG)		Gross domestic product (GDP)
Core independent variable	Digital finance (DF)	Digital finance (DF)	Complied digital financial development index
		Coverage index of digital finance (CDF)	The transaction penetration rate
		Use depth index of digital finance	The per capita transaction amount
		UDF	The per capita deal count
	Monetary policy (MP)		The RMB loan balance of financial institutions
	Consumption level (CL)		The total consumption of residents
	Fixed capital formation level (FC)		The total amount of fixed capital formation
Control variable	Export level (EL)		Net exports of goods and services
	Fiscal policy (FP)		The general budget expenditure of local finance
	COVID-19		Before 2019 (include 2019), 0. Otherwise, 1

Source: Summarized from 4.1.

the whole, the world economy has been almost at the standstill (Açikgöz & Günay, 2020; Mirza et al., 2020; Rizvi et al., 2020; Stiglitz, 2020). In this context, it's necessary to take the influence of the global pandemic into account when considering the control variables. Therefore, this paper sets the impact of COVID-19 on economic growth as a dummy variable. Specifically, the years before 2019 (include 2019) are set as '0' while other years are assigned as '1', then introduce them into the regression model to observe the impacts on economic growth. The measurement of all variables is shown in Table 3.

4.2. Data source

This paper selected the data of 31 provinces in mainland China from 2011 to 2020. Digital finance index (*DF*), coverage index of digital finance (*CDF*), and use depth index of digital finance (*UDF*) are derived from the index report compiled by the Digital Finance Research Center of Peking University. The raw data in index compilation came from the public data of representative digital financial companies or third-party organizations, such as Ant Group, Tongbanjie Financial Technology Group, Mi-me.com, the People's Bank of China (PBOC), and the Zero-One Finance. Besides, the data of consumption level (*CL*), fixed capital formation level (*FC*), export level (*EL*), and fiscal policy (*FP*) were from the National Bureau of Statistics of China and the CEIC China Economic Database. In particular, it is worth mentioning that the data of digital financial index and the national statistical database of China are respectively updated to 2018, so the data of 2019 is calculated from the average of 2017 and 2018, while the data of 2020 is replaced by the mean of 2018 and 2019. In the end, the summary statistics of variables is shown in Table 4.

Table 4. The summary statistics of variables.

Variables		Mean	Std.Dev.	Min	Max	Observations
EG	overall	23877.760	20358.370	611.500	1.08e + 05	310
	between		19401.650	1152.390	80119.940	31
	within		7000.202	−3169.373	51744.720	10
DF	overall	207.665	87.299	16.220	377.730	310
	between		24.066	175.164	269.199	31
	within		84.017	18.655	316.195	10
CDF	overall	186.924	26.958	147.242	259.433	310
	between		80.849	29.892	288.112	31
	within		26.958	147.242	259.433	10
UDF	overall	203.998	81.219	23.537	291.882	310
	between		89.190	6.760	400.400	31
	within		34.964	153.374	291.995	10
MP	overall	31409.160	82.268	−1.757	312.403	310
	between		26377.850	405.050	145169	31
	within		10493.210	−1.40e + 04	72573.170	10
CL	overall	8491.699	7036.197	142.700	34097.100	310
	between		6738.755	276.354	28761.210	31
	within		8632.642	542.600	39657.500	10
FC	overall	12876.350	8414.599	1066.164	33110.740	310
	between		4602.961	4892.891	23037.720	31
	within		2404.023	2209.888	20863.790	10
EL	overall	−774.446	4713.683	−9973.600	47744	310
	between		3482.889	−8554.330	10440.320	31
	within		3231.347	−1.23e + 04	36529.230	10
FP	overall	4905.492	2782.281	705.910	17297.850	310
	between		2438.998	1154.504	12251.590	31
	within		1402.013	−633.701	9951.748	10
COVID-19	overall	0.8	0.400	0	1	310
	between		0	0.8	0.8	31
	within		0.400	0	1	10

Source: Authors' processing in Stata16.

4.3. Empirical model and estimation method

This paper selected economic growth as the ultimate goal and aimed to reveal the impact of digital finance on the effectiveness of monetary policy by constructing the interaction and evaluating its impact on economic growth. Therefore, the empirical test model in this paper is as follows.

$$EG_{it} = \alpha_0 + \alpha_1 DF_{it} + \alpha_2 (MP_{it} \times DF_{it}) + \alpha_3 CV_{it} + \nu_i + \tau_{it} \tag{10}$$

In equation (10), i, t, EG, MP, DF, and CV mean regions, time, economic growth, monetary policy, digital finance, and control variables, respectively. $MP \times DF$ is the core explanatory variable that represents the interaction term between monetary policy and digital finance. In addition, α_2 is a parameter to be estimated. If $\alpha_2 > 0$, then the development of digital finance has a positive impact on the effectiveness of the monetary policy. In other words, digital financial development can promote economic growth and enhance the effectiveness of monetary policy. On the contrary, $\alpha_2 < 0$ signifies that digital financial development has a negative influence on the effectiveness of the monetary policy, indicating that digital financial development will retrench economic growth. That is to say, monetary policy is a failure.

In general, economic growth will produce spatial spillover effects (Nsiah et al., 2016). Therefore, these 'spatial spillover effects' of regional economic interaction must

be taken into consideration when revealing the impact of digital finance on monetary policy effectiveness. To this end, it's obliged to employ spatial econometrics tools to give specific solutions. According to the research of Anselin et al. (2008), model (10) violates the Gauss Markov hypothesis and ignores the problems of spatial heterogeneity and dependence. Hence, it's necessary to construct a spatial weight matrix that specifies 'neighborhood sets' for each observation to characterize the spatial structure among cross-section individuals. Based on this, a $N \times N$ positive weight matrix W is constructed and introduced into model (10). Therefore, $W \times EG$, the interaction of the spatial weight matrix and the economic growth, can explain the spatial effects of economic growth. Further, equation (10) can be rewritten as equation (11).

$$EG_{it} = \alpha_0 + \alpha_1 DF_{it} + \alpha_2 (MP_{it} \times DF_{it}) + \alpha_3 CV_{it} + \alpha_4 (W \times EG_{it}) + \nu_i + \tau_{it} \tag{11}$$

Scholars have made many useful attempts on the method of setting spatial weight, mainly based on the Euclidean distance method, the geographic distance method, and the spatial adjacency matrix method (Anselin, 2002). However, due to the imbalance of regional economic development and divergent population density, the Euclidean distance method and geographic distance method are not prevailingly used in the specific analysis. Therefore, this paper drew lessons from Anselin (2002) and employed the spatial adjacency matrix method, the foremost method used in spatial measurement, to introduce spatial matrices. More details can be seen in formula (12).

$$W_{ij} = \begin{cases} 1, & if\ i\ is\ adjacent\ to\ j \\ 0, & otherwise \end{cases} \tag{12}$$

Equation (11) only reflects the spatial effect of the dependent variable, but it doesn't work on other variables. Although the Spatial Dubin Model (SDM) reveals the spatial effects of all variables, the results are erratic as the number of variables increases. In practice, many empirical studies employed the 'point estimation' method to test the spatial spillover effect of spatial regression models but leading to erroneous conclusions with biases (Pace et al., 2011). Therefore, to guarantee the validity of the empirical results, frontier econometric theory employs the partial derivative to decompose the direct effect and indirect effect (Lee & Yu, 2010). Generally, the direct effect measures the impact of independent variables on dependent variables, while the indirect effect reflects the influence of independent variables on the neighbor regions' dependent ones. Through the decomposition, the spatial difference characteristics of monetary policy can be revealed under the influence of digital finance.

Besides, according to the basic comprehension of economic growth theory, economic growth and the intermediate targets of monetary policy are often affected by the economic growth in the previous period, that is, there is a prominent 'path dependence' feature. Therefore, equation (11) can be further rewritten into a dynamic spatial model to reflect the dynamic characteristics of economic growth and enhance the robustness of the model. To this end, the lag item of economic growth ($EG_{i,t-1}$) is introduced in equation (13).

$$EG_{it} = \alpha_0 + \beta EG_{i,t-1} + \alpha_1 DF_{it} + \alpha_2 (MP_{it} \times DF_{it}) + \alpha_3 CV_{it} + \alpha_4 (W \times EG_{it}) + \nu_i + \tau_{it} \quad (13)$$

5. Results and discussion

In this section, this paper mainly revealed the spatial impact of digital financial development on the effectiveness of monetary policy from both static and dynamic perspectives. In summary, the static spatial panel model includes two parts. The one is the overall estimation results of digital financial development, which reveals the overall effect of digital finance on the effectiveness of the monetary policy. The other one is the estimation results after introducing the COVID-19 and the digital financial structure index, attempting to test the heterogeneity of the impact. On this basis, through the decomposition of direct effect and indirect effect, we can further observe the provincial differences in spatial effects of digital finance on the effectiveness of monetary policy to enrich research findings and conclusions. Furthermore, the dynamic panel model enhances the unbiasedness, robustness, and scientificity of testing results based on the static spatial panel. Therefore, the spatial impact of digital financial development on the effectiveness of monetary policy can be comprehensively reflected through the combination of static and dynamic spatial panel models.

5.1. Estimation results of the static spatial panel model

5.1.1. Overall estimation results

At the overall level, the impacts of digital finance and its interaction with the monetary policy on economic growth indeed reflected the impact of digital finance on the effectiveness of the monetary policy. As plenty of variables were involved in the model, this study employed the stepwise regression method in estimation to gradually introduce control variables. In Table 5, model (1) is the benchmark model, and with the introduction of control variables step by step, estimation results are namely presented from model (2) to model (5). By comparison, it is found that the influence direction of variables in each model remains unchanged, i.e., there is no multicollinearity among variables. Model (5) shows the results that have introduced all variables, from which we can know that R^2 reaches the maximum, meaning the model has enhanced its explanatory power. Also, the variable of $W \times EG$ has passed the test at the significance level of 1%, indicating that establishing a spatial lag autoregressive model is appropriate.

In terms of core variables, the effect of digital financial development (*DF*) on economic growth is significantly negative at the significance level of 1%, implying that digital financial development within the sample interval has produced adverse effects on economic growth in China. It can be explained by the following three aspects.

First, the attendant security challenges accompanied by the increase in digital financial demand have attenuated the potential benefits of digital finance (Igoni et al., 2020). In China, P2P online lending is a typical example that confirms this view. During the peak period of 2017, the number of P2P online lending platforms is over 5000. Meanwhile, the balance of online loans was close to 1 trillion yuan that May,

Table 5. Estimated results of the spatial autoregressive model.

	Model				
Variables	(1)	(2)	(3)	(4)	(5)
Constant	10154.95	2873.862	−3162.782	−3117.015	−3062.806
	(4.23) ***	(1.75) *	(-2.36) **	(-2.31) **	(-2.41) **
DF	−17.664	−27.942	−35.082	−35.339	−35.636
	(-4.51) ***	(-8.13) ***	(-11.72) ***	(-11.79) ***	(-12.93) ***
DF × MP	0.001	0.001	0.001	0.001	0.0005
	(29.90) ***	(11.25) ***	(16.86) ***	(16.89) ***	(10.86) ***
CL		1.118	0.661	0.662	0.629
		(16.55) ***	(7.12) ***	(7.15) ***	(7.57) ***
FC			0.783	0.771	0.453
			(10.92) ***	(10.62) ***	(5.98) ***
EL				−0.029	−0.069
				(-1.00)	(-2.56) ***
FP					1.817
					(8.51) ***
W × EG	0.345	0.456	0.535	0.539	0.420
	(5.93) ***	(9.06) ***	(12.23) ***	(12.31) ***	(9.77) ***
R^2	0.721	0.920	0.946	0.945	0.959
Observations	310	310	310	310	310

Note: ***, ** and * represent the significance levels of 1%, 5%, and 10%, respectively.
Source: Authors' processing in Stata16.

and the transaction amount reached 248.8 billion yuan. However, by mid-November 2020, it returned to zero, which not only harmed the stability of China's financial system but offset its promoting dividend on economic growth.

Second, the conclusion implied the deviation that digital finance served for the real economy. The birth of digital finance is highly related to the financial repression for the real economy in emerging market countries. The core of digital finance is to provide strong financial support for the real economy. Whereas digital finance is mainly invested in the money market, capital market, bond market, foreign exchange market, and other virtual economic fields, failing to achieve the expected goal of reducing the corporate financing costs.

Third, the lack of digital financial education may lead to this conclusion. Services provided by financial intermediaries are essential for technological innovation and economic development, so financial education should be attached to great importance to making consumers stay attuned to changes in their financial needs and circumstances (Gretta, 2017). However, most demand subjects of digital finance in China are farmers and low-income groups whose financial literacy is generally low, which will ultimately influence the effect of digital finance in promoting economic growth. Of course, this is also a thorny problem faced by emerging market countries, needing extensive concern.

However, does the conclusion mean the monetary policy transmission mechanism a failure? Obviously, this conclusion is untenable, therefore, we must supplement it with more evidence. Further, the estimation results indicated that the interaction between digital finance and monetary policy ($DF \times MP$) had a significantly positive influence on economic growth. That is to say, whether digital finance can have a positive impact on economic growth is relevant to the moderating effect of monetary policy. In fact, using monetary policy to intervene in digital financial institutions has become an important part of China's monetary policy operation. Specifically, in terms

of digital financial payment institutions, as early as 2017, the People's Bank of China has stipulated that payment institutions should deposit the clients' reserves with a certain proportion to the special deposit account of the designated institutions. It can be seen from the test results that this policy operation effect is quite significant. In other words, monetary policy can still achieve the goal of promoting the economy when encountered with the shock of digital finance.

Digital financial services, armed with effective oversight supervision capability, were competent to expand the economies of scale and remained essential in closing the gap of financial inclusion (Igoni et al., 2020). Whereas, it is only a short-term decision to introduce digital finance into the quantitative framework of monetary policy. In the long run, price-based monetary policy tools are the better choice. Why? Woodford (2001) believed that economic growth and its stability were only related to the central bank's ability to control short-term nominal interest rates, especially through the 'channel' system to enforce policies. Therefore, emerging market countries should not only use monetary policy to intervene in the development of digital finance but promote the process of interest rate marketization in the long term, realizing the transformation of quantitative monetary policy tools to price monetary policy tools.

From the perspective of control variables, the fixed capital formation level (*FC*), consumption level (*CL*), and fiscal policy (*FP*) all have significant positive impacts on economic growth. Specifically, fixed capital formation plays an extremely important role in determining the development of industrial structure, which has become an important driving force to promote economic growth (Wang et al., 2020). At present, China has entered a new stage of high-quality development. Thus, the economic structure has gradually shifted to expanding domestic demand, indicating that household consumption will become a crucial driving force for economic growth (Tian et al., 2016). Moreover, fiscal policy has opposite effects on income inequality in the short and long term. Generally, appropriate fiscal redistribution can achieve balanced and sustainable growth by reducing net income inequality (Cevik & Correa-Caro, 2020). Meanwhile, it should be noted that monetary policy and fiscal policy are both important components of the national macro-control framework, but their focuses are quite different. The monetary policy emphasizes the 'demand', while fiscal policy pays more attention to the 'supply'. Therefore, to some extent, the empirical results support the achievements of China's supply-side structural reform.

In particular, the impact of China's net exports on economic growth is negative and passes the test at the significance level of 1%. Due to the remarkable changes in the trade environment, the trade surplus space of China has been largely squeezed, leading the trading account imbalanced. From the perspective of China's development reality, this is mainly a structural contradiction. According to the data of the State Administration of foreign exchange of China, in the fourth quarter of 2019, China's service trade deficit was 59.7 billion dollars, and its initial revenue deficit was 25.7 billion dollars. Besides, other accounts are in surplus. The service trade deficit and the first income deficit may be the main reasons for the negative effect of net export. Apparently, this has affected the export-oriented economic development that China has been pursuing for a long time.

5.1.2. Introduction of COVID-19 and heterogeneity estimation

The pandemic of COVID-19 has negatively affected the global economy. Labor costs, economic costs, as well as financial costs have been increasing dramatically, which will have huge impacts on all countries, especially for the developing emerging market countries (Arner et al., 2020; Baber, 2020). Globally, as of 4:52pm CEST, 9 June 2021, there have been 173,674,509 confirmed cases of COVID-19, including 3,744,408 deaths, reported to WHO (the World Health Organization). From the perspective of actual development and future evolution trend, the impact of COVID-19 is profound and will last for a long time. Nowadays, the prevention of COVID-19 has been implemented for more than one year. For example, central banks in various countries have taken a series of measures to deal with it. It can be seen from Table 6 that in emerging market countries, China and Russia have released liquidity through monetary policy. Thereinto, China invested more than 240 billion dollars to increase liquidity, reflecting China's determination of reviving its economy. Hence, this paper took China as a sample to analyze the effectiveness of monetary policy was quite representative. The use of monetary policy helped the economy return to the normal level, and further stimulates economic growth. Therefore, it is supposed to consider the prevalence of COVID-19 under the influence of monetary policy.

The outbreak of COVID-19 is likely to be a catalyst to propel faster adoption of activities relying on digital financial services (Arner et al., 2020). Through all kinds of digital means, digital finance offers the convenience of acquiring resources quickly and efficiently to the stakeholders. In general, digital finance has played an important role in alleviating the impact of COVID-19 on the economy. Meanwhile, COVID-19 has also exerted an influence on emerging market economies, promoting the development of digital finance to the fast track. Thus, from this point of view, it's reasonable to take COVID-19 into account when revealing the influence of digital finance on the effectiveness of monetary policy. Then, to further enhance the scientificness of the research results, the 'special' external variable of COVID-19 is ought to be introduced into the empirical model.

According to the above analysis, the development of digital finance also contains two subindexes, namely coverage index of digital finance (*CDF*) and use depth index of digital finance (*UDF*). Hence, besides introducing the control variable of COVID-19, this section also showed corresponding estimation results of the impact of two subindexes on the effectiveness of monetary policy in Table 7. Thereinto, model (6) is

Table 6. Initiative measures of central banks.

Central Bank	Measures
US Federal Reserve	1. Cut federal funds rate by 50 basis points. 2. Added additional liquidity of more than 3 trillion dollars.
Bank of Japan	1. Issued statement to increase asset purchase to stimulate liquidity. 2. Provided bank liquidity with 43 billion dollars.
People Bank of China	Injected more than $240 billion in the economy to increase liquidity.
Bank of England	1. New lending facility among larger firms. 2. Cut interest rate to 0.1%.
European Central Bank	Announced 750 billion Euros asset-purchase program.
Central Bank of Russia	Increase 4 billion dollars to induce economy.
Reserve Bank of Australia	56 billion dollars to stimulate liquidity.

Source: concluded from Baber (2020).

Table 7. Estimation results after introducing COVID-19.

	Model				
Variables	(6)	(7)	(8)	(9)	(10)
Constant	−54.785	−3745.852	−1296.049	−540.079	1782.843
	(-0.04)	(-2.83) ***	(-0.97)	(-0.35)	(1.26)
DF	−31.221				
	(-10.46) ***				
CDF		−37.3061		−32.525	
		(-12.74) ***		(-10.28) ***	
UDF			−30.904		−27.475
			(-10.73) ***		(-9.51) ***
DF × MP	0.0005				
	(11.62) ***				
CDF × MP		0.0005		0.0005	
		(10.34) ***		(11.17) ***	
UDF × MP			0.0005		0.0005
			(13.07) ***		(13.99) ***
CL	0.662	0.628	0.593	0.662	0.666
	(8.02) ***	(7.59) ***	(7.08) ***	(8.04) ***	(8.04) ***
FC	0.496	0.441	0.379	0.488	0.440
	(6.56) ***	(5.84) ***	(4.80) ***	(6.47) ***	(5.67) ***
EL	−0.061	−0.069	−0.062	−0.061	−0.054
	(-2.30) **	(-2.57) ***	(-2.24) ***	(-2.32) ***	(-2.00) **
FP	1.500	1.855	1.748	1.519	1.440
	(6.63) ***	(8.67) ***	(8.20) ***	(6.68) ***	(6.67) ***
COVID-19	−1210.619			−1244.655	−1531.549
	(-3.69) ***			(-3.82) ***	(-4.90) ***
W × EG	0.318	0.437	0.356	0.33	0.253
	(6.25) ***	(9.87) ***	(7.89) ***	(6.32) ***	(5.16) ***
R^2	0.958	0.957	0.956	0.964	0.964
Observations	310	310	310	310	310

Note: ***, **, and * represent the significance levels of 1%, 5%, and 10%, respectively.
Source: Authors' processing in Stata16.

the estimation result of the total index after introducing COVID-19, while model (7) and model (8) respectively manifested the results of subindexes without introducing COVID-19. But model (9) and model (10) are the results of the subindexes with the influence of COVID-19. By comparison, the results indicated that after the introduction of COVID-19, the direction of influence kept unchanged, and the model was still relatively stable. For this reason, we took models (6), (9), and (10) as benchmark models for analysis. However, it should be noted that since other control variables except COVID-19 have been analyzed, so we will focus on analyzing the impacts of COVID-19 and core variables.

From the results manifested in models (6), (9) and (10), it can be seen that COVID-19 has a significantly negative impact on China's economic growth, with influence coefficients of −1210.619, −1244.655 and −1531.549, respectively. However, with the prompt adjustment of the 'dual circulation' development strategy, China is equipped with the capability to meet the challenge of COVID-19. According to the Government Work Report, China was the only major economy in the world with positive economic growth in 2020, with the gross domestic product (GDP) growing by 2.3 percent. This further confirmed China's great achievements in fighting against COVID-19 and transforming the pattern of economic growth.

It's worth noting that the impact of digital finance on economic growth is still negative after introducing COVID-19, and the results have passed the test at the

significance level of 1%. In the meantime, the impact coefficient seemed significantly greater after the introduction of COVID-19. Therefore, to some extent, the outbreak of COVID-19 has expanded the adverse effects of digital finance on economic growth. Nevertheless, it's reassuring that the interaction between digital finance and monetary policy has a positive impact on economic growth, and has passed the test at the significance level of 1%. That is, monetary policy can still have a corrective effect on the economic effects of digital finance and achieve the policy goal of promoting economic growth. Generally speaking, the role of digital finance in promoting economic growth needs to be regulated by monetary policy. Therefore, under the background of the current COVID-19 pandemic, 'safety' remains the main purpose of digital financial regulation. Besides, incorporating digital finance into the monetary quantity regulation framework is still an urgent task.

From the perspective of *CDF* and *UDF*, the influence coefficients were not changed after introducing the control variable of COVID-19. The results suggested that *CDF* and *UDF* both had negative effects on economic growth and passed the test at the significance level of 1%, which was consistent with the ones from the total digital finance index test. Moreover, the research results of *CDF* and *UDF* further implied that no matter the breadth or the depth, there were great differences in the development of digital finance in different regions, which will be destructive to digital finance in enhancing economic growth.

Furthermore, the interactions of $CDF \times MP$ and $UDF \times MP$ had significant positive effects on economic growth, and all the results passed the significance test at the significance level of 1%, which was consistent with the test results from the overall level. Besides, it can be seen from the subindex level that although digital finance has impaired economic growth, monetary policy can play a significant regulatory role and further promote economic growth. Hence, the results of the total index and the subindexes revealed that monetary policy can intervene in digital finance effectively, indicating that without the regulation of monetary policy, the adverse effect of digital finance on economic growth will be further aggravated.

5.2. Decomposition results of direct and indirect effects

In the spatial autoregressive model, except for economic growth, we cannot observe the spatial effects of variables. According to the estimation method given in section 4, this paper further processed the spatial autoregressive model with the decomposition methods of direct and indirect effects. The direct effect portrays the effect of the variables in the region, while the indirect effect depicts the effect of these variables in neighboring regions. So, we display all the decomposition results of each variable in Tables 8 and 9. Among them, model (11) showed the estimated results of the total index of digital finance, while model (12) and model (13) presented the estimation results of digital financial subindexes. In particular, it's noteworthy that the total effects in Tables 8 and 9 are the sum of direct and indirect effects. Therefore, we will not take efforts to explain and analyze it in this part. Also, more attention will be paid to the influences of the core variables and control variables on the economic

Table 8. Decomposition results of digital financial development index.

	Model		
	(11)		
Variables	Total effect	Direct effect	Indirect effect
DF	−46.095	−31.357	−14.738
	(-5.94) ***	(-9.92) ***	(-3.08) ***
DF × MP	0.001	0.0005	0.0002
	(9.84) ***	(11.72) ***	(4.24) ***
CL	0.970	0.663	0.306
	(6.79) ***	(8.24) ***	(3.64) ***
FC	0.743	0.508	0.235
	(5.78) ***	(6.92) ***	(3.37) ***
EL	−0.089	−0.061	−0.028
	(-2.26) **	(-2.31) **	(-1.96) **
FP	2.188	1.499	0.690
	(6.45) ***	(7.92) ***	(3.72) ***
COVID-19	−1784.041	−1233.824	−550.218
	(-4.24) ***	(-3.79) ***	(-3.90) ***

Note: ***, ** and * represent the significance levels of 1%, 5%, and 10%, respectively.
Source: Authors' processing in Stata16.

Table 9. Decomposition results of digital financial development from subindex Level.

	Model					
	(12)			(13)		
Variables	Total effect	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect
CDF	−48.964	−32.689	−16.275			
	(-5.74) ***	(-9.73) ***	(-3.04) ***			
UDF				−36.961	−27.500	−9.461
				(-5.96) ***	(-9.09) ***	(-2.82) ***
CDF × MP	0.0008	0.0005	0.0003			
	(9.70) ***	(11.28) ***	(4.26) ***			
UDF × MP				0.0007	0.0005	0.0002
				(10.2) ***	(13.96) ***	(3.66) ***
CL	0.988	0.664	0.325	0.889	0.666	0.224
	(6.67) ***	(8.26) ***	(3.60) ***	(7.28) ***	(8.29) ***	(3.46) ***
FC	0.745	0.500	0.245	0.603	0.450	0.152
	(5.68) ***	(6.83) ***	(3.35) ***	(5.28)	(5.99) ***	(3.00) ***
EL	−0.091	−0.061	−0.030	−0.072	−0.054	−0.018
	(-2.28) **	(-2.33) ***	(-1.97) **	(-1.98) **	(-2.00) *	(-1.72) ***
FP	2.259	1.519	0.7404	1.914	1.436	0.478
	(6.32) ***	(7.18) ***	(3.65) ***	(7.26) ***	(7.13) ***	(3.81) ***
COVID-19	−1868.59	−1268.829	−599.761	−2059.709	−1549.583	−510.126
	(-4.41) ***	(-3.93) ***	(-3.94) ***	(-5.40) ***	(-4.98) ***	(-3.76) ***

Note: ***, **, and * represent the significance levels of 1%, 5%, and 10%, respectively.
Source: Authors' processing in Stata16.

growth in neighboring regions, that is the 'spatial spillover effect'. Hence, this part focused on analyzing the impacts of each variable on the adjacent areas.

5.2.1. Decomposition results of digital financial development index

According to the results of the model (11), it can be seen that digital financial development (*DF*) has a predominantly negative impact on the economic growth in neighboring regions. Moreover, the development of digital finance showed the spatial agglomeration of 'high-low' and 'low-high' characteristics. In essence, economic

growth satisfied the depressed demand for financial services endogenously, completed the shortboard of the financial service system, and established a sound financing mechanism. Under these circumstances, China's digital finance is bound to experience explosive development. Theoretically, the higher the economic development, the higher the development level of digital finance. But why are the empirical results opposite? This can only show that the 'polarization effect' in China's current development of digital finance is extremely significant. Furthermore, under the joint action of Internet tools and financial technology, digital finance has advanced the aggregation of resources than traditional finance, accelerated the factors flow of economic development from surrounding areas to the core regions, thereby inhibiting the economic growth of neighboring areas. Generally speaking, the development of digital finance not only harms the economic growth in the local region but also has an adverse impact on neighboring regions. This conclusion is consistent with the analysis mentioned above.

Although there is only one monetary policy as a country's benchmark, that does not mean that monetary policy has no greater impact on some regions than others of the country (Crone, 2007). So, can monetary policy continue to be effective in the face of the negative spatial correlation effect caused by the development of digital finance? Let's focus on the estimation results of the interaction between digital finance and monetary policy ($DF \times MP$). Model (11) showed that $DF \times MP$ had a significant positive impact on the economic growth in the local region and neighboring ones. On the one hand, it confirmed that monetary policy can eliminate the adverse effects of digital financial development on economic growth. On the other hand, it further illustrated that the fundamental attribute of monetary policy was not equipped with obvious spatial difference characteristics. This has something to do with FinTech, such as big data and cloud computing. Compared with the traditional financial market, the segmentation characteristic of the digital financial market is gradually slowing down, so monetary policy can function well.

At the same time, it's worth noting that the direct effect is greater than the indirect effect by comparing the influence coefficient. This signified that monetary policy played a protective role in promoting the effect of digital finance, but the adjustment intensity of monetary policy was still varied in different regions. Besides, no matter in the local region or adjacent regions, the coefficients of $DF \times MP$ are still small, which indicates that monetary policy not only intervenes with the development of digital finance but also needs further reinforcement.

From the indirect effect of the control variables, the consumption level (CL), fixed capital formation level (FC), and fiscal policy (FP) all had significant positive impacts on the economic growth in neighboring areas, implying that there is a significant 'spatial spillover effect' in China's consumption, fixed capital formation, and fiscal policy. Specifically, the 'spatial spillover effect' of consumption is closely related to the construction of China's integrated market, the formation of regional urban agglomeration, and the transformation of the regional economic growth model. Meanwhile, the 'spatial spillover effect' of fixed capital formation has something to do with capital flow and value allocation. At the regional level, the investment level in some regions has not 'squeezed' the surrounding areas, that is because China's economic growth is mainly driven by investment (Chen & Funke, 2013). Hence, fixed

capital formation remains irreplaceable in economic growth under the background of expanding domestic demand and changing economic development modes. Besides, the 'spatial spillover effect' of fiscal policy depends on China's current fiscal budget and distribution system, as well as the industrial spatial correlation.

What's more, it should be noted that the export level (*EL*) and COVID-19 have a significant negative effect on economic growth. The conclusion fully denoted that the current export contraction and epidemic impact were the regional common characteristic in China. Obviously, it's also a global common feature. In consequence, reviving exports is not only a major problem for China but a worldwide challenge. It needs all countries to build a new cooperation mechanism to lead the global economy out of difficulties and back to normal.

5.2.2. Decomposition results of digital financial development from subindex level

In this section, the indirect effect analysis is still the main content. The spatial effect of *CDF* on the effectiveness of monetary policy was decomposed, whose results were shown in model (12). It can be seen that the impacts of *CDF* on the economic growth of neighboring areas are negative, and the results have passed the test at the significance level of 1%. In other words, the negative impacts of *CDF* are highly concerned with the spatial imbalance of digital financial development. However, there is a positive 'spatial spillover effect' in the interaction of $CDF \times MP$, meaning that the aggregate control of monetary policy can offset the adverse effects of digital finance in low-level areas to a certain extent.

The spatial decomposition results of *UDF* on the effectiveness of monetary policy were manifested in the model (13), from which we can know that the impact of *UDF* on economic growth is significantly negative in adjacent areas. However, from the perspective of $UDF \times MP$, the direct and indirect effects were both positive and passed the test at the significant level of 1%. Therefore, monetary policy can not only guide digital finance to promote local economic development but have the 'spatial spillover effect', which is more conducive to developing digital finance to enhance economic growth in neighboring regions. From this point of view, the test results of *UDF* have provided effective evidence for the overall test.

Also, no matter for *CDF* or *UDF*, it can be found that the influence coefficients of direct effect are greater than that of indirect effect by comparing model (12) and model (13). This shows that although monetary policy is a macro policy, there are still significant regional differences. According to Owyang and Wall (2009), regional differences in the depth of monetary policy were related to the concentration of the industrial sector. That is to say, the spatial differences in the 'moderating effect' of monetary policy are mainly relevant to the concentration of the digital finance industry in different regions. Therefore, taking *CDF* and *UDF* into consideration in various regions is quite necessary when making full use of monetary policy to intervene in digital finance in the new era.

5.3. Robustness test of the dynamic spatial panel model

5.3.1. Shape recognition of dynamic spatial panel model

To some extent, the direct effect and indirect effect decomposition of the spatial econometric model have improved the credibility and scientificity of the estimation

results. However, from the perspective of attributes, the models mentioned above still belongs to the static spatial panel model. According to the definition of the modeling theory (Martin, 2012; Martin & Sunley, 2006), we know that a region's economic growth level often has significant path dependence and hysteresis effect. If this factor cannot be considered, the model will be incomplete, and the estimated results will be affected as well. Therefore, to improve the robustness of the estimated results, the study will introduce the lag term of the dependent variable and rewrite the static spatial panel model into a dynamic one.

Generally speaking, the dynamic spatial panel model contains the dynamic SAR model, the dynamic SEM model, and the dynamic SAC model (Anselin et al., 2008; Elhorst, 2003). Therefore, the first step of building a dynamic panel model is to identify its shape. It is necessary to test the regression residuals correlation, dependent variable autocorrelation, and generalized autocorrelation before establishing various dynamic spatial panel models. In general, the methods to test the regression residuals correlation are mainly comprised of GLOBAL Moran MI, GLOBAL Geary GC, GLOBAL Getis-Ords GO, Moran MI Error Test, LM Error (Burridge), LM Error (Robust). The means for verifying dependent variable autocorrelation primarily include LM Lag (Anselin) and LM Lag (Robust). And the approaches to examine generalized autocorrelation principally contain LM SAC (LMErr + LMLag_R) and LM SAC (LMLag + LMErr_R) (Anselin & Kelejian, 1997; Bera et al., 2001; Elhorst, 2010; LeSage & Pace, 2009).

Nevertheless, it should be noted that in the analysis of the static spatial panel model, the autocorrelation of dependent variables is also confirmed. Therefore, to reflect the consistency of research, this part will further carry out tests from two dimensions, namely the total index of digital finance and its subindexes. At the same time, to embody the challenges brought by the COVID-19 to the robustness of the model, we utilized the method of identifying dynamic spatial panel models to obtain estimation results in two cases. The one is to introduce COVID-19 as a control variable, the other is not to add COVID-19 into the models. The estimation results were shown in Table 10. Among them, model (14), (16) and (18) respectively presented the recognition results of the dynamic spatial model of *DF*, *DFS*, and *DFD* without the introduction of COVID-19, while model (15), (17) and (19) were on behalf of those corresponding results with introducing the control variable of COVID-19.

By comparison, it can be seen that, in residual space autocorrelation, all kinds of test methods reject the original hypothesis at a significance level of 1%. In addition, LM Lag (Anselin) and LM Lag (Robust) both rejected the null hypothesis at the 1% significance level, implying the spatial autocorrelation of the dependent variable. What's more, LM SAC (LMErr + LMLag_R) and LM SAC (LMLag + LMErr_R) rejected the null hypothesis at the 1% significance level as well, manifesting the existence of generalized spatial autoregression. Comprehensively speaking, the null hypothesis was rejected by the residual space autocorrelation test and the dependent variable spatial autocorrelation test. Therefore, this study can establish the dynamic SEM model, the dynamic SAR model, and the dynamic SAC model. In the above part, the static SAR model has been established and taken the robustness test. Then, in this part, we will further build a dynamic SAR model and take a robustness test as well.

Table 10. Spatial panel model form test.

Inspection type		Spatial Panel Autocorrelation Tests					
		(14)	(15)	(16)	(17)	(18)	(19)
Residual spatial autocorrelation test	GLOBAL Moran MI	0.775	0.774	0.775	0.799	0.812	0.802
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	GLOBAL Geary GC	0.348	0.349	0.346	0.324	0.313	0.318
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	GLOBAL Getis-Ords GO	−13.803	−3.784	−13.795	−14.235	−14.451	−14.289
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	Moran MI Error Test	2.997	2.991	2.995	3.400	3.440	3.412
		(0.000)***	(0.007)	(0.003)	(0.003)	(0.009)	(0.009)
	LM Error (Burridge)	1408.155	1404.278	1406.657	1486.638	1532.181	1497.949
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	LM Error (Robust)	2718.663	2669.109	2385.253	2986.429	3019.075	2625.448
		(0.000)	(0.000)	(0.000)	(0.000)	(0.044)	(0.044)
Dependent variable spatial autocorrelation test	LM Lag (Anselin)	175.69	185.105	132.251	207.7	216.190	159.490
		(0.000)	(0.0000)	(0.000)	(0.000)	(0.000)	(0.000)
	LM Lag (Robust)	1486.197	1449.936	1110.846	1707.491	1703.083	1286.990
		(0.0001)	(0.000)	(0.000)	(0.0001)	(0.000)	(0.000)
Generalized spatial autoregressive test	LM SAC (LMErr + LMLag_R)	2894.353	2854.214	2517.504	3194.129	3235.264	2784.938
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	LM SAC (LMLag + LMErr_R)	2894.353	2854.214	2517.504	3194.129	3235.264	2784.938
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Note: () is the *p* value.
Source: Authors' processing in Stata16.

5.3.2. Estimated results of the dynamic spatial panel model

Based on the shape recognition results of the dynamic spatial panel model, we used the 'SPREGDPD' command in Stata to further estimate the effects of variables in each model. The estimated results were shown in Table 11. In which, model (20) and model (21) gave the dynamic spatial panel estimation results of *DF*, model (22) and model (23) showed the corresponding results of *CDF*, while model (24) and model (25) presented the relevant results of *UDF*. It's apparent that when all the control variables are introduced, no matter in the overall level or the structural level, the estimation results remain unchanged after the establishment of the dynamic spatial panel model. On the whole, the estimated results of the model are quite steady, which fully suggests that the reliability, scientificity, and explanatory ability of the conclusion are solid.

6. Conclusion

COVID-19 has swept the world, which was identified as Public Health Emergency of International Concern (PHEIC) in 2020, becoming the biggest uncertainty of global economic recovery and growth. Yet at the same time, COVID-19 provides new opportunities for the development of digital finance. As banks and other traditional financial institutions were affected by the epidemic, digital finance in emerging market countries has become an effective substitute for the financial system, playing an important role in promoting consumer consumption and relieving small and micro-enterprises. However, due to the imperfect supervision, digital finance in emerging market countries has also caused a series of risks, especially monetary policy risk. Hence, has the rapid development of digital finance in emerging market countries

Table 11. Estimated results of the dynamic spatial panel model.

	Model					
Variable	(20)	(21)	(22)	(23)	(24)	(25)
Constant	1059.066	490.497	933.059	279.291	949.780	206.388
	(2.95) ***	(1.32) *	(2.99) ***	(0.78)	(2.19) **	(0.586)
EG_{t-1}	1.408	1.317	1.349	1.275	1.479	1.360
	(11.50) ***	(10.84) ***	(12.28) ***	(11.76) ***	(11.25) ***	(10.17) ***
W × EG	0.016	0.016	0.016	0.016	0.013	0.014
	(6.53) ***	(6.05)	(6.20) ***	(5.38) ***	(5.33) ***	(5.32) ***
DF	−25.432	−22.572				
	(−9.04) ***	(−7.14) ***				
CDF			−25.296	−19.733		
			(−7.70) ***	(−4.97) ***		
UDF					−19.985	−18.254
					(−7.83) ***	(−7.20) ***
DF × MP	0.0003	0.0003				
	(6.69) ***	(6.33) ***				
CDF × MP			0.0004	0.0004		
			(6.68) ***	(6.47) ***		
UDF × MP					0.0003	0.0003
					(6.07) ***	(6.29) ***
CL	YES	YES	YES	YES	YES	YES
FC	YES	YES	YES	YES	YES	YES
EL	YES	YES	YES	YES	YES	YES
FP	YES	YES	YES	YES	YES	YES
COVID-19	NO	YES	NO	YES	NO	YES
Wald	2114.490	1732.929	1850.761	1514.668	2166.033	1783.786
Raw Moments R^2 Adj	0.9194	0.9273	0.9272	0.9319	0.9119	0.9219
Engle LM ARCH Test	95.273***	94.951***	94.265***	94.124***	95.448***	95.575***

Note: ***, ** and * represent the significance levels of 1%, 5%, and 10%, respectively.
Source: Authors' processing in Stata16.

affected the effectiveness of the monetary policy? Should digital finance be included in the quantitative framework of monetary policy? These are the main research questions of this article.

Based on the research questions and theoretical analysis framework, this paper took China as the research sample, constructed a spatial econometric model, and empirically analyzed the impact of digital finance on the effectiveness of monetary policy and its heterogeneity.

Theoretical analysis showed that the development of digital finance can increase the money supply to a certain extent, affecting the regulatory capability of the central bank and making the effect of monetary policy confronted with greater uncertainty. In addition, emerging market countries generally regarded economic growth as the ultimate goal of monetary policy, so the empirical tests were mainly carried out from this perspective.

Subsequently, the empirical tests indicated that, from the perspective of core variables, the impact of the total index of digital finance on economic growth was significantly negative, that is, digital finance has impaired the effectiveness of the monetary policy. Furthermore, the interaction between digital finance and monetary policy had a significant positive impact on economic growth, suggesting that the 'moderating effect' of monetary policy is beneficial to digital finance in promoting economic growth. Combined with these two conclusions, we can infer that the negative impact of digital finance on economic growth is mainly related to the lack of monetary

policy, and digital finance should be included in the quantitative framework of monetary policy. The test results were confirmed from the subindexes level as well.

In terms of spatial spillover effect, the development of digital finance had obvious characteristics of the 'polarization effect' and the 'spatial spillover effect'. Meanwhile, the negative impact of digital finance on economic growth is not only exclusive in the local region, but also appears in neighboring areas. However, the spatial decomposition results of the interaction of digital finance and monetary policy are all positive, and the 'aggregate control' attribute of monetary policy remains unchanged. Besides, by comparing the coefficients of direct effect and indirect effect, we can see there is a significant regional difference in the 'moderating effect' of monetary policy, with significant spatial heterogeneity.

As for control variables, consumption level, fixed capital formation level, and fiscal policy all had a significant positive impact on economic growth, with a positive 'spatial spillover effect'. Whereas, the impacts of COVID-19 and export level on economic growth were both negative. Hence, coping with the challenges of COVID-19 and revitalizing exports were important breakthroughs for emerging market countries to recover the domestic economy.

Finally, the robustness test of the dynamic spatial econometric model showed that the estimation results were generally stable and reliable. Based on this, this paper proposed the following three suggestions.

First, monetary policy should be strengthened to intervene in the development of digital finance. Actually, the intervention of monetary policy in digital financial development can mitigate its impact on economic growth, so it is indispensable to strengthen the intervention and regulation of monetary policy. However, the current intervention of monetary policy in digital finance mainly remains in the third-party payment field. Therefore, in the new era, the application of monetary policy should be gradually extended to major digital financial forms such as online banking services, financial holding companies, and P2P lending, to guide digital finance to develop normatively and ultimately enhance the transmission effectiveness of the monetary policy.

Second, we should integrate digital financial development into the quantitative framework of monetary policy. It is necessary to improve the liquidity classification standard, innovate the statistical caliber of the monetary level, complete the statistical monitoring system, and pay close attention to the proportion of high-quality currency at the monetary level and its dynamic changes. Then, emerging forms of digital finance, such as P2P lending and crowdfunding, will be gradually integrated into the social financing scale, to standardize the digital financial industry and enhance the effectiveness of the monetary policy.

Third, it is essential to build a 'double pillar' policy framework to compensate for the shortage of monetary policy. Under the background of preventing systemic financial risks, monetary policy is 'difficult to support' the development of digital finance single-handed, so another 'double pillar' policy framework should be established to give a hand. The monetary policy mainly promotes the reasonable growth of monetary credit and social financing in the Internet channel. Specifically speaking, the macro-prudential policy directly affects the digital financial system itself, suppresses

the fluctuation, and makes up for the vacuum areas where monetary policy functions its efficacy. Hence, through policy coordination, the digital financial system can develop steadily and sustainably.

Acknowledgments

The authors are grateful to the anonymous reviewers who provided valuable comments and suggestions to significantly improve the quality of the paper, and appreciate the Digital Finance Research Center of Peking University and Chongqing Intelligent Finance Research Collaborative Innovation Team for providing the data and other support.

Disclosure statement

The authors declare no conflict of interest. There is no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the position presented in, or the review of, the manuscript entitled.

Author contributions

S.J. and S.Q. conceived and designed the research questions. S.J. constructed the models and analyzed the optimal solutions. S.J., S.Q., and H.Z. wrote the paper. S.Q., H.Z. reviewed and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding

The work was supported by the National Social Science Foundation Youth Project of China (18CGL024); Humanities and Social Sciences Research Project of Chongqing Municipal Education Commission (19SKGH128); the Science and Technology Research Program of Chongqing Municipal Education Commission (KJQN201801102); the Graduate Student Innovation Project of Chongqing University of Technology (clgycx 20202100; clgycx 20203130).

ORCID

Song Jiang http://orcid.org/0000-0002-1666-7964
Shuang Qiu http://orcid.org/0000-0003-0561-0089
Hong Zhou http://orcid.org/0000-0001-5839-3570

References

Açikgöz, Ö., & Günay, A. (2020). The early impact of the COVID-19 pandemic on the global and Turkish economy. *Turkish Journal of Medical Sciences*, *50*(SI-1), 520–526. https://doi.org/10.3906/sag-2004-6

Ali, R., Barrdear, J., Clews, R., & Southgate, J. (2014). The economics of digital currencies. *Bank of England Quarterly Bulletin, Q3*. SSRN: https://ssrn.com/abstract=2499418

Al-Laham, M., Al-Tarwneh, H., & Abdallat, N. (2009). Development of electronic money and its impact on the central bank role and monetary policy. *Issues in Informing Science and Information Technology*, *6*, 339–349. https://doi.org/10.28945/3328

Allen, F. (2012). Trends in financial innovation and their welfare impact: an overview. *European Financial Management*, *18*(4), 493–514. https://doi.org/10.1111/j.1468-036X.2012.00658

Allen, S., Čapkun, S., Eyal, I., & Fanti, G. (2020). *Design choices for central bank digital currency: policy and technical considerations* [No. w27634]. National Bureau of Economic Research. https://doi.org/10.3386/w27634

Anselin, L. (2002). Under the hood issues in the specification and interpretation of spatial regression models. *Agricultural Economics*, *27*(3), 247–267. https://doi.org/10.1111/j.1574-0862.2002.tb00120.x

Anselin, L., & Kelejian, H. H. (1997). Testing for spatial error autocorrelation in the presence of endogenous regressors. *International Regional Science Review*, *20*(1-2), 153–182. 01397.x https://doi.org/10.1111/j.1539-6975.2010

Anselin, L., Le Gallo, J., & Jayet, H. (2008). Spatial panel econometrics. In *The econometrics of panel data* (pp. 625–660). Springer. https://doi.org/10.1007/978-3-540-75892-1_19

Arner, D. W., Barberis, J. N., Walker, J., Buckley, R. P., Dahdal, A. M., & Zetzsche, D. A. (2020). Digital finance & the COVID-19 crisis. *University of Hong Kong Faculty of Law Research Paper* (2020/017). SSRN: https://ssrn.com/abstract=3558889

Baber, H. (2020). Spillover effect of Covid19 on the global economy. *Transnational Marketing Journal*, *)*, *8*(2), 177–196. https://doi.org/10.33182/tmj.v8i2.1067

Bakare, A. S. (2011). A theoretical analysis of capital formation and growth in Nigeria. *Far East Journal of Psychology and Business*, *3*(2), 11–24. https://econpapers.repec.org/article/fejarticl/v_3a3a_3ay_3a2011_3ai_3a2_3ap_3a11-24.htm.

Bera, A., Sosa-Escudero, W., & Yoon, M. (2001). Tests for the error component model in the presence of local misspecification. *Journal of Econometrics*, *101*(1), 1–23. https://doi.org/10.1016/S0304-4076(00)00071-3

Berentsen, A. (1998). Monetary policy implications of digital money. *Kyklos*, *51*(1), 89–118. https://doi.org/10.1111/1467-6435.00039

Binder, M., Lieberknecht, P., Quintana, J., & Wieland, V. (2017). *Model uncertainty in macroeconomics: On the implications of financial frictions* [CEPR Discussion Paper No. DP12013]. SSRN: https://ssrn.com/abstract=2961776.

Bordo, M. D., & Levin, A. T. (2017). Central bank digital currency and the future of monetary policy (No. w23711). *National Bureau of Economic Research*. SSRN: https://ssrn.com/abstract=3023109

Buchak, G., Matvos, G., Piskorski, T., & Seru, A. (2018). Fintech, regulatory arbitrage, and the rise of shadow banks. *Journal of Financial Economics*, *130*(3), 453–483. https://doi.org/10.2139/ssrn.2941561

Carrier, J. G., & Heyman, J. M. (1997). Consumption and political economy. *The Journal of the Royal Anthropological Institute*, *3*(2), 355–373. https://doi.org/10.2307/3035024

Castells, M. (2017). *Another economy is possible: Culture and economy in a time of crisis*. John Wiley & Sons, https://doi.org/10.1177/1742766519838186

Cevik, S., & Correa-Caro, C. (2020). Growing (un) equal: Fiscal policy and income inequality in China and BRIC+. *Journal of the Asia Pacific Economy*, *25*(4), 634–653. https://doi.org/10.1080/13547860.2019.1699985

Chen, X., & Funke, M. (2013). The dynamics of catch-up and skill and technology upgrading in China. *Journal of Macroeconomics*, *38*, 465–480. https://doi.org/10.1016/j.jmacro.2013.07.002

Chicheke, A. (2009). *Monetary policy, inflation, unemployment and the Phillips curve in South Africa* [Doctoral dissertation, University of Fort Hare]. http://hdl.handle.net/20.500.11837/715.

Crone, T. M. (2007). A pattern of regional differences in the effects of monetary policy. *Business Review*, *108*(3), 9–19. https://ideas.repec.org/a/fip/fedpbr/y2007iq3p9-19.html

David-West, O., Iheanachor, N., & Kelikume, I. (2018). A resource-based view of digital financial services (DFS): An exploratory study of Nigerian providers. *Journal of Business Research*, *88*, 513–526. https://doi.org/10.1016/j.jbusres.2018.01.034

DeLong, J. B., Summers, L. H., Feldstein, M., & Ramey, V. A. (2012). Fiscal policy in a depressed economy. *Brookings Papers on Economic Activity*, *2012*(1), 233–297. [with comments and discussion]. https://doi.org/10.2307/23287218

Duca, J. V., & Whitesell, W. C. (1995). Credit cards and money demand: A cross-sectional study. *Journal of Money, Credit and Banking*, *27*(2), 604–623. https://doi.org/10.2307/2077886

Durgun, Ö., & Timur, M. C. (2015). The effects of electronic payments on monetary policies and central banks. *Procedia - Social and Behavioral Sciences*, *195*, 680–685. https://doi.org/10.1016/j.sbspro.2015.06.271

Elhorst, J. P. (2003). Specification and estimation of spatial panel data models. *International Regional Science Review*, *26*(3), 244–268. https://doi.org/10.1177/0160017603253791

Elhorst, J. P. (2010). Spatial panel data models. In M. M. Fischer & A. Getis (Eds.), *Handbook of applied spatial analysis*. Springer. https://doi.org/10.1007/978-3-642-03647-7_19

Ely, B. (1996). *Digital money and monetary policy: Separating facts from fiction in the future of money in the information age* [Paper presentation]. Cato Institute's 14th Annual Monetary Conference. http://www.Cato.org/moneyconf

Feng, G., Jingyi, W., Fang, W., Tao, K., Xun, Z., & Zhiyun, C. (2020). Measuring China's digital financial inclusion: Index compilation and spatial characteristics. *Economics (Quarterly)*, *19*(04), 1401–1418. https://doi.org/10.13821/j.cnki.ceq.2020.03.12.

Friedman, M. (1968). The role of monetary policy. *American Economic Review*, *58*(1), 1–17. https://doi.org/10.1007/978-1-349-24002-9_11

Fung, B., Molico, M., & Stuber, G. (2014). *Electronic money and payments: Recent developments and issues*. https://ideas.repec.org/p/bca/bocadp/14-2.html.

Funk, R. J., & Hirschman, D. (2014). Derivatives and deregulation: Financial innovation and the demise of Glass–Steagall. *Administrative Science Quarterly*, *59*(4), 669–704. https://doi.org/10.2139/ssrn.2374496

Gandja, S. V., Estay, C., & Tchankam, J. P. (2015). Alternative finance for micro-enterprises: A foundation for sustainable development or just humanitarian aid? *Strategic Change*, *24*(1), 33–47. https://doi.org/10.1002/jsc.1996

Giles, J. A., & Williams, C. L. (2000). Export-led growth: A survey of the empirical literature and some non-causality results. Part 2. *The Journal of International Trade & Economic Development*, *9*(4), 445–470. https://doi.org/10.1080/096381900750056867

Glocker, C., & Piribauer, P. (2021). Digitalization, retail trade, and monetary policy. *Journal of International Money and Finance*, *112*, 102340. https://doi.org/10.1016/j.jimonfin.2020.102340

Gomber, P., Koch, J. A., & Siering, M. (2017). Digital finance and FinTech: Current research and future research directions. *Journal of Business Economics*, *87*(5), 537–580. https://doi.org/10.1007/s11573-017-0852-x

Gretta, S. A. A. B. (2017). Financial inclusion and growth. *The Business & Management Review*, *8*(4), 434. https://cberuk.com/cdn/conference_proceedings/conference_78515.pdf.

Hasan, I., and Kwak, B., & Li, X. (2020, November 12). *Financial technologies and the effectiveness of monetary policy transmission*. SSRN: https://ssrn.com/abstract=3743203 or https://doi.org/10.2139/ssrn.3743203

Hu, B., & Zheng, L. (2016). Digital finance: Definition, models, risk, and regulation. In *Development of China's financial supervision and regulation* (pp. 31–58). Palgrave Macmillan. https://doi.org/10.1057/978-1-137-52225-2_2

Humphrey, D. B., Pulley, L. B., & Vesala, J. M. (1996). Cash, paper, and electronic payments: A cross-country analysis. *Journal of Money, Credit and Banking*, *28*(4), 914–939. https://doi.org/10.2307/2077928

Igoni, S., Onwumere, J. U. J., & Ogiri, I. H. (2020). The Nigerian digital finance environment and its economic growth: Pain or gain. *Asian Journal of Economics, Finance and Management*, 1–10. https://globalpresshub.com/index.php/AJEFM/article/view/824

LeSage, J., & Pace, R. K. (2009). *Introduction to spatial econometrics*. Chapman & Hall/CRC. https://doi.org/10.1111/j.1467-985X.2010.00681_13.x

Keister, T., & Sanches, D. (2019). *Should central banks issue digital currency?* [Federal Reserve Bank of Philadelphia Working Paper no. 19–26]. https://doi.org/10.21799/frbp.wp.2019.26

Lee, L. F., & Yu, J. (2010). Estimation of spatial autoregressive panel data models with fixed effects. *Journal of Econometrics*, *154*(2), 165–185. https://doi.org/10.1016/j.jeconom.2009.08.001

Lyons, A. C., & Kass-Hanna, J. (2021). Financial inclusion, financial literacy and economically vulnerable populations in the Middle East and North Africa. *Emerging Markets Finance and Trade*, *57*(9), 2699–2738. https://doi.org/10.1080/1540496X.2019.1598370

Manyika, J., Lund, S., & Singer, M. (2016). *Digital finance for all: Powering inclusive growth in emerging economies* (pp. 1–15). McKinsey Global Institute. https://ideas.repec.org/p/bca/bocadp/14-2.html.

Martin, R. (2012). Regional economic resilience, hysteresis, and recessionary shocks. *Journal of Economic Geography*, *12*(1), 1–32. https://doi.org/10.1093/jeg/lbr019

Martin, R., & Sunley, P. (2006). Path dependence and regional economic evolution. *Journal of Economic Geography*, *6*(4), 395–437. https://doi.org/10.1093/jeg/lbl012

Mathai, K. (2009). What is monetary policy? *Finance & Development*, *46*, 46–47. https://www.imf.org/external/pubs/ft/fandd/2009/09/pdf/basics.pdf.

McCallum, B. T. (1993). *Specification and analysis of a monetary policy rule for Japan* (No. w4449). National Bureau of Economic Research. https://www.nber.org/papers/w4449.

Meaning, J., Dyson, B., Barker, J., & Clayton, E. (2018). *Broadening narrow money: Monetary policy with a central bank digital currency*. https://doi.org/10.2139/ssrn.3180720

Mirza, N., Naqvi, B., Rahat, B., Rizvi, S. K. & Abbas, (2020). Price reaction, volatility timing, and funds' performance during COVID-19. *Finance Research Letters*, *36*, 101657. https://doi.org/10.1016/j.frl.2020.101657

Mishkin, F. S. (2007). *The economics of money. Banking, and financial markets.* Pearson Education. http://qiewuyfive.ru/rokib.pdf

Mishra, P., & Montiel, P. (2013). How effective is monetary transmission in low-income countries? A survey of the empirical evidence. *Economic Systems*, *37*(2), 187–216. https://doi.org/10.1016/j.ecosys.2012.12.001

Mishra, P., Montiel, P., Pedroni, P., & Spilimbergo, A. (2014). Monetary policy and bank lending rates in low-income countries: Heterogeneous panel estimates. *Journal of Development Economics*, *111*, 117–131. https://doi.org/10.1016/j.jdeveco.2014.08.005

Mitha, A. Z., Arner, S. A., & Douglas, W. (2020). *Governing global digital finance (July 12, 2020)* [University of Hong Kong Faculty of Law Research Paper, No. 2020/045]. SSRN: https://ssrn.com/abstract=3678518 or https://doi.org/10.2139/ssrn.3678518

Muli, C. M. (2019). *The effect of digital finance on money demand in Kenya* [Doctoral dissertation, University of Nairobi]. http://erepository.uonbi.ac.ke/handle/11295/109385

Nsiah, C., Fayissa, B., & Wu, C. (2016). The spatial effects on the rate of economic growth: Evidence from Sub-Saharan Africa. *The Journal of Developing Areas*, *50*(1), 275–288. https://doi.org/10.1353/jda.2016.0005

Obinne, G., Efanga, U., & Clifford, E. (2020). *Investigating the impact of digital finance on money supply in Nigeria*. https://www.researchgate.net/publication/343470464

Owyang, M. T., & Wall, H. J. (2009). Regional VARs and the channels of monetary policy. *Applied Economics Letters*, *16*(12), 1191–1194. https://doi.org/10.1080/13504850701367247

Ozili, P. K. (2018). Impact of digital finance on financial inclusion and stability. *Borsa Istanbul Review*, *18*(4), 329–340. https://doi.org/10.1016/j.bir.2017.12.003

Ozili, P. K. (2020). *Comparing digital finance in the UK, US, India and Nigeria*. SSRN: https://ssrn.com/abstract=3742184 or https://doi.org/10.2139/ssrn.3742184

Pace, R. K., LeSage, J. P., & Zhu, S. (2011). *Spatial dependence in regressors and its effect on estimator performance*. SSRN 1801241. https://ssrn.com/abstract=1801241

Pakhnenko, O., Rubanov, P., Hacar, D., Yatsenko, V., & Vida, I. (2021). Digitalization of financial services in European countries: Evaluation and comparative analysis. *Journal of International Studies*, *14*(2), 267–282. https://doi.org/10.14254/2071-8330.2021/14-2/17

Plassaras, N. A. (2013). Regulating digital currencies: bringing Bitcoin within the reach of IMF. *Chicago Journal of International Law*, *14*, 377.
Rahman, A. J. (2018). Deflationary policy under digital and fiat currency competition. *Research in Economics*, *72*(2), 171–180. https://doi.org/10.1016/j.rie.2018.04.004
Rizvi, S. K. A., Mirza, N., Naqvi, B., & Rahat, B. (2020). Covid-19 and asset management in EU: A preliminary assessment of performance and investment styles. *Journal of Asset Management*, *21*(4), 281–291. https://doi.org/10.1057/s41260-020-00172-3
Ross, S. A. (2002). Neoclassical finance, alternative finance and the closed end fund puzzle. *European Financial Management*, *8*(2), 129–137. https://doi.org/10.1111/1468-036X.00181
Salvary, S. C. (2006). Countries in transition and monetary policy: a framework for policy development. *The IUP Journal of Monetary Economics*, *4*(1), 19–36. https://ssrn.com/abstract=1000638
Santoso, W., Trinugroho, I., & Risfandy, T. (2019). What determine loan rate and default status in financial technology online direct lending? Evidence from Indonesia. *Emerging Markets Finance and Trade*, *56*(2), 1–19. https://doi.org/10.1080/1540496X.2019.1605595
Scheau, M. C. (2020). A cryptocurrency spectrum short analysis. *Journal of Risk and Financial Management*, *13*(8), 184. https://doi.org/10.3390/jrfm13080184
Settlements, B. F. I. (2008). Electronic finance: a new perspective and challenges. *Social Science Electronic Publishing*, *42*(1-2), 1–4. https://doi.org/10.2139/ssrn.1187567
Snellman, J. S., Vesala, J. M., & Humphrey, D. B. (2001). Substitution of noncash payment instruments for cash in Europe. *Journal of Financial Services Research*, *19*(2/3), 131–145. https://doi.org/10.1023/A:1011151219545
Stiglitz, J. (2020). Priorities for the COVID-19 economy. *Project Syndicate*, 1. https://www.socialeurope.eu/priorities-for-the-covid-19-economy
Tanaka, K., Yamada, T., & Watanabe, T. (2010). Applications of gram: Charlier expansion and bond moments for pricing of interest rates and credit risk. *Quantitative Finance*, *10*(6), 645–662. https://doi.org/10.1080/14697680903193371
Tehranchian, A. M., Jafari Samimi, A., & Yazdandoust, A. (2012). The impact of modern technology on demand for money in Iran. *Iranian Economic Review*, *16*(32), 133–148. https://ideas.repec.org/a/eut/journl/v17y2012i2p133.html.
Tian, X., Geng, Y., Dai, H., Fujita, T., Wu, R., Liu, Z., Masui, T., & Yang, X. (2016). The effects of household consumption pattern on regional development: a case study of shanghai. *Energy*, *103*, 49–60. https://doi.org/10.1016/j.energy.2016.02.140
Topcu, E., Altinoz, B., & Aslan, A. (2020). Global evidence from the link between economic growth, natural resources, energy consumption, and gross capital formation. *Resources Policy*, *66*, 101622. https://doi.org/10.1016/j.resourpol.2020.101622
Tristram, C. (2001). The technology review 10: Emerging technologies that will change the world. *Technology Review*, *104*(4), 97–103. https://doi.org/10.1152/physiol.00016.2004
Tule, M. K., & Oduh, M. O. (2016). Financial innovations and the future of monetary policy in Nigeria. *Economics of Innovation and New Technology*, *26*(5), 453–476. https://doi.org/10.1080/10438599.2016.1229854
Turnovsky, S. J. (1997). Fiscal policy in a growing economy with public capital. *Macroeconomic Dynamics*, *1*(3), 615–639. https://doi.org/10.1017/S1365100597004045
Wang, R., Qi, Z., & Shu, Y. (2020). Multiple relationships between fixed-asset investment and industrial structure evolution in China–based on Directed Acyclic Graph (DAG) analysis and VAR model. *Structural Change and Economic Dynamics*, *55*, 222–231. https://doi.org/10.1016/j.strueco.2020.09.001
Wasiaturrahma, W., Wahyuningtyas, Y. T., & Ajija, S. R. (2019). Non cash payment and demand for real money in Indonesia. *Journal of Economics, Business & Accountancy Ventura*, *22*(1), 1–8. https://doi.org/10.14414/jebav.v22i1.1575
Wong, C. Y., & Eng, Y. K. (2020). P2P finance and the effectiveness of monetary controls. *The Manchester School*, *88*(4), 617–639. https://doi.org/10.1111/manc.12312
Woodford, M. (2001). The Taylor rule and optimal monetary policy. *American Economic Review*, *91*(2), 232–237. https://doi.org/10.1257/aer.91.2.232

Yan, Z. Y. (2013). Some thoughts on the current Internet financial risks. *Zhejiang Jin Rong*, *32*(12), 40–42.

Yin, X. S., Yi, Z. H., & Xiang, Y. B. (2020). The selection and co-location of traditional and structure monetary policy instruments: An analysis from the perspective of structural leverage resolving. *Financial Research*, *63*(6), 60–77.

Zavolokina, L., Dolata, M., & Schwabe, G. (2016, December). FinTech transformation: How IT-enabled innovations shape the financial sector. In *FinanceCom 2016* (pp. 75–88). Springer. https://doi.org/10.1007/978-3-319-52764-2_6

Zetzsche, D., Buckley, R., Arner, D., & Barberis, J. (2017). *From fintech to teach-in: The regulatory challenges of data-driven finance*. Social Science Electronic Publishing. https://doi.org/10.2139/ssrn.2959925.

Zhu, X., Song, B., Ni, Y., Ren, Y., & Li, R. (2016). Digital finance-from traditional finance to digital and internet finance. In *Business trends in the digital era* (pp. 161–190). Springer. https://doi.org/10.1007/978-981-10-1079-8_9.