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Systemic Risk Arising from Shadow Banking and Sustainable Development: A Study of Wealth Management Products in China

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Abstract: Shadow banking is a main way for the financial market to serve the real economy today, and this process is closely related to systemic risk. This study examines the impact of shadow banking associated with sustainable development in China's banking on systemic risk. We analyze the data obtained from a rich sample of 31 listed commercial banks in China and shadow banking represented by wealth management products (WMPs) by constructing a dynamic complex interbank network model. The results show that the risks and vulnerabilities generated by shadow banking spread out through the interbank network and cause systemic risk to increase. The effect operates through increasing the number of default banks, reducing banks' survival rate and profit, and forcing central bank bailout funds expansion. However, it has a positive impact in terms of augmenting liquidity and enhancing investment opportunities. Furthermore, the variability in the influence of different categories of shadow banking is assessed, emphasizing that short-term shadow banking exerts a more pronounced impact on systemic risk. In addition, the heterogeneity of the shadow banking effect on different types of commercial banks is explored, revealing that local and rural commercial banks experience a more conspicuous effect compared to state-owned and joint-stock banks. Our findings highlight that improving external supervision, promoting financial internal governance, and constraining credit linkages are vital for alleviating the increase in risks in shadow banking and maintaining the sustainable development of banking.

Keywords: systemic risk; shadow banking; complex network; sustainable development; wealth management products (WMPs)



Citation: Pan, H.; Fan, H. Systemic Risk Arising from Shadow Banking and Sustainable Development: A Study of Wealth Management Products in China. *Sustainability* **2024**, *16*, 4280. <https://doi.org/10.3390/su16104280>

Academic Editor: Cuong Nguyen

Received: 26 April 2024

Revised: 15 May 2024

Accepted: 17 May 2024

Published: 19 May 2024



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1. Introduction

Following the global financial crisis in 2007–2008, many countries, such as the United States (US) and China, implemented looser economic policies to foster economic recovery [1,2]. Within this context, shadow banking, serving as a supplemental informal financial sector to traditional bank credit, has seen a significant expansion over the past decade. Shadow banking engages in economic activities via diverse mechanisms, including asset management plans, trust loans, and outsourced wealth management, which increases credit accessibility and expands investor options [3,4]. In recent years, the ascent of financial technology and its widespread implementation have propelled shadow banking into the global spotlight, garnering increased attention from nations worldwide. US investment firms are involved in novel shadow banking activities by utilizing intricate combinations of on- and off-balance-sheet operations to capitalize on liquidity arbitrage [5]. European financial markets are predominantly influenced by representative financial systems, such as those of Germany and the United Kingdom, which play a pivotal role in shaping the development of Europe's shadow banking and exert a significant impact on European banking [6]. In developing regions, particularly in China, as the financial market expands

and innovates, commercial banks exhibit an increasing interest in shadow banking activities. Consequently, shadow banking not only complements traditional financial models, but has also evolved into an indisputable financial entity [7–9]. Nevertheless, the intrinsic complexity of and lack of transparency in shadow banking, coupled with its intimate ties to the mainstream financial sector, particularly the banking system, heighten potential systemic risks, thereby jeopardizing financial stability and sustainable development [10,11].

Systemic risk typically refers to the potential collapse or dysfunction of a financial system triggered by an event, resulting in significant socio-economic consequences [12,13]. The rapidly evolving shadow banking sector was once regarded as a significant contributor to financial systemic risk, providing funding for high-risk ventures through maturity mismatches, liquidity conversions, leveraged trading, and incomplete credit risk transfers. However, the concealment of relevant information to evade supervision has undermined the stability and sustainability of the financial system [14,15]. According to the Flow of Funds data in the US, shadow banks have amassed systemic risk due to excessive leverage and endogenous operational behavior, currently posing a significant impediment to the sustainable development of the financial system [16]. The pertinent shadow banking activities in European Union member states suggest a close interconnection between shadow banking and traditional financial institutions, with the expansion of shadow banking exerting a substantial influence on the stability and advancement of the financial system [17]. According to the report by Moody's, as a nation with the most prominent shadow banking activities in the emerging financial market, China's shadow banking assets reached CNY 59.2 trillion by the end of 2020, surpassing 50% of the total assets within the banking system and accounting for approximately 58.3% of China's GDP, thereby establishing shadow banking as an integral component within China's financial framework. Given the increasingly prominent role of shadow banking in China and even the world economy, the growing interdependence and complexity between shadow banking and the traditional banking system, there is a gradual exposure of potential risks associated with shadow banking. Effectively cognizing these risks poses a challenge to the existing framework for analyzing financial stability. In this context, considering that the emergence of systemic risks in shadow banking is typically rooted in the direct or indirect connections and dependencies among commercial banks, and recognizing the nature of the financial system as a complex network, we place particular emphasis on addressing the following inquiry: What impact will shadow banking have on Chinese banks' systemic risks and sustainable development through the dynamic complex interbank network?

Despite numerous studies on regulatory arbitrage, credit intermediation, risk-taking, and the negative economic and environmental consequences of shadow banking in emerging markets, there remains a relative dearth of information on systemic risks associated with shadow banking in China [18,19]. China provides an ideal setting for investigating the systemic risk of shadow banking, given its government-dominated structure and frequent policy changes in the financial system, particularly within the banking sector (e.g., robust interest rate regulations by the central bank), which facilitates the examination of the correlation between commercial banks and shadow banks [20]. Simultaneously, the salient characteristic of China's shadow banking lies in its adherence to conventional commercial banks [21]. Consequently, it is more viable to investigate and cognize the risks associated with shadow banking within the framework of the banking system. Given the absence of macro-prudential regulations, such as capital adequacy ratio, for shadow banking activities—the off-balance-sheet assets of Chinese commercial banks—their financial risks remain highly concealed and difficult to quantify [22]. Moreover, previous studies on financial risk have predominantly relied on static indicators and data at a single point in time, thereby overlooking the dynamic evolution of financial network structure over time and under varying market conditions [23]. This study aims to bridge this existing gap by employing the complex network theory to model China's banking system. Specifically, we focus on the micro-inter-bank credit perspective and comprehensively analyze the direct and indirect relationships among commercial banks, shadow banks, and the central bank.

Therefore, a multi-level and dynamic evolution model for the interbank network system is constructed in this study. This model enables us to not only capture the static interconnections between banks at a specific time point, but also analyze the dynamic changes in these connections over time and infer the propagation of risk within the network. The year 2018 is selected as the sample year for this study and excludes subsequent years, considering that the enforcement of China's stringent regulatory policy has had a direct exogenous impact on the oversight of shadow banking activities by commercial banks since 2018 [9]. Simultaneously, in China, there are primarily two categories of shadow banking operations, namely wealth management products (WMPs) and entrusted loans [24]. WMPs exhibit the closest association with commercial banks and represent the most prevalent off-balance-sheet shadow banking services offered by these institutions, while entrusted loans predominantly originate from informal financial entities [25]. Building upon relevant research [26], this study utilizes WMPs issued by commercial banks as representations for their shadow banking activities. Specifically, we use a sample of 31 listed commercial banks in China as of 2018 and data on three types of WMPs provided by commercial banks, aiming to empirically investigate the dynamic evolution of systemic risks arising from shadow banking within the banking system and its implications on banking sustainable development. In addition, whether the categories of WMPs can differentiate the impact of shadow banking on systemic risk in banking is examined, and subsequently an in-depth analysis of the heterogeneity in how different types of commercial banks are affected by shadow banking operations to enhance an understanding of the specific implications for systemic risks posed by shadow banking is conducted.

In comparison to the existing literature, three significant contributions have been made by this study. First, the literature on the determinants of banking systemic risk is enriched. Previous research has identified various factors that influence banking systemic risk, including bank size, asset structure, ownership structure, macroeconomic conditions, and regulatory frameworks [27–31]. By establishing a correlation between shadow banking and systemic risk in the banking sector, we demonstrate that shadow banking amplifies banking systemic risks in China through complex interbank networks. This finding holds significant practical implications as it enables regulators and policymakers to better identify the sources of risk, implement effective measures to mitigate them, and improve banking sustainability.

Second, we provide novel insights into the existing body of literature on shadow banking, particularly in relation to its systemic risk and sustainability implications. Numerous existing studies have focused on the impact of shadow banking on financial system sustainability, including its activities, magnitude, change in characteristics, risk-taking behavior, and regulatory circumvention [32–35]. However, we use the dynamic complex network method to provide a new analytical framework, and deeply study the evolution process and propagation mechanism of systemic risks arising from shadow banking in China's banking market. The findings demonstrate that shadow banking amplifies the number of bank defaults within the system, diminishes the survival rate of banks and profitability, and exacerbates the burden on central bank bailouts. This more accurately elucidates the impact of shadow banking on banking system sustainability, thereby holding significant implications for guidance and expanding our comprehension of systemic risks associated with shadow banking.

Third, a valuable supplement to the existing body of literature on the dynamic evolution of shadow banking and its risk aversion and regulation is provided. Although many studies on shadow banking have been conducted from the perspective of commercial banks, they primarily focus on analyzing the operational activities of shadow banking, overlooking the crucial interaction between commercial banks and shadow banks [23,36]. Consequently, the existing research fails to effectively capture the transmission and dynamic evolution of risks associated with shadow banking. This study examines the systemic risk of shadow banking implications on banking sustainable development, investigates the heterogeneous impacts of shadow banking on various types of commercial banks, and underscores the

significance of targeted supervision to mitigate shadow banking risks and promote the sustainable development of banking, while also emphasizing the importance of establishing manageable credit relationships between shadow banks and financial institutions.

The remainder of this study is organized as follows. The next section reviews the related literature. Section 3 presents the methodology, constructs the complex dynamic banking network model, and describes the calculation process of systemic risk. Section 4 shows the relevant dates, reports the main results and discussions, and Section 5 concludes this study.

2. Literature Review

2.1. Shadow Banking

The global financial crisis triggered by the 2008 US subprime mortgage crisis placed shadow banking in the spotlight. In recent years, the close connections between formal financial institutions and shadow banking, particularly their heightened vulnerability following the crisis, have brought shadow banking into sharp focus for both the government and academia [37–39]. The rapid proliferation of shadow banking has engendered a plethora of excessive risk-taking behaviors and fostered the emergence of a precarious financial system [10,40]. Theoretically, shadow banking serves as a regulatory arbitrage strategy to circumvent capital regulations in the presence of relatively stringent policy formulations and binding regulatory restrictions [41,42]. Consequently, the absence of policy protection renders depositors' funds in shadow banking susceptible to potential risks [43,44]. Typically, the abrupt liquidity shortage stemming from shadow banking can potentially trigger severe bank runs and widespread bank failures. Furthermore, the extensively overlapping nature of shadow banking operations exposes significant risks, amplifying systemic vulnerabilities and impeding sustainable development [3,19,45].

In contrast to shadow banking in developed countries such as Europe and the United States, China's shadow banking exhibits unique characteristics, serving as a credit intermediary that plays a pivotal role in facilitating the conversions of credit, liquidity, and term [46,47]. According to various initiators, China's shadow banking can be categorized into three types: commercial bank shadow banking, non-financial institution shadow banking, and private lending. Among these types, the predominant forms of shadow banking are commercial bank WMPs and non-financial institution-entrusted loans [24]. In the past decade, shadow banking has gradually emerged as a significant component of China's financial system, perceived as an alternative to conventional commercial banks within the context of emerging market systems [48,49]. Chinese commercial banks play a central role in the realm of shadow banking, enabling them to attain enhanced cost-effectiveness and income generation through off-balance-sheet shadow banking activities. However, this phenomenon also presents a formidable challenge to both financial sustainability and the orderly development of the sector [42,50].

The Chinese government's economic stimulus plan has prompted shadow banking to be increasingly active, which has garnered significant research attention regarding its impact on risk. The study conducted by Li and Lin (2016) [51] demonstrates that shadow banking contributes to an increase in financial fragility through the augmentation of bank interest margin, equity risk, and deposit liability. The shadow banking sector in China operates outside the purview of government regulation; due to the influence of high leverage and significant information asymmetry, shadow banking activities exhibit higher levels of risk compared to financial asset activities, such as stocks and bonds [52,53]. Shen et al. (2020) [54] employed a composite index model to find that shadow banking effectively transfers risks to the financial system, thereby distorting the proportion of risk assets and liquidity. Liu and Xie (2021) [42] posited that the intensification of macro-prudential regulation has exacerbated financial frictions, facilitated the expansion and growth of shadow banking, and heightened regulatory arbitrage risks within this sector. Commercial banks are inclined to augment their revenue streams through expanded shadow banking operations, specifically the increased issuance of WMPs. However, a threat

to the stability of the banking industry is posed by this practice [36]. Additionally, shadow banking serves as a crucial avenue for mitigating debt rollovers, prompting frequent participation in such activities by local governments and state-owned enterprises. Despite these actions providing investors with the belief that offering corresponding collateral can reduce potential default risks and secure implicit guarantees [55], enterprises engaged in shadow banking face heightened risks [35].

The aforementioned study conducted a comprehensive analysis of shadow banking, uncovering its interconnections and associated risks with the stability of the financial system. However, a detailed explanation of the specific mechanisms of risk propagation is often lacking in these studies, and there are evident deficiencies in the investigation of the micro-level process of risk evolution, especially the new regulatory requirements' emphasis on the necessity of comprehending and simulating the internal dynamics of shadow banking in order to more effectively mitigate the systemic risk associated with non-bank financial institutions. To address the gaps in the current research, we aim to construct a multi-tiered dynamic complex interbank network model. This model is designed to simulate the dynamic interactions between shadow banks and traditional commercial banks, as well as among different entities within shadow banking. The application of this model not only enables a more accurate tracking and analysis of risk propagation paths, but also identifies potential points of risk aggregation, facilitating a greater understanding and prediction of shadow banking behavior at the micro-level. This will significantly advance the development and implementation of regulatory strategies for shadow banking, offering substantial backing for the overall stability of the financial system.

2.2. Banking Systemic Risk and Sustainability

Within the financial market, the banking system constitutes a pivotal component of the overall financial system, with considerable attention being devoted to addressing the issue of banking systemic risk and sustainability [56,57]. The systemic risk in the banking sector can typically be identified as the potential for a systemic collapse arising from the accumulation and transmission of risks through interbank lending and derivatives transactions [58,59]. Many countries have adopted a vigilant and cautious approach towards banking systemic risk, aiming to investigate the origins and transmission mechanisms of such risks to maintain the sustainable development of banking. This endeavor is directed toward establishing a robust financial security network and mitigating the occurrence of financial crises [60,61].

In recent years, numerous scholars have developed various models and methodologies for quantifying banking systemic risks to investigate banking sustainability. Billio et al. (2012) [62] employed high-dimensional statistical methods to analyze financial data and observed significant temporal variations in banking systemic risks. Tobias and Brunnermeier (2016) [63] introduced the CoVaR index, which assesses the systemic and sustainable impacts of an individual bank on other banks during adverse risk conditions. The SRISK index was proposed by Acharya et al. (2017) [7] to examine the impact of the leverage ratio and capital adequacy ratio on banking systemic risk and sustainability. Meuleman and Vander (2020) [64] constructed a dynamic panel framework to assess the long-term and short-term impacts of systemic risk on banking sustainability by analyzing information pertaining to the bank life cycle. However, these approaches suffer from certain limitations. They tend to overlook the complexity and dynamics of financial markets, while also failing to address the complex interconnections among financial institutions within the scope of banking systemic risk and sustainability studies [65]. Consequently, the analysis of banking systemic risk and sustainability based on the complex network theory has been progressively undertaken. Allen and Gale (2000) [58] pioneered the investigation of banking systemic risk by constructing an interbank network, where banks were represented as nodes. Subsequently, the analysis of systemic risks in banking sustainability has increasingly focused on the connectivity and concentration of interbank networks, as well as the heterogeneity and centrality of network structures [66–68]. Lenzu and Tedeschi (2012) [69]

utilized endogenous banking signal confidence as a benchmark, demonstrating that a banking network characterized by a higher signal confidence exhibits greater strength and heightened systemic risk. The study conducted by Lux (2015) [70] employed fundamental reinforcement learning algorithms to endogenize preference relationships among banks. The findings ultimately reveal that an interbank network structure characterized by a core–periphery configuration is more conducive to facilitating risk sharing and banking sustainable development. Zhang et al. (2018) [71] examined the contagion of risks under both endogenous and random network mechanisms, revealing that the impact of risk contagion was more severe in random network mechanisms compared to endogenous network mechanisms. Moreover, based on the network effect of risk contagion, systemic risk is significantly influenced by changes in debt and capital availability among banks, and the composition and diversity of portfolios can influence banking sustainable development through interbank networks [72,73].

Financial markets and the banking system exhibit various elements and behaviors that have potential risks, with some studies delving into the determining influence of specific factors on banking systemic risk and sustainability. Credit cycles are recognized as the primary source of systemic risk, given that excessive lending by banks during economic booms and their subsequent credit tightening during recessions both contribute to an increase in banking systemic risks and run counter to banking sustainability [74]. Banking systemic risk and sustainability are also influenced by factors such as bank size, the structure of bank assets, and ownership composition [27–29]. Simultaneously, the liquidity of the financial market and bank capital are significantly negatively correlated with banking systemic risk. Adequate liquidity can effectively mitigate the occurrence of risk contagion and promote sustainable development, while a liquidity crisis has the potential to trigger bank runs and exacerbate systemic risks [10,75]. The presence of complex financial instruments, such as derivatives, and the behavior of interbank trading can contribute to banking systemic risks. The valuation of these financial products, which exhibit a strong correlation with underlying assets, along with interbank investment behavior can significantly amplify the potential propagation of systemic risks and work against banking sustainability [76]. Furthermore, the determination of banking systemic risk and sustainability are also influenced by the central bank's implementation of monetary policy, prudential supervision, fluctuations in leverage ratios associated with the macroeconomic environment, and changes in economic cycles [30,31,77].

In the aforementioned study, many effective methodologies and potential sources of risks have been proposed for analyzing banking systemic risk and sustainability. While the interbank risk of contagion has been examined through the lens of network theory, these approaches often fail to account for the dynamic economic behaviors of financial institutions and the gradual evolution of systemic risks. Furthermore, a limited number of the abovementioned studies take into account shadow banking as a primary source of risk, overlooking its potential to trigger systemic risks and disrupt the stability of the financial system. After the implementation of asset management regulations in 2021, the oversight and risk management of shadow banking have assumed heightened significance. The new regulations not only alter the framework of asset management, but also elevate the scrutiny of the risks associated with non-bank financial institutions. Therefore, to address the gaps in the existing research, our objective is to examine the risks associated with non-bank financial institutions by developing a dynamic and intricate network model. Our study not only comprehensively examines the impact of shadow banking risk on the sustainable development of banking, but also investigates how risk sources and transmission channels interact to drive changes in systemic risks within banks. Through this approach, we are able to more precisely simulate and comprehend the interactions and mechanisms of risk propagation within shadow banking and between it and traditional banking. The in-depth analysis facilitates regulatory authorities in formulating more efficacious strategies for the prevention and alleviation of systemic risks, thereby ensuring the enduring stability and sustainable development of the financial system.

3. Methodology

The core constituents of the complex banking network are the interconnections among commercial banks, shadow banks, and the central bank. This study is based on a standard interbank network model, which integrates a multi-layered and dynamic banking system, including commercial banks, WMPs representing shadow banking, and central banks, to capture the evolving dynamics of the real banking market. We consider the interbank lending network between commercial banks and the credit network involving shadow banking, illustrating the diverse credit operations of various banks under the supervision of the central bank. Subsequently, the dynamic analysis addresses bank defaults, risk contagion, and the evolution of systemic risk within the complex, multi-layered interbank network.

3.1. Banking Interbank Market with Shadow Banking

In this study, the banking market network encompasses Z bank agents ($Z = C + S$), which include C commercial bank agents and S shadow bank agents symbolized by three distinct categories of WMPs (shadow bank I, shadow bank II, and shadow bank III). A central bank agent that executes regulatory directives is also incorporated.

Let $U = \{1, 2, \dots, Z\}$ represent the banking market at any given time, t ($t > 0$). Bank connectivity can be symbolized using a binary matrix, J , where $J_{i,j}$ is either 0 or 1. $J_{i,j} = 1$ denotes a credit or lending relationship between bank i and bank j ; otherwise, $J_{i,j} = 0$ [66,67]. Given the unique properties of shadow banking and the inherent lack of information symmetry [78], credit or lending relationships are exclusively formed between commercial banks and between commercial banks and shadow banks, resulting in $J_{i,j} \equiv 0$ amongst shadow banks. P represents the interbank lending matrix, reflecting the lending assets or liabilities of each bank, $i \in U$, toward its associated banks [79], via the interbank lending or credit network. The aggregate interbank lending owned by bank $i \in U$ can be denoted as $P_i = \sum_{j=1}^Z p_{i,j}$, where $i \neq j$. Here, the lending vector, p , is a directed vector implying that $p_{i,j} \neq p_{j,i}$. Figure 1 provides a visualization of the banking network with shadow banking as well as the derived interbank lending matrix.

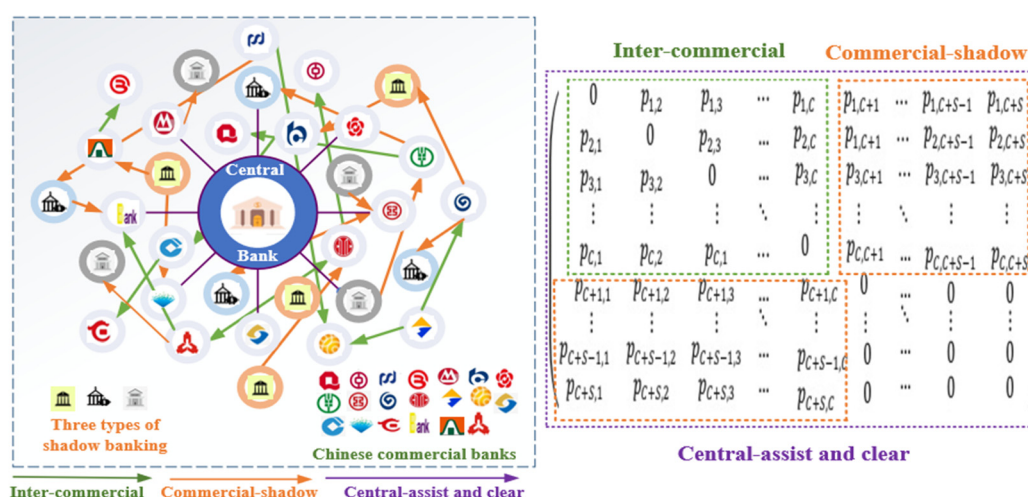


Figure 1. Banking network with shadow banking (Left) and its interbank lending matrix (Right).

3.2. Commercial Bank and Shadow Banking Operations

We aim to depict the dynamic evolution of banks using a balance sheet. Serving as the benchmark for banking activities, the balance sheet varies at each time point. It undergoes a dynamic evolution based on discrete time intervals, $t = 1, 2, 3, \dots, T$. For enhanced clarity when analyzing the experiment results, this study employs a simplified balance sheet structure, which encompasses two core components: assets, including liquidity, M , and investment, R , and liabilities, composed of deposits or financing, T , interbank lending, P ,

and owner's equity, O . Leveraging this balance sheet framework, we can articulate the initial liquidity of bank i in the system as follows:

$$M_i^{t-1} = D_i^{t-1} + P_i^{t-1} + O_i^{t-1} - R_i^{t-1} \quad (1)$$

where at time $t - 1$, bank i 's liquidity, deposits or financing, and owner's equity are denoted as M_i^{t-1} , D_i^{t-1} , and O_i^{t-1} , respectively. The symbol P_i^{t-1} stands for the total interbank lending by bank i , calculated as $P_i^{t-1} = \sum_{j=1}^Z p_{i,j}^{t-1}$. When bank i borrows from bank j , $p_{i,j}^{t-1} > 0$, and when bank i lends to bank j , $p_{j,i}^{t-1} < 0$. Notice that $p_{i,j}^{t-1} = -p_{j,i}^{t-1}$. If no interbank lending occurs between bank i and bank j , then $p_{i,j}^{t-1} = -p_{j,i}^{t-1} = 0$. Lastly, R_i^{t-1} represents bank i 's total investment, defined as $R_i^{t-1} = \sum_{k=1}^{\pi} R_i^{t-1-k}$, which signifies bank i 's sum of investments over π investment periods.

With the evolution of the interbank network and the ongoing transactions, capital circulates throughout the system causing dynamic shifts in each bank's liquidity. At the next time, t , the updated liquidity of bank i can be illustrated as follows:

$$M_i^t = (D_i^t - D_i^{t-1}) - r_d D_i^{t-1} + \tau \sum_{k=1}^{\pi} R_i^{t-k} + R_i^{t-\pi} \quad (2)$$

where r_d represents either the deposit or financing rate, and $r_d D_i^{t-1}$ symbolizes the interest remitted by commercial bank i to its depositors or the benefits conferred by shadow bank i to its investors. τ signifies the investment return rate. $\tau \sum_{k=1}^{\pi} R_i^{t-k}$ and $R_i^{t-\pi}$, respectively, denote the return on investment and the total investment recouped upon maturity by bank i .

The unpredictability and volatility of deposits and investor financing can be attributed to various behavioral factors, subsequently inducing stochastic disturbances in banking liquidity. In this study, we postulate that the deposits or financing, D_i^t , of bank i adhere to a normal distribution:

$$D_i^t = |\bar{D} + \bar{\sigma}_D \varepsilon_t|, \varepsilon_t \sim N(0, 1) \quad (3)$$

where $\bar{D}$ signifies the mean value of either commercial bank deposits or shadow bank financing, whereas σ_D represents the standard deviation of random fluctuations in both commercial bank deposits and shadow bank financing.

Within the banking system, institutions determine subsequent business operations predicated on updated liquidity status, predominantly encompassing dividend distribution and reinvestment strategies.

Should the updated liquidity of bank i exceed zero ($M_i^t > 0$), it enables the execution of dividend activities. Specifically, for a commercial bank, the structure of its dividend distribution is as follows:

$$B_i^t = \max \left[0, \min \left[\tau \sum_{k=1}^{\pi} R_i^{t-k} - d_r D_i^{t-1}, M_i^t - L_i^t, M_i^t + \sum_{k=1}^{\pi-1} R_i^{t-k} - (1 + \xi) D_i^t \right] \right] \quad (4)$$

$L_i^t = \lambda D_i^t$ signifies the legally mandated reserve requirement that commercial bank i must uphold at time t , where λ represents the reserve requirement ratio and ξ denotes the deposit ratio. If bank i operates as a shadow bank, its dividend distribution is different from commercial banks, and the structure of its dividend distribution is as follows:

$$B_i^t = \max \left[0, \min \left[\xi \left(\sum_{k=1}^{\pi} R_i^{t-k} - d_r D_i^{t-1} \right), M_i^t \right] \right] \quad (5)$$

where ξ symbolizes the financing ratio pertaining to shadow bank i . To streamline the discussion, this study equates the financing ratio of shadow banks with the deposit ratio of commercial banks.

Following the payment of dividends, should bank i retain a surplus of liquidity, such funds may be reinvested. When bank i functions as a commercial bank, the reinvestment adopts the subsequent form:

$$I_i^t = \min[\max[0, (M_i^t - B_i^t - L_i^t)], \psi_i^t] \quad (6)$$

In the instance where bank i operates as a shadow bank, the form of its reinvestment unfolds as follows:

$$I_i^t = \min[\max[0, (M_i^t - B_i^t)], \psi_i^t] \quad (7)$$

A crucial distinction between commercial banks and shadow banks regarding reinvestment lies in that the former falls under capital regulation obligations, whereas the latter is exempt from mandatory reserve requirements. ψ_i^t represents bank i 's investment opportunity. This study treats it as stochastic in nature, akin to deposits or financing, implying that ψ_i^t adheres to a normal distribution, given by $\psi_i^t = |\bar{\psi} + \bar{\psi}\sigma_\psi\phi_t|$, $\phi_t \sim N(0, 1)$. $\bar{\psi}$ denotes the mean investment opportunity across banks, while σ_ψ represents the standard deviation pertaining to the bank's investment opportunities.

As banking networks evolve and banking operations advance, bank i encountering negative liquidity ($M_i^t < 0$) is likely to default. Defaulting banks will enter the defaulting banks collection, D , and await either assistance or clearing under the central bank network.

3.3. Central Bank Assistance and Clearing

As a regulatory body, the central bank crucially ensures the stability of the banking system, primarily through capital regulation [77]. This study discusses how the central bank provides assistance to defaulting commercial banks and clears defaulting shadow banks. The procedure adopted by the central bank to assist commercial bank i is delineated as follows:

$$g_i^t = \begin{cases} L_i^t - M_i^t, & \text{if } L_i^t > M_i^t \\ 0, & \text{otherwise} \end{cases}, \quad (8)$$

The assistance rendered by the central bank to commercial bank i is symbolized through the aid vector g , which signifies the bailout amount designated for each commercial bank should they default. When the liquidity of commercial bank i falls short of the central bank's capital regulation requirements, the central bank delivers legal reserve requirement support ($L_i^t - M_i^t$). Conversely, commercial bank i possesses adequate capital and is not reliant upon central bank support.

As shadow banking circumvents capital regulation, in this study, the central bank utilizes the default mechanism referred to by Eisenberg and Noe (2001) [80] for clearing shadow banks, detailed as follows:

$$F_i^t = \begin{cases} P_{i,j}^t, & \text{if } M_i^t \geq P_i^t \\ O_i^t * \frac{p_{i,j}^t}{\sum_{j=1}^x p_{i,j}^t}, & \text{if } M_i^t < P_i^t \text{ and } O_i^t > 0 \\ 0, & \text{otherwise} \end{cases} \quad (9)$$

where $p_{i,j}^t$ represents the lending amount transacted between shadow bank i and commercial bank j . $\sum_{j=1}^x p_{i,j}^t$ constitutes the cumulative lending of shadow bank i to all commercial banks. x signifies the maximum count of commercial banks from which a shadow bank can secure lending; in this study, x is established as 3.

3.4. Dynamic Systemic Risk Analysis

Dynamic quantification of systemic risk enables a more precise evaluation of the banking system's stability. This study explores the influence of shadow banking on the banking systemic risk by adopting the calculating method proposed by Jiang and Fan

(2021) [73]. It involves normalizing the average count of defaulted banks in the interval $[t + 1, t + Y]$ and documenting the resultant systemic risk value as ZS^t as follows:

$$ZS^t = \frac{1}{YH} \sum_{f=1}^H \sum_{y=t+1}^{t+Y} \frac{A_f^y}{W_f^y} \quad (10)$$

where Y is defined as the time interval. The systemic risk at any given time can be represented by the average ratio of defaulting banks in the upcoming period, Y . This study sets Y to be equal to 10. H represents the total number of system operations. The number of defaulting banks during the f th system run is denoted as A_f^y , whereas W_f^y denotes surviving banks. The algorithm applied to discern defaulting banks, surviving banks, and calculate defaulting banks is shown in Figure 2, which is divided into the following 5 steps:

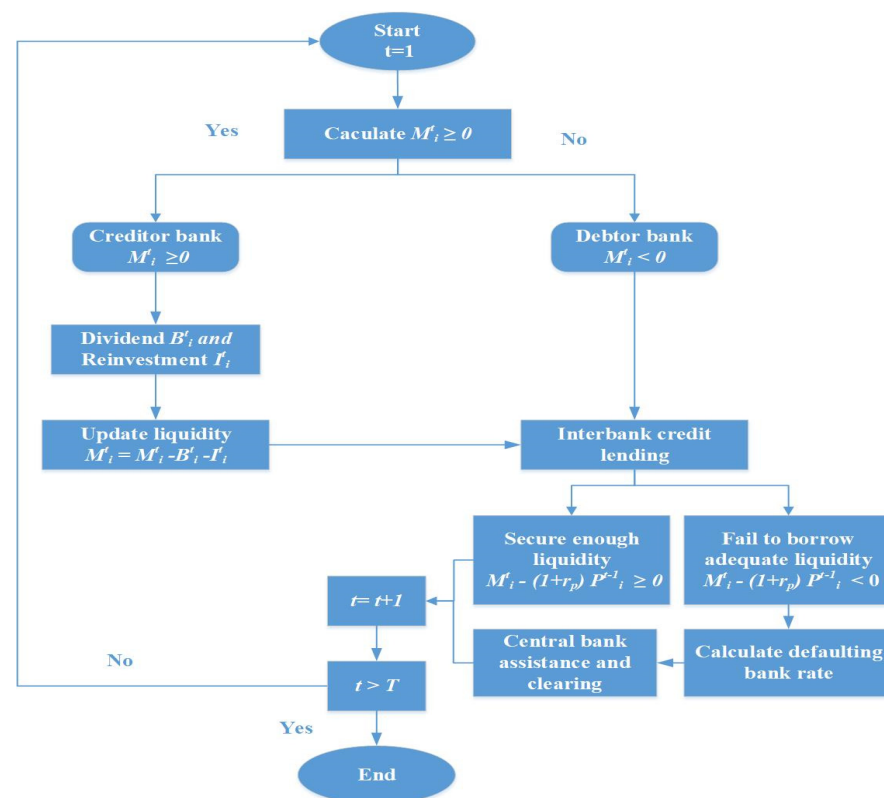


Figure 2. Dynamic process algorithm of systemic risk analysis.

Step 1: Determined the balance sheet of bank i ; the corresponding initial parameters and variables are respectively performed. Subsequently, confirm the initial liquidity, M_i^{t-1} , of bank i .

Step 2: Calculate the liquidity, M_i^t , of bank i at time t . If bank i possesses adequate liquidity ($M_i^t > 0$), it should provide dividends, B_i^t , and carry out reinvestments, I_i^t . Otherwise, step 3 is executed.

Step 3: After dividend distribution and reinvestment, the liquidity of bank i is updated to $M_i^t = M_i^t - B_i^t - I_i^t$. Should the liquidity of bank i remain positive, it acts as a creditor bank capable of lending liquidity to indebted banks. However, if the liquidity is negative, bank i becomes a debtor bank. Interbank lending commences based on each bank's liquidity. In the event that debtor bank i can secure enough liquidity from creditor banks to offset its previous loan and interest (i.e., $M_i^t - (1 + r_p) P_i^{t-1} \geq 0$, where r_p is the interbank offered rate), it advances to the next timestep. Conversely, if debtor bank i fails to borrow adequate liquidity for repaying the prior loan and interest (i.e., $M_i^t - (1 + r_p) P_i^{t-1} < 0$), it enters the collection of defaulting banks, D , and proceeds to step 4.

Step 4: Should the defaulting bank, i , be a commercial bank, it receives assistance from the central bank, which enables it to proceed to the next timestep. In the case that the defaulting bank, i , is a shadow bank, it is cleared by the central bank and its status is still in the defaulting collection, D . The liquidity and debts of the assisted or cleared defaulting bank, i , are reset to zero, denoted as $M_i^t = 0$ and $P_i^t = 0$.

Step 5: The banking network system evolves to the subsequent timestep, $t = t + 1$, and repeats step 2–step 4, until $t > T$.

4. Results

4.1. Data

The implementation of stringent regulatory policies in China post-2018 has led to an exogenous impact on the regulation of shadow banking activities within commercial banks [9]. Consequently, this study chose 2018 as the benchmark year for the sample, excluding any samples beyond this period. This study comprises a sample from 31 commercial banks categorized into state-owned, joint-stock, and city commercial banks, all of which are listed on China's A-share market (refer to Table 1 for details). State-owned commercial banks, along with joint-stock banks are relatively large banks of systemic significance. City commercial banks have a relatively small scale and demonstrate a pronounced reliance on sustainable development.

Table 1. Commercial banks list.

Stock Code	Bank Name	Stock Code	Bank Name
601988	Bank of China (BOC)	600000	Pudong Development Bank (SPDB)
601939	China Construction Bank (CCB)	002142	Bank of Ningbo (BONB)
601398	Industrial and Commercial Bank of China (ICBC)	002839	Zhangjiagang Rural Commercial Bank (ZRCB)
600926	Bank of Hangzhou (BOH)	600908	Wuxi Rural Commercial Bank (WRCB)
601166	Industrial Bank Co., Ltd. (CIB)	601288	Agricultural Bank of China (ABC)
601328	Bank of Communications (BCM)	601997	Bank of Guiyang (BOG)
600928	Bank of Xi'an (BOX)	601009	Bank of Nanjing (BON)
000001	Ping An Bank Co., Ltd. (PAB)	002958	Qingdao Rural Commercial Bank (QRCB)
600016	China Minsheng Bank (CMBC)	002936	Bank of Zhengzhou (BOZ)
600036	China Merchants Bank (CMB)	600919	Bank of Jiangsu (BOJ)
601998	China CITIC Bank (CITIC)	002807	Jiangyin Rural Commercial Bank (JRCB)
601818	China Everbright Bank (EB)	603323	Suzhou Rural Commercial Bank (SZRCB)
600015	Hua Xia Bank Co., Ltd. (HB)	002948	Bank of Qingdao (BQD)
601169	Bank of Beijing (BOB)	601577	Bank of Changsha (BCS)
601229	Bank of Shanghai (BOS)	601838	Bank of Chengdu (BOCD)
601128	Changshu Rural Commercial Bank (CRCB)		

As indicated by the relevant studies [23], WMPs issued by commercial banks serve as a representation of their shadow banking operations. The variety of WMPs issued by commercial banks is typically categorized based on the investment cycle as a defining parameter. According to the investment cycle, commercial banks' WMPs can be primarily classified into five categories: under 1 month, 1–3 months, 3–6 months, 6–12 months, and over 1 year. This study provides statistics on the issuance of the five categories of WMPs from March 2016 to June 2018, illustrated in Figure 3. The issuance in the range of 1–3-month, 3–6-month, and 6–12-month WMPs are in the top-three positions, exhibiting a notable disparity with the remaining two categories. Thus, selecting these three categories of WMPs (shadow bank I, shadow bank II, and shadow bank III) is representative of shadow banking samples.

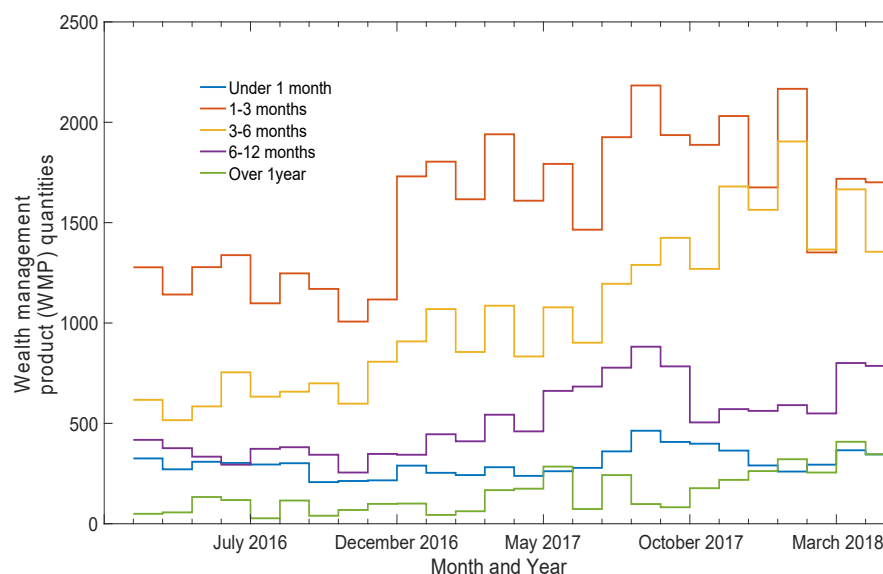


Figure 3. Commercial banks' WMP issuance statistics.

The data related to commercial bank were collected manually from the bank's annual reports and Chinese Stock Market and Accounting Researching database (CSMAR). Macro-level data, inclusive of central bank data, were sourced from the People's Bank of China. Relevant data pertaining to the three categories of WMPs, which represent shadow banking, were retrieved from the wealth management product manual and Wind database. We used MATLAB R2023b to execute algorithms for analyzing banking systemic risks. Variable definitions are presented in Table 2.

Table 2. Variable definitions.

Variable Name	Variable	Definition
Total number of banks	Z	The number of commercial and shadow banks within the banking network system
Number of commercial banks	C	The combined number of state-owned banks, joint-stock banks, and city commercial banks
Number of shadow banks	S	The combined number of three categories of WMPs
Deposits or financing	D	Bank deposits or WMP amount
Deposit or financing rate	r_d	Bank deposits rate or WMP financing rate
Deposit or financing volatility	σ_D	Standard deviation of bank deposits or WMP financing
Investment	R	Investment in bank assets or WMPs
Investment periods	π	Bank investment strategy or investment period of WMPs
Investment return rate	τ	Bank return on assets or WMP yield
Investment volatility	σ_ψ	Standard deviation of investments in banks or WMPs
Reserve requirement ratio	λ	People's Bank of China monetary policy tool—reserve requirement
Deposit ratio	ξ	Bank deposit cash ratio
Interbank offered rate	r_p	People's Bank of China of national interbank offered rate

Notes: This table presents definitions of the main variables used in this study.

4.2. Shadow Banking and Banking Systemic Risk

Given the prevalence of systemic risks, this study aims to elucidate the relationship between shadow banking activities (WMPs) and China's banking systemic risks, as well as the impact of shadow banking on banking sustainable development. As a comparative measure, China's banking systemic risk, excluding shadow banking operations, is also calculated. Figure 4 illustrates the influence of shadow banking operations on systemic risk within China's banking sector. Initial observations indicate that both banking systems exhibit relatively high levels of systemic risks at the beginning, a consequence of the

inherent heterogeneity among constituent banks. Variations in their respective business activities result in irregular liquidity fluctuations, thereby contributing to an escalation in systemic risks. Over time, systemic risks have diminished and achieved stability due to the banking network's inherent self-regulating mechanism that addresses manageable risks, thereby curtailing the overall systemic risk. This observation aligns with the actual conditions of China's banking system. However, the banking system that integrates shadow banking operations inherently possesses higher systemic risks than one excluding such operations. This implies a substantial increase in systemic risks within China's banking infrastructure attributable to shadow banking activities. This observation corroborates the depiction of shadow banking as a high-risk and poorly sustainable entity [44].

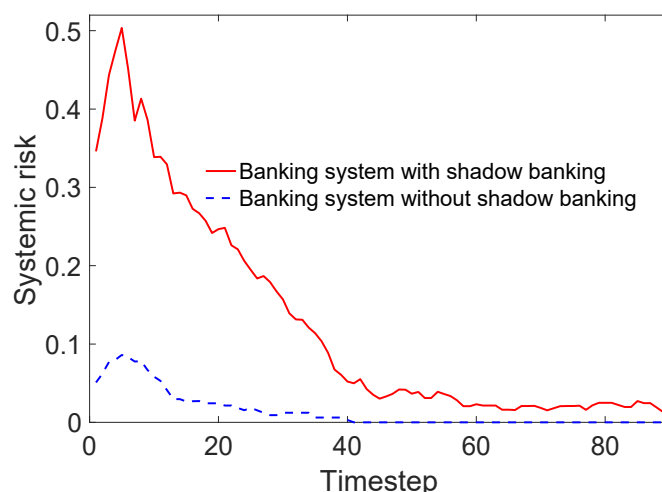


Figure 4. Effect of shadow banking on banking systemic risk.

Having established the significant influence of shadow banking operations on China's banking systemic risk, this study further investigates its particular impacts. Figure 5a–c present the variations in three key metrics within China's banking system: the cumulative number of default banks, survival rate of banks, and the total amount of central bank bailout funds. A comparison is drawn between banking systems operating with and without shadow banking activities. The integration of shadow banking operations into China's banking system initially demonstrates no discernible impact, suggesting that the banking system incorporating these operations exhibits greater stability compared to its counterpart without them. Over time, the banking system exhibits a dramatic increase in the cumulative number of default banks involved in shadow banking operations. Concurrently, the survival rate of banks plummets, and the intensity of central bank bailout funds escalates. This implies that the initiation of regulatory arbitrage-based shadow banking operations could infuse significant liquidity into the banking system, thereby curtailing systemic risks and maintaining stability within the banking framework in the short term. However, over time, unregulated shadow banking activities and fund allocations, which lack strict management and restriction, can result in ineffectively controlling the high-risk behaviors associated with shadow banking operations. Consequently, the risks emanating from shadow banking operations, when disseminated through the interbank network, can lead to defaults spreading to numerous banks, thereby escalating systemic risks and destabilizing the sustainable development of China's banking system.

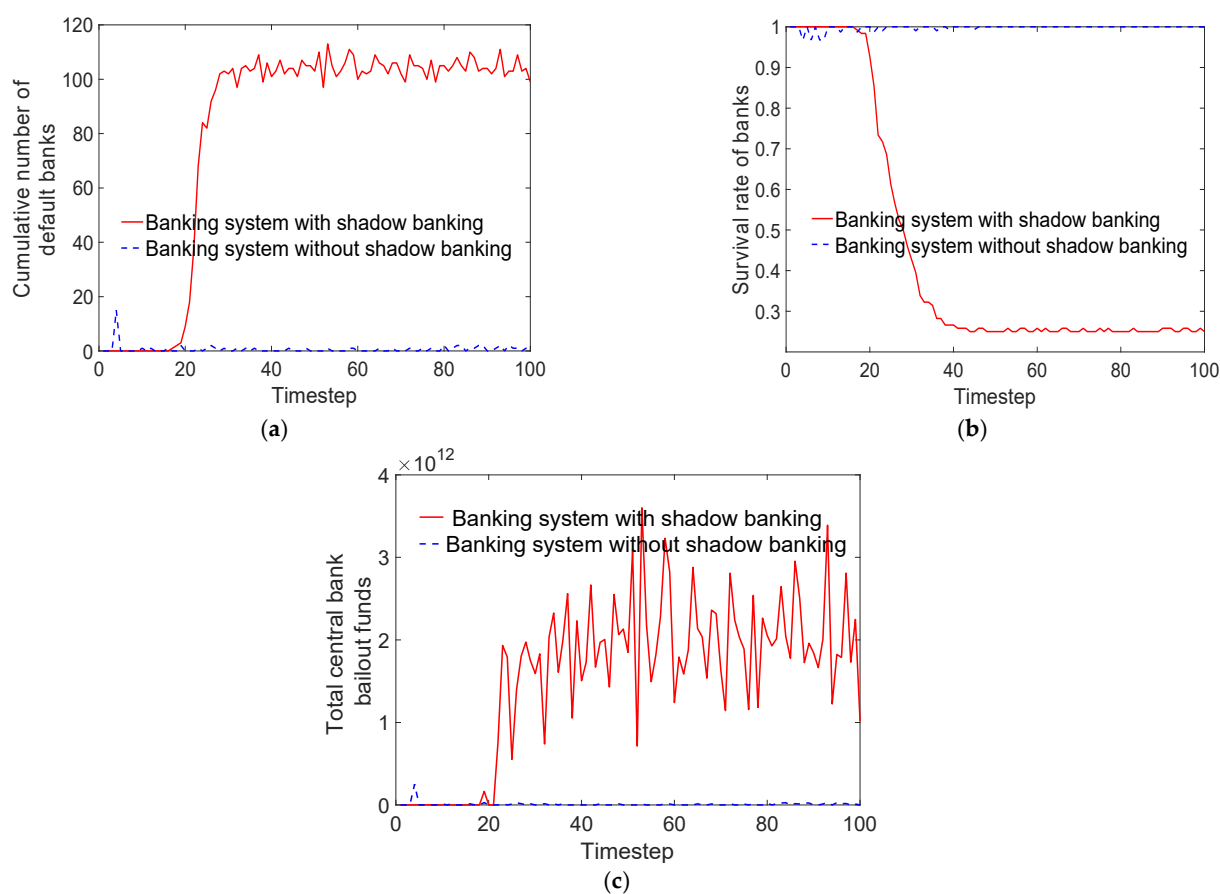


Figure 5. (a–c) Effects of shadow banking on the cumulative number of default banks, the survival rate of banks, and the total amount of central bank bailout funds within the banking system, respectively.

4.3. Shadow Banking's Performance

Systemic risk is significantly based on liquidity, investment opportunities, and average profit. Hence, an in-depth analysis of the impacts of shadow banking activities on these factors within the banking system could enhance our understanding of how shadow banking operations contribute to systemic risks and influence sustainable development of China's banking. Figure 6 illustrates the impacts of shadow banking operations on the banking system's liquidity, investment opportunities, and average profit. Figure 6a demonstrates that the liquidity of the banking system has been enhanced by shadow banking operations. This enhancement in liquidity can be attributed to the ability of shadow banking operations to bypass regulatory measures, such as capital adequacy controls, credit size restrictions, and investment project limitations, thereby mitigating liquidity constraints and augmenting the banking system's liquidity. As illustrated in Figure 6b, akin to enhancing liquidity, shadow banking operations have the potential to augment investment opportunities for banks within the system. By supplying abundant liquidity, shadow banking operations allow banks to obtain more investment prospects and allocate resources more effectively. Consequently, shadow banking operations augment investment opportunities in China's banking system, compared to systems devoid of such operations. However, it is worth noting that, as depicted in Figure 6c, although shadow banking operations may initially elevate the average profit of banks, over time, this profit tends to gradually decline, even dipping into the negative. This demonstrates that shadow banking's high-profit arbitrage activities, achieved through regulatory evasion, generate elevated returns in the short term. Accordingly, the average profit of banks linked with this credit increases, thereby boosting the overall banking system's average profit. Nevertheless, as the extent of regulatory arbitrage in shadow banking operations intensifies, so does the systemic risk it engenders. In the event of shadow bank activities defaulting due to

insolvency, affiliated banks may rapidly plunge into financial turmoil, leading to a decrease or even a downturn in the banking system's average profit.

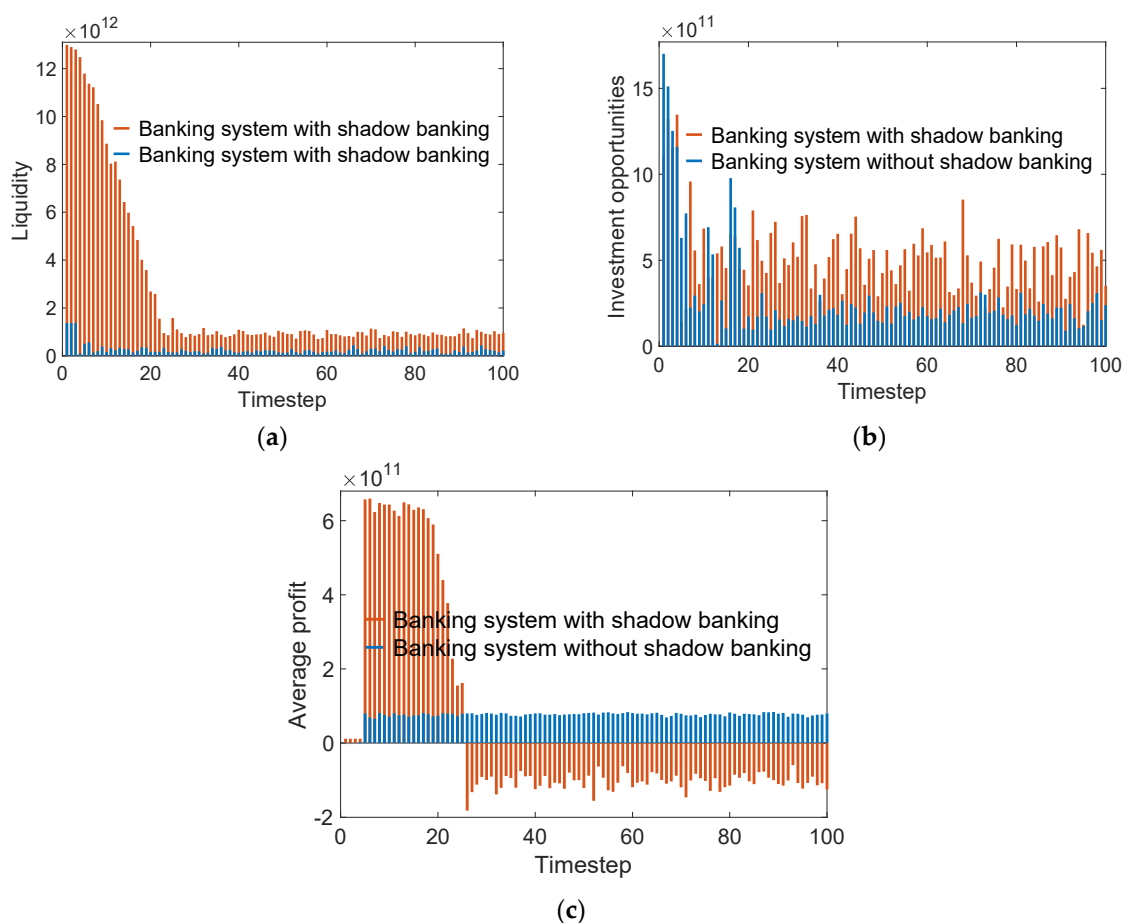


Figure 6. (a–c) Effects of shadow banking on the liquidity, investment opportunities, and the average profit of the banking system, respectively.

As demonstrated above, shadow banking operations contribute significantly to the sustainability of China's banking system through its impact on liquidity, investment opportunities, and average profit. Thus, a more detailed investigation into the extent and intensity of the effects of various types (shadow bank I, shadow bank II, and shadow bank III) of shadow banking operations on the banking system is imperative for policymakers and regulators to implement effective regulations and reasonable control over shadow banking.

The evolution of the liquidity, investment opportunities, and average profit for the three categories of shadow banking operations in the banking system is illustrated in Figure 6. Specifically, the liquidity of shadow bank I, denoted by the range of 1–3-month WMPs, is significantly higher compared to shadow bank II and shadow bank III, represented by the range of 3–6-month and 6–12-month WMPs, respectively, as depicted in Figure 7a. Furthermore, the data in Figure 7c indicate that shadow bank I generates a higher average profit than the other two categories of shadow banking (shadow bank II and shadow bank III). These findings suggest that regulatory arbitrage in the realm of shadow banking operations is more pronounced in short-term WMPs compared to medium- and long-term WMPs. Regulatory arbitrage facilitates the ability of shadow banking operations, particularly through short-term WMPs, to generate excessive returns and enhance liquidity, thereby exerting a more pronounced influence on systemic risk and being more averse to banking sustainable development. As WMPs have matured, however, their impact on systemic risk has diminished. In contrast to the variations in liquidity and average

profit, Figure 7b demonstrates the significant impact on investment opportunities from the three categories of shadow banking operations. This illustrates that the impact of shadow banking operations on investment opportunities is analogous, as various forms of shadow banking activities (different-term WMPs) all contribute liquidity to the system and enhance banks' access to diverse investment prospects. This observation also indicates that, although the impact of different categories of shadow banking operations on banking system stability may vary in magnitude, there is a consistent trend towards increasing vulnerability within the banking system.

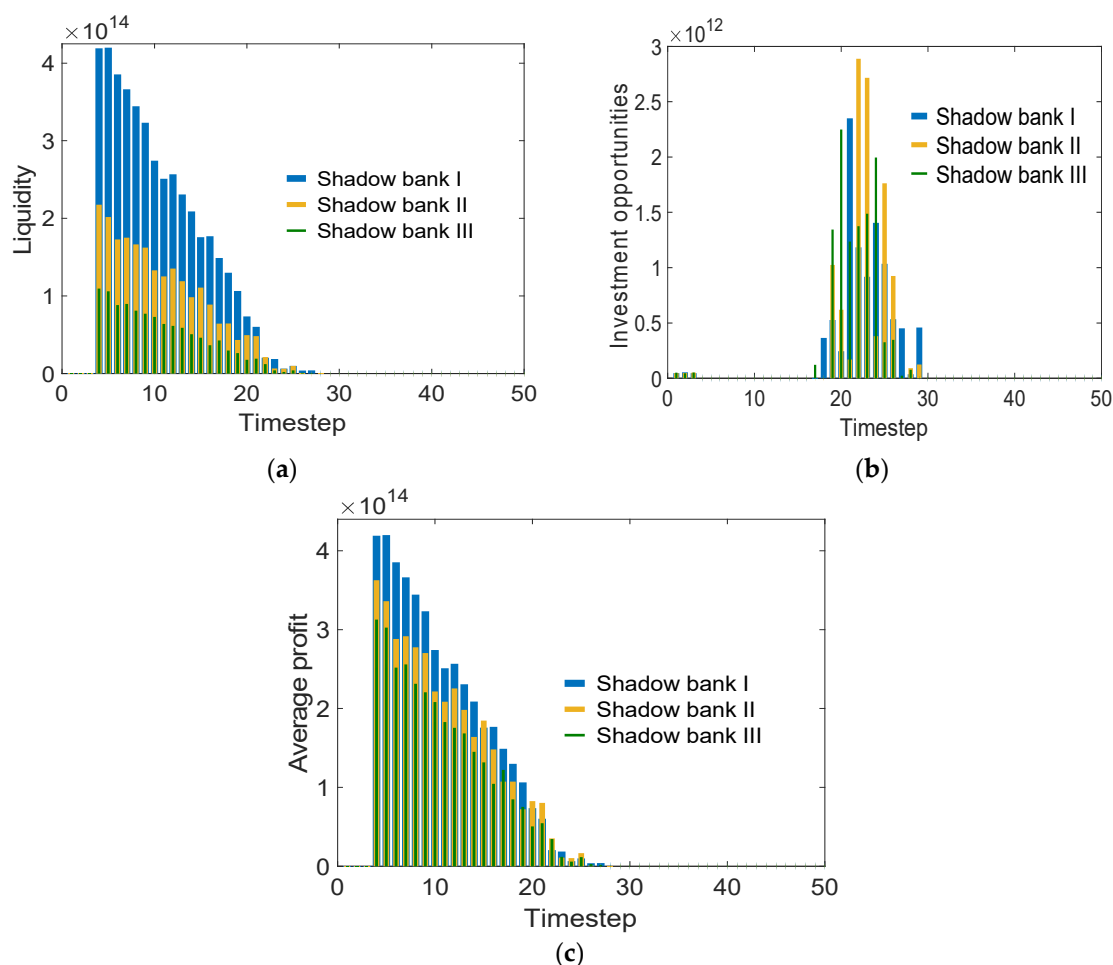


Figure 7. (a–c) Liquidity, investment opportunities, and average profit across various categories of shadow banking, respectively.

4.4. Shadow Banking's Effect on Commercial Banks

The above analysis demonstrates the impact of shadow banking activities on banking systemic risk and sustainable development, and highlights the disparate effects of different categories of shadow banking operations. Furthermore, this study aims to investigate the specific implications of shadow banking operations for heterogeneous commercial banks' sustainable development within the banking system.

The specific impacts of shadow banking operations on the liquidity of the 31 listed commercial banks are illustrated in Figure 8. It is evident that shadow banking activities have significantly augmented the liquidity of all commercial banks compared to their liquidity under a non-shadow banking scenario within the banking system. State-owned banks, such as BOC, CCB, ICBC, and ABC, exhibit elevated levels of liquidity when shadow banking operations are not taken into consideration, whereas joint-stock banks, local banks, and rural commercial banks demonstrate comparatively lower liquidity. These changes

in liquidity primarily stem from the scale of a commercial bank's own assets, its business investment strategy and direction, as well as the macroeconomic environment. Within a banking system devoid of shadow banking activities, commercial banks maintain a stable level of liquidity. However, the operations of shadow banking have resulted in a liquidity shock to the banking system. Notably, besides state-owned banks such as BOC and CCB, joint-stock banks, like EB and HB, local banks, including BOB and BOS, as well as rural commercial banks, like WRCB and QRCB, have also experienced significant increases in liquidity levels. This finding contradicts the notion that only large banks are affected by shadow banking [36]. Moreover, it signifies a broader and deeper impact of shadow banking operations on China's banking system liquidity. Given the close relationship between liquidity and systemic risk, it can be inferred that shadow banking acts as one of the primary catalysts for volatility within the banking system.

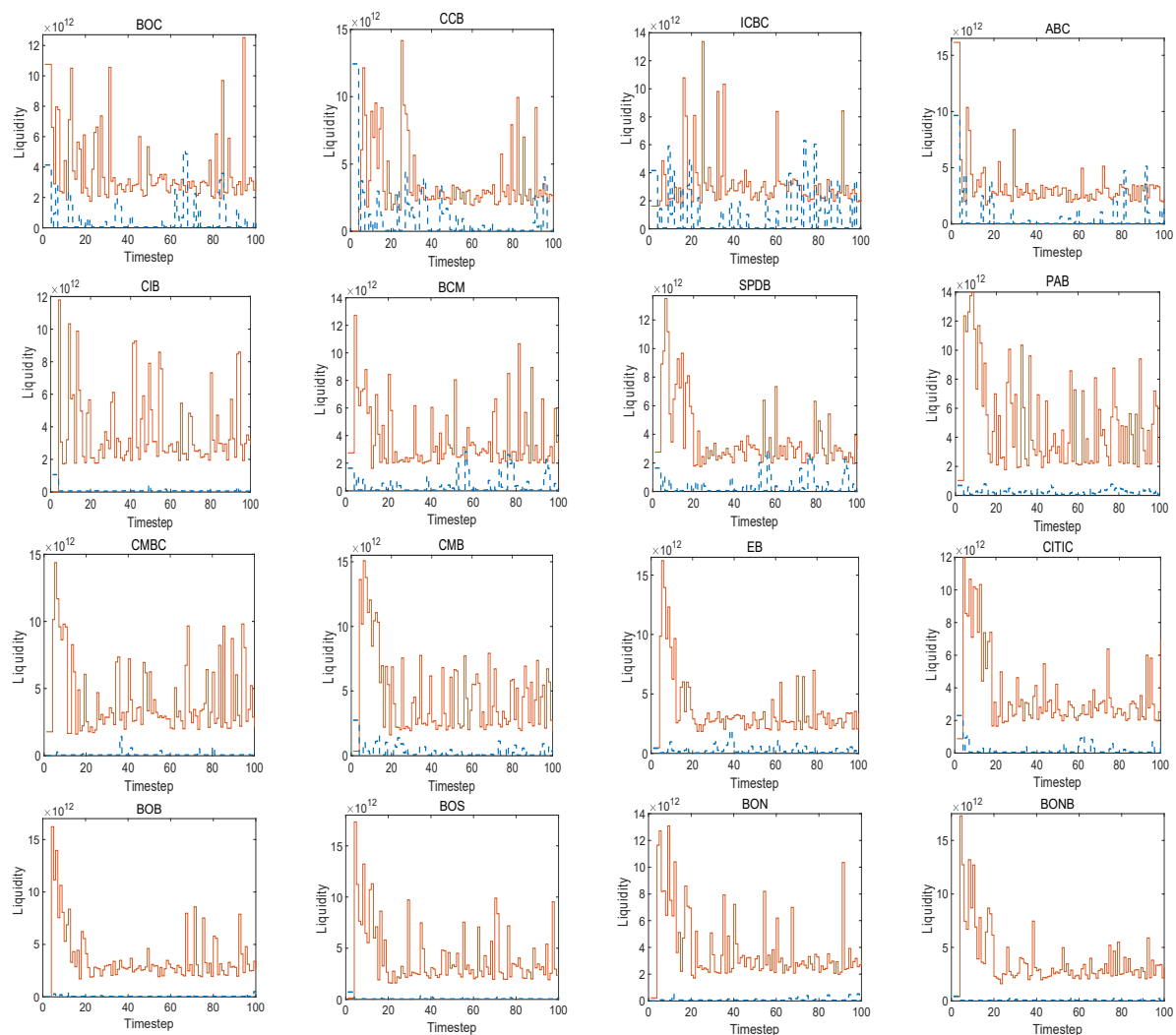


Figure 8. Cont.

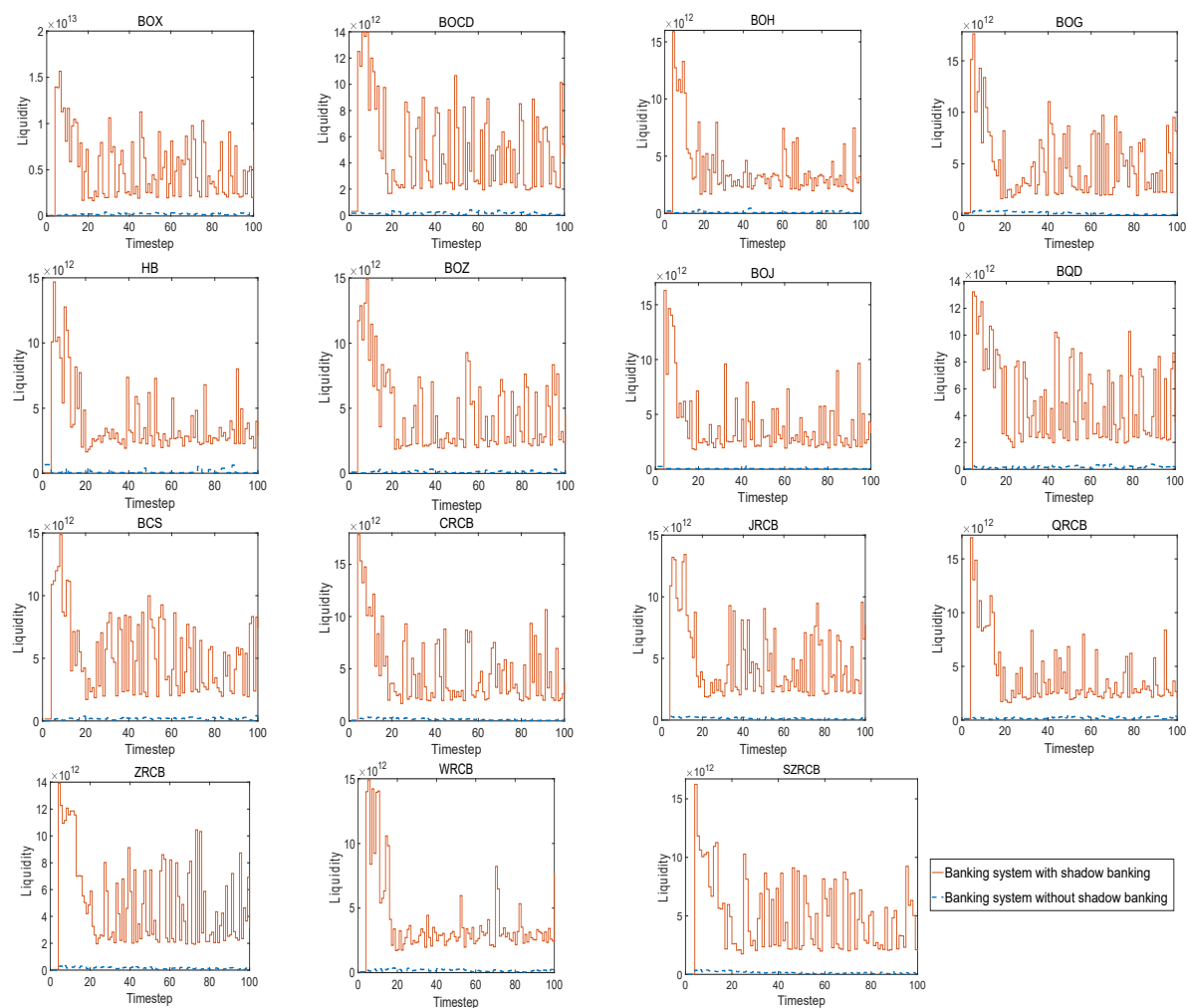


Figure 8. Impacts of shadow banking on the liquidity of commercial banks.

Figure 9 illustrates the specific impact of shadow banking activities on investment opportunities for commercial banks within the banking system. It is evident that the presence of shadow banking has augmented investment prospects for all categories of commercial banks, albeit with variations in performance among different types. For state-owned banks, such as BOC and ABC, as well as joint-stock banks, like SPDB and CIB, the original investment opportunities were already relatively high. The performance of shadow banking operations has indeed enhanced their investment opportunities, albeit not significantly. However, the execution of shadow banking activities has significantly enhanced investment opportunities for local banks, such as BOCD and BOX, as well as rural commercial banks, like WRCB and QRCB. This is attributed to the relatively limited branch networks of local and rural commercial banks compared to state-owned and joint-stock banks, resulting in their comparatively lower ability to attract deposits. Consequently, shadow banking operations serve as a significant source of supplementary liquidity for these banks. This also indicates the proactive business strategies adopted by local banks and rural commercial banks in addressing shadow banking, alongside their relatively higher leverage ratios. The above example demonstrates that commercial banks with different attributes exhibit distinct responses to shocks originating from shadow banking. In comparison to large state-owned and joint-stock banks, small- and medium-sized local banks as well as rural commercial banks display greater vulnerability towards significant changes resulting from the impact of shadow banking. This is because shadow banking has a serious impact on banking sustainability, and these smaller institutions are more

reliant on the sustainable development of banking. While shadow banking has expanded investment opportunities for these banks, it has also engendered vulnerabilities and risks.

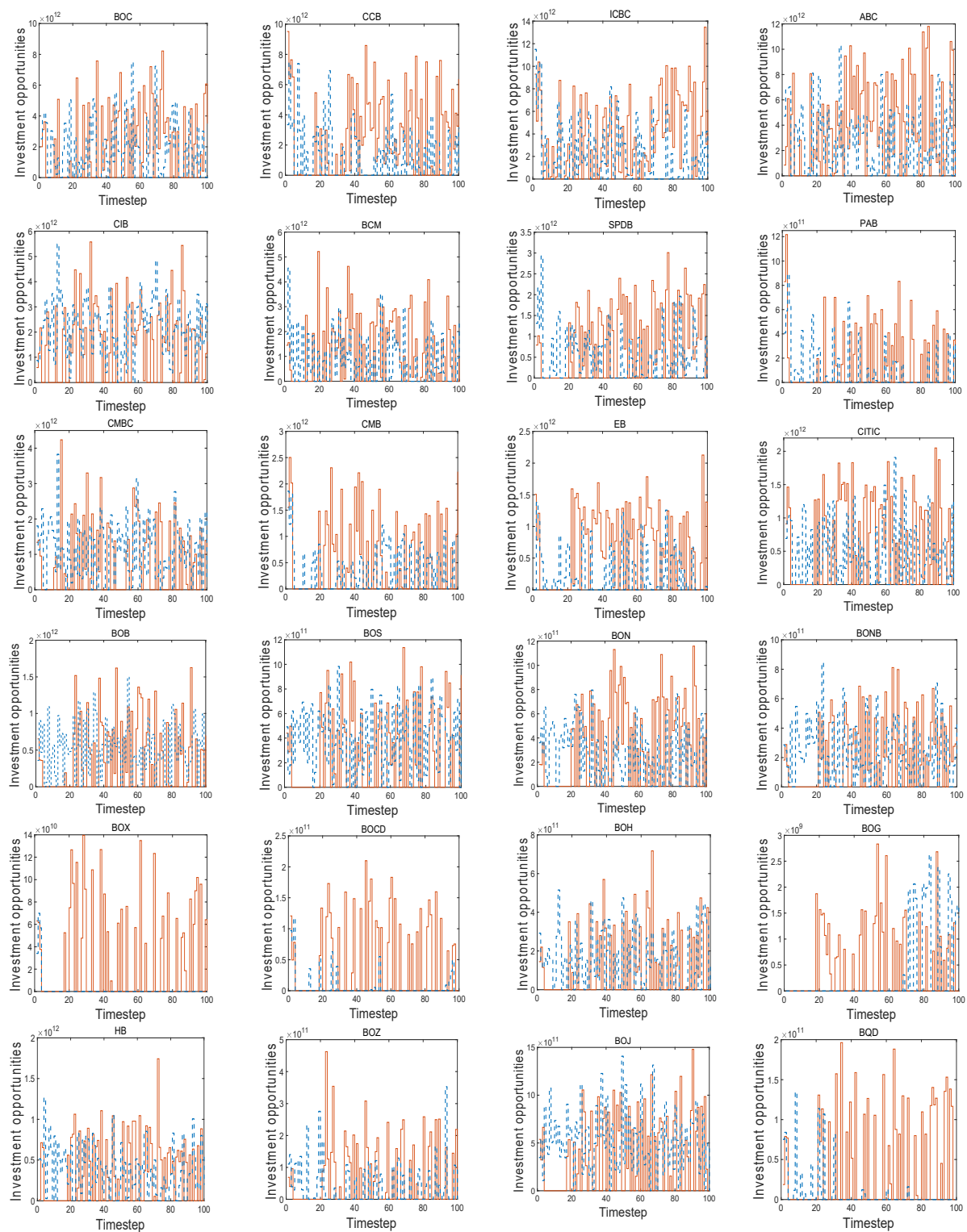


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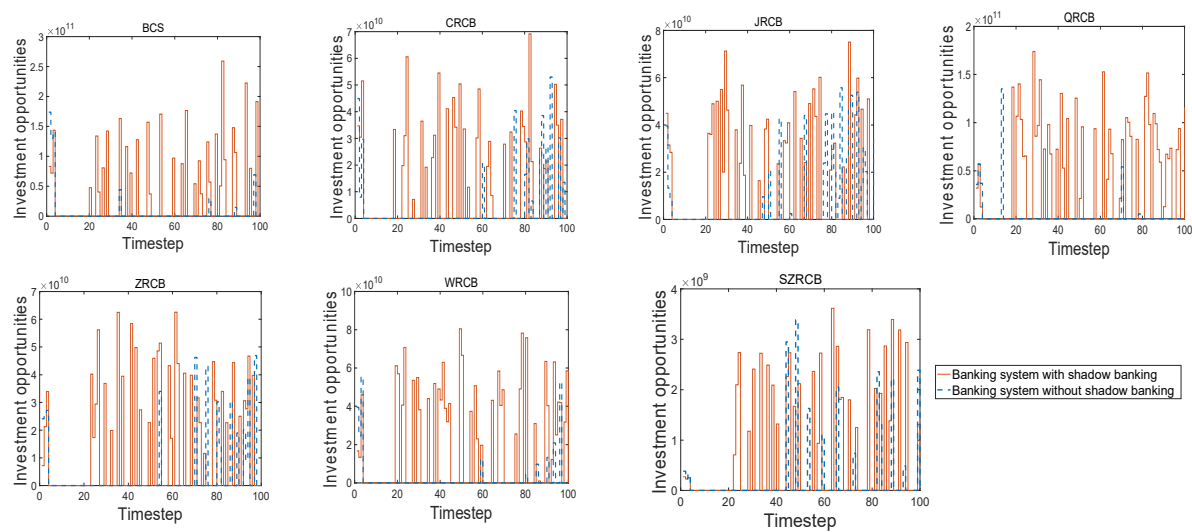


Figure 9. Impacts of shadow banking on the investment opportunities of commercial banks.

The precise impact of shadow banking operations on the profit of commercial banks within China's banking system is illustrated in Figure 10. Evidently, within the banking framework without shadow banking, all commercial banks demonstrate positive profits. State-owned banks, such as BOC and ICBC, along with joint-stock banks, like CIB and SPDB, exhibit significantly higher profits compared to other local and rural commercial banks. This indicates that large state-owned banks directly controlled by the state and joint-stock banks with state involvement have a greater capacity to generate profits, crucial for upholding banking system sustainability. Upon the introduction of shadow banking operations into the banking system, however, the profit of all commercial banks notably decreased and sustained negative levels. This demonstrates the substantial impact of shadow banking activities on the profitability of commercial banks. Although shadow banking offers crucial additional liquidity to commercial banks, they are compelled to pay a higher risk premium to compensate for the limited liquidity resulting from shadow banking's unorthodox and hazardous business practices. Additionally, commercial banks encounter rollover risks associated with shadow banking due to maturity mismatch. These factors can lead to ineffective investments by commercial banks, resulting in declining profits and eventually leading to negative profit growth. Although the impact of regulatory arbitrage in shadow banking may vary based on the type of commercial bank, it is undeniable that the risks stemming from shadow banking can significantly compromise the sustainable development of the banking system. This underscores the critical need to streamline the credit connection between commercial banks and shadow banking, regulate and oversee shadow banking activities effectively, and develop tailored regulatory strategies for different commercial bank types.

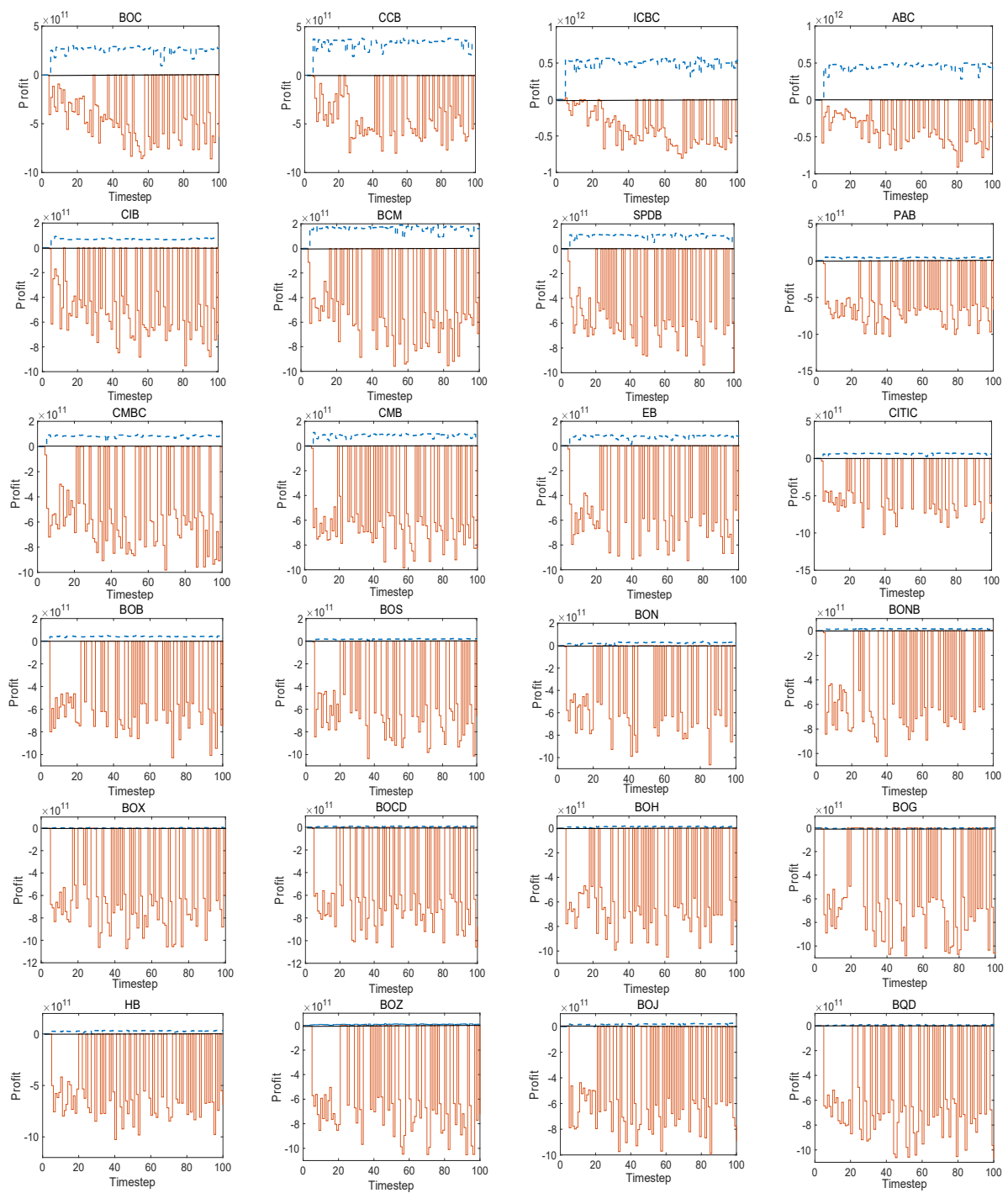


Figure 10. Cont.

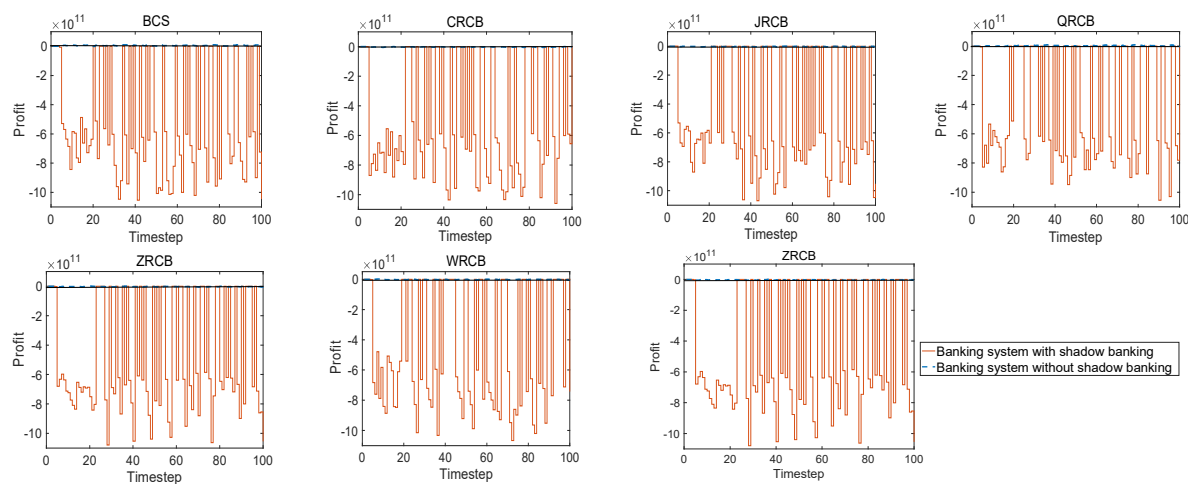


Figure 10. Impacts of shadow banking on the profits of commercial banks.

5. Conclusions and Implications

In response to the global financial crisis, the Chinese government implemented a robust economic stimulus package aimed at stabilizing the economy. However, this initiative has inadvertently fueled an exponential growth of shadow banking in China. If not effectively regulated, this phenomenon could pose serious threats to the sustainable development of China's financial and economic sectors. The present study investigates the impact of shadow banking on China's financial system, which serves as the cornerstone of its finance sector. It also delves into the association between shadow banking operations, predominantly exemplified by WMPs, and systemic risk within the banking domain. Significant contributions to the existing literature in three key areas are made: firstly, by expanding the investigation into the sources of banking systemic risks; secondly, by filling the gap in understanding how shadow banking propagates risks through interbank network channels, considering the dynamic economic behavior exhibited by banks; and thirdly, by adding risk aversion regulations of shadow banking operations and promoting the sustainable development of banking. Moreover, bank-level microdata are employed to further examine the variability in the impact of different categories of shadow banking and explore its heterogeneous effects on various types of commercial banks.

The study finds that shadow banking, exemplified by WMPs, indeed transmits risks through the complex dynamic interbank network, thereby augmenting the vulnerability of China's banking system. Using the three key metrics of the banking system, we find that, while shadow banking, characterized by regulatory arbitrage and high-risk attributes, may sustain short-term banking system stability, in the long run, it is likely to substantially elevate the occurrence of bank defaults, diminish the survival rate of banks, and intensify reliance on central bank bailouts. The impact performance of shadow banking is further analyzed, and the results show that shadow banking circumvents the liquidity constraints imposed by relevant policies, thereby significantly enhancing China's banking system liquidity and improving investment opportunities. However, inefficient investments due to maturity mismatch can substantially reduce the average profit. Finally, the results reveal that, among three categories of WMPs, shadow banking associated with short-term WMPs exerts a more pronounced influence on liquidity, investment opportunities, and profitability, while simultaneously presenting heightened systemic risk. Moreover, compared with state-owned and joint-stock commercial banks, local banks and rural commercial banks may be heavily impacted by shadow banking operations regarding their liquidity, investments, and profits due to a limited branch network and reduced ability to attract deposits.

The results provide several policy insights into bank management and policymakers to effectively oversee and regulate the sustainable development of shadow banking in China. Firstly, although certain aspects of shadow banking have been brought into view following regular oversights in recent years, there remains a dearth of specific relevant

regulatory policies tailored to individual categories within the realm of shadow banking. Therefore, it is imperative to implement a stratified regulatory approach for shadow banking with diverse risk profiles, particularly those involving high-risk financial instruments, such as asset-backed securities, necessitating more stringent capital and liquidity management protocols. Secondly, accelerating the resolution of issues related to information disclosure and transparency is imperative for the effective regulation of shadow banking. Financial regulatory authorities should establish mandatory disclosure regulations and improve the transparency and efficiency of risk management in the financial market, for instance, by establishing a centralized information platform. Concurrently, regulatory authorities should conduct periodic risk assessments and stress tests on shadow banking to promptly recalibrate regulatory strategies and safeguard the stability of the financial system. Thirdly, it is imperative to incentivize pertinent shadow banking entities to embrace financial technological tools (e.g., blockchain and artificial intelligence) in order to refine the precision of their risk management practices and augment transparency within their operational framework. Simultaneously, paying attention to international cooperation is a crucial component in the effective regulation of shadow banking, achieved through the establishment of a robust information-sharing platform to harmonize regulatory policies. Finally, it is advisable to establish a transparent exit mechanism for shadow banking and potential bailout policies, considering the high-risk spillover characteristics of shadow banking and promoting internal risk management of financial institutions. The transition of credit linkages within the financial system should be facilitates from “unconstrained” to “constrained”, encouraging commercial banks to strategically leverage shadow banking operations for orderly development. The aforementioned policy recommendations are designed to offer regulatory authorities a comprehensive and systematic regulatory framework for the promotion of sustainable development within the shadow banking, ultimately fostering high-quality and sustainable growth within the financial industry.

Shadow banking in the financial market has diversity, and focusing solely on WMPs to represent shadow banking operations may lead to bias in exploring the impact of systemic risks caused by shadow banking on sustainable development and restricted model assumptions. Meanwhile, the banking system in China differs from that in developed Western markets, and the risks associated with shadow banking may vary across different banking systems. Furthermore, in order to assess the sustainability of banking, it is imperative not only to investigate the mechanisms of internal risks, but also to scrutinize the ramifications of external liquidity shocks. Therefore, there remain numerous aspects requiring study in future work. For example, by gathering a wider range of shadow banking data for a comprehensive analysis to enhance the model’s accuracy and broaden the applicability of research findings; undertaking a comparative analysis of the Chinese banking system in relation to that in other nations, in order to attain a wider perspective for research purposes; and analyzing specific liquidity shock events (e.g., 2013 cash crunch and 2022 turmoil in the stock), we can gain a deeper understanding of the impact of liquidity risks on shadow banking activities, offering more comprehensive and effective recommendations for the formulation of financial regulatory policies and the sustainable development of banking.

Author Contributions: Conceptualization, H.P. and H.F.; methodology, H.P.; software, H.P.; validation, H.P.; formal analysis, H.P.; resources, H.P.; data curation, H.P.; writing—original draft preparation, H.P.; writing—review and editing, H.F.; supervision, H.F. All authors contributed to writing the paper. All authors have read and agreed to the published version of the manuscript.

Funding: The authors are grateful for the support provided by the Philosophy and Social Science Project of Zhejiang Province of China (24NDQN030YB).

Institutional Review Board Statement: Written informed consent was obtained from individual or guardian participants.

Informed Consent Statement: Written informed consent for publication was obtained from all participants.

Data Availability Statement: The data are available from the corresponding authors upon request.

Conflicts of Interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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