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Derivatives holdings and bank systemic risk: Cross-country evidence

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ABSTRACT

In this paper, we analyse data from 493 listed banks across 28 countries to investigate the impact and mechanisms through which banks' derivatives holdings influence systemic risk. Our empirical results indicate that banks' derivatives holdings significantly increase systemic risk. Regarding the underlying mechanisms, we find that derivatives holdings increase systemic risk by increasing asset risk, leverage risk, and operational risk. After conducting a series of robustness checks, our findings remain consistent. Heterogeneity analysis reveals that the effect of banks' derivatives holdings on systemic risk is particularly pronounced during periods of economic downturns and accommodative monetary policy. Furthermore, this influence is especially significant when banks exhibit higher leverage and lower liquidity. We also examine the differential impacts of various types of derivatives holdings on systemic risk. Our research enriches the understanding of the driving factors and transmission channels of systemic risk, assisting regulatory agencies in better identifying and addressing the systemic risk associated with derivatives holdings.

1. Introduction

In recent years, the widespread application of financial technology across countries and the significant reduction in the costs of financial innovation have led to rapid growth in the derivatives market. According to data from the Bank for International Settlements, as of June 2023, the notional amount of global over-the-counter derivatives reached a staggering \$714.7 trillion. Moreover, banks, as major participants in the derivatives market, have significantly increased their derivatives holdings, which has become a crucial factor driving the growth of bank size (Mayordomo et al., 2014). For banks, derivatives can serve as essential tools for managing macro risks such as interest rate and exchange rate risks, thereby ensuring their effective functioning as financial intermediaries (Li and Marinč, 2014). However, derivatives have also evolved into important instruments for investment and speculation, providing banks with enhanced returns while simultaneously exposing them to greater risks (Hirtle, 2009; González et al., 2016; Trapp and Weiß, 2016). Misuse of derivatives can lead to substantial risks for banks, potentially resulting in catastrophic losses. For example, in the 2012 "London Whale" incident, JPMorgan Chase suffered billions of dollars in losses due to a failed derivatives trading strategy. Additionally, the complex structures of derivatives often render their risks

opaque, making it challenging for regulatory authorities to measure and supervise them effectively, which further exacerbates the accumulation of risk. As financial intermediaries are responsible for credit transformation, maturity transformation, and liquidity transformation, the stability of the banking sector is crucial for the normal functioning of the real economy and the overall stability of the financial system. In this paper, we analyse the economic consequences of banks' derivatives holdings from the perspective of systemic risk, thereby contributing to the literature on this subject.

Since the 2008 global financial crisis, systemic risk has attracted significant attention from both regulators and academics. Authorities such as the Financial Stability Board and the Bank for International Settlements describe systemic risk as a threat that can rapidly spread within the financial system, disrupting financial services and potentially negatively impacting the real economy. This finding indicates that systemic risk not only possesses strong contagion and destructive power within the financial system but also has serious spillover effects on the real economy, adversely affecting macroeconomic stability. In this context, identifying the drivers of systemic risk, understanding its transmission channels, and developing effective strategies for prevention and mitigation are of vital theoretical and practical importance.

In recent years, scholars have extensively studied the determinants of

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systemic risk. Some studies analysed banks' systemic risk's driving factors from a macro perspective. For example, [Chen et al. \(2021\)](#) discover that a stringent regulatory environment can lead to capital shortages for banks during crises, resulting in more severe systemic risk. [Wang et al. \(2025\)](#) find that sudden stops in international capital inflows significantly increase a country's systemic risk. Additionally, some researchers point out that public health emergencies, such as the COVID-19 pandemic, negatively impact the stability of the financial system ([Duan et al., 2021](#)). Furthermore, banks typically exhibit a greater contribution to systemic risk in environments of elevated economic policy uncertainty ([Duan et al., 2022](#)).

Moreover, some studies have examined the determinants of systemic risk from a micro perspective by incorporating banks' financial indicators. For example, most studies suggest that systemic risk is proportional to bank size. Large banks tend to have more complex asset portfolios, exhibit closer interconnections with other institutions in the financial system, and possess a higher level of irreplacability. When crises occur, large banks usually experience greater losses, leading to more serious impacts on financial stability and, consequently, a greater contribution to systemic risk ([Laeven et al., 2016](#)). Furthermore, some empirical studies indicate that factors such as bank leverage, the noninterest income ratio, the long-term total liabilities ratio, and equity structure all influence bank systemic risk ([Acharya and Kulkarni, 2012](#)).

While prior research has discussed how banks' derivatives holdings influence corporate behaviour and value (e.g., [Choi et al., 2016](#); [Said, 2011](#)), there is still limited exploration of how derivatives holdings affect bank systemic risk contributions. Only a few studies, such as [Mayordomo et al. \(2014\)](#) and [Teeramongkol and Leemakdej \(2018\)](#), have conducted preliminary analyses on individual country bank samples. At the same time, existing research lacks an exploration of the mechanisms through which banks' derivatives holdings impact systemic risk. In this context, we conduct the most detailed study to date on the effects of banks' derivatives holdings on systemic risk and their underlying mechanisms, utilizing a more representative cross-country sample, thereby addressing the gap in the current literature.

In this paper, we empirically examine the relationship between derivatives holdings and bank systemic risk using data from publicly listed banks in 28 countries from 1999 to 2020. The results show that derivatives holdings significantly promote bank systemic risk. Our subsequent examination of the underlying mechanism reveals that derivatives holdings can increase systemic risk by increasing banks' asset risk, leverage risk, and operational risk. In terms of macro heterogeneity, we find that when the real economy in a bank's home country experiences lower growth and a more accommodating monetary environment, derivatives holdings are more likely to lead to greater systemic risk. With respect to micro heterogeneity, when a bank has a higher leverage ratio and a lower ratio of liquid assets, the promoting effect of derivatives holdings on systemic risk becomes more pronounced. Furthermore, by categorizing the derivatives holdings, we discover that the promotion of systemic risk primarily stems from interest rate derivatives, equity derivatives, commodity derivatives, and credit derivatives, whereas foreign exchange derivatives have no significant impact.

This paper contributes to the literature primarily in the following areas:

First, compared with existing studies, we conduct a detailed analysis of the relationship between banks' derivatives holdings and systemic risk using more representative data. Our findings show that banks' derivatives holdings significantly increase systemic risk. Furthermore, through the categorization of derivatives, we identify the distinct effects of different types of derivatives on systemic risk, thereby contributing to a more nuanced understanding of the relationship between derivatives holdings and bank systemic risk.

Second, through theoretical analysis and empirical testing, we demonstrate that banks' derivatives holdings increase systemic risk via asset risk, leverage risk, and operational risk channels. The literature on systemic risk mechanisms predominantly concentrates on specific types

of channels, such as bank assets or liabilities ([Black et al., 2016](#); [Duan et al., 2021](#)). By thoroughly examining both the asset and liability sides of banks, along with their operational risks, this paper provides fresh insights into the pathways that contribute to systemic risk.

The structure of this study is as follows: Section 2 provides an overview of the literature and develops the hypotheses. Section 3 describes the data, variables, and empirical model. Section 4 reports and discusses the empirical results. Section 5 analyses the channels through which derivatives holdings affect banks' systemic risk. Section 6 presents the heterogeneous effects. Section 7 presents the differential impact of different types of derivatives on systemic risk. Finally, in Section 8, we conclude the study.

2. Literature review and hypothesis development

2.1. Literature review

Our research is closely related to the literature on banks' derivatives holdings and systemic risk.

First, a body of literature exists that focuses on the drivers and economic consequences of banks' derivatives holdings. Studies on the factors driving banks' derivatives holdings indicate that banks with lower capital adequacy ratios, higher loan write-offs, and narrower net interest margins are more inclined to use derivatives ([Sinkey and Carter, 2000](#)). Additionally, larger asset and loan sizes, as well as lower bank concentration, are significant factors encouraging banks to engage in derivatives trading ([Bazih and Vanwalleghem, 2021](#)). Most research focuses on the economic consequences of banks' derivatives holdings, which can be broadly categorized into value effects and risk effects.

In terms of value effects, there is no consensus in academia regarding how banks' derivatives holdings impact their value. Some studies suggest that engaging in derivatives trading enhances bank efficiency, thereby positively affecting bank value ([Chang et al., 2018](#); [Choi et al., 2016](#); [Said, 2011](#)). For instance, [Chang et al. \(2018\)](#) find that European banks using derivatives achieve higher profitability and increased deposit inflows, ultimately increasing bank value. Similarly, [Choi et al. \(2016\)](#) use data from US bank holding companies (BHCs) to show that derivatives held for hedging purposes contribute to increased bank value. [Said \(2011\)](#) also finds a positive correlation between derivatives usage and bank performance and efficiency, leading to improved market value. However, some studies have presented conflicting conclusions. For example, [Bazih and Vanwalleghem \(2021\)](#) examine banks in developing countries and find that derivatives usage diminishes the value of emerging market banks. [Miloş and Miloş \(2022\)](#) also find that, owing to suboptimal risk hedging effects or excessive volatility in derivatives returns, banks' holdings and use of derivatives can harm their market value.

Regarding the risk effects of banks' derivatives holdings, most studies indicate that these holdings increase banks' risk exposure, thereby increasing their risk and vulnerability ([Attig and Dai, 2009](#); [Ghosh, 2017](#); [Keffala, 2015](#); [Li and Marinč, 2014](#); [Trapp and Weiß, 2016](#)). For instance, [Keffala \(2015\)](#) uses data from banks in emerging market countries and employs a GMM model to examine the impact of derivatives on bank stability before and after the 2008 financial crisis, finding that the use of options and futures significantly undermines bank stability. Similarly, [Ghosh \(2017\)](#) analyses data from US commercial banks and finds that in the postcrisis period, banks' holdings of derivatives reduce profitability, thereby increasing the likelihood of default and bankruptcy. [Li and Marinč \(2014\)](#) use data from US BHCs to look into the relationship between using derivatives and risk exposure. They find that banks' risk exposure increases when they use interest rates, exchange rates, and credit derivatives. This positive relationship between derivatives and risk is applicable to both trading and hedging derivatives. [Attig and Dai \(2009\)](#) reach similar conclusions based on Canadian bank data. [Trapp and Weiß \(2016\)](#) explore how banks' derivatives holdings affect equity returns during financial crises and find

that banks that use derivatives more extensively suffer greater shocks, leading to extreme losses in equity value.

On the other hand, some studies suggest that banks' derivatives holdings do not necessarily increase their risk levels and that holding certain types of derivatives may actually help reduce risk in the banking sector (Bazih and Vanwalleghem, 2021; Mayordomo et al., 2014; Purnanandam, 2007). For instance, Bazih and Vanwalleghem (2021) find in their study of emerging market banks that hedging derivatives can effectively promote bank stability and lower bankruptcy risk. Mayordomo et al. (2014) investigate the relationship between banks' derivatives holdings and systemic risk using US bank data and conclude that overall, derivatives trading does not increase systemic risk, whereas interest rate derivatives may help reduce it. Purnanandam (2007) finds that using derivatives as risk management tools enables banks to better manage risks and enhance operational efficiency. Additionally, some research suggests that the purpose of holding derivatives determines their impact on bank risk. For instance, Li and Yu (2010) contend that derivatives offer a dual effect: their use for hedging can reduce potential risks, but their speculative use could increase overall risk levels for commercial banks.

Another relevant body of literature focuses on the bank systemic risk. Systemic risk can be rapidly transmitted within financial markets, leading to failures in the inherent mechanisms of the financial system while also imposing substantial adverse shocks on the macroeconomy (Rodríguez-Moreno and Peña, 2013). In light of the serious threat that systemic risk poses to the economic and financial system, regulators and academics are increasingly emphasizing the identification and prevention of systemic risk drivers. Since the 2008 global financial crisis, numerous studies have explored how macroeconomic factors influence the systemic risk of individual banks. For example, Black et al. (2016) find that heightened sovereign default risk during the European debt crisis significantly increased the systemic risk of individual banks. Brunnermeier et al. (2020) show that asset price bubbles in real estate and stock markets can increase the systemic risk of banks in the host country. Chen et al. (2021), using cross-country data and promoting Basel II regulation as an exogenous shock, has discovered that strict regulatory constraints exacerbate banks' contribution to systemic risk. Duan et al. (2021) examine the impact of the COVID-19 pandemic on banking system stability and find that the severity of the pandemic is positively correlated with banks' systemic risk levels. Andries and Balutel (2022) investigate the factors influencing systemic risk from a cultural perspective and conclude that individualism and masculinity serve as primary drivers of bank systemic risk. In addition, some papers investigate how to prevent and mitigate systemic risk. For example, Meuleman and Vander Venet (2020) find that the use of macroprudential policies can help alleviate bank systemic risk and maintain the stability of the financial system.

Moreover, numerous studies emphasize that systemic risk is influenced not only by external shocks or macroeconomic factors but also by microlevel factors at the bank level. An extensive body of literature explores how financial indicators and business structures affect bank systemic risk levels. For instance, research by Bostandzic and Weiss (2018) and Varotto and Zhao (2018) identifies bank size as a primary driver of systemic risk, with larger banks typically contributing more to systemic risk. Furthermore, banks with higher leverage, lower asset liquidity, and poorer loan quality generally exhibit greater systemic risk (Wang et al., 2025). Yang et al. (2020), using income composition data from US commercial banks, investigate how business diversification affects systemic risk and report that diversification leads to more serious systemic risk.

2.2. Hypothesis development

Through a literature review, we find that while there is growing interest in systemic risk among academics and regulators, research on the microlevel drivers of systemic risk from the perspective of bank asset

holdings is relatively limited. Specifically, studies on how banks' derivatives holdings influence their individual contributions to systemic risk remain scarce. This paper incorporates the behaviour of banks' derivatives holdings into the analysis system of systemic risk drivers, establishes the connection between banks' derivatives holdings and systemic risk, and proposes potential mechanisms. These findings contribute to a deeper understanding of the origins of systemic risk and provide a theoretical foundation for policy-makers and regulators to formulate relevant policies aimed at mitigating systemic risk.

Banks' derivatives holdings may significantly increase systemic risk for several reasons.

First, banks' derivatives holdings could significantly increase their asset risk. Research has shown that by using derivatives, banks can, on the one hand, improve their profit levels, increase their cash flow, and support banks in issuing more commercial loans (Purnanandam, 2007; Zhao and Moser, 2017); on the other hand, derivatives (especially credit derivatives) can provide banks with default protection, so holding derivatives will reduce banks' incentives to monitor credit assets and encourage banks to relax credit standards, thus leading to a decline in bank loan quality (Cebenoyan and Strahan, 2004; Shanker, 1996). As banks expand their loan portfolios while simultaneously reducing loan quality, the risk associated with these loans increases significantly. Given that loans are a core component of bank assets, this heightened loan risk inevitably contributes to an overall increase in the risk associated with bank assets. Additionally, the inherent complexity, flexibility, and riskiness of derivatives further increase asset risk. According to Berg and Gider (2017) and Duan et al. (2022), asset risk is a critical factor in increasing banks' contributions to systemic risk. As a result, banks' derivatives holdings may increase systemic risk through an elevated asset risk channel.

Second, banks' derivatives holdings may increase their leverage risk. As financial intermediaries, banks use monetary funds as their main business commodities and fulfil roles in credit transformation, maturity transformation, and liquidity transformation. In pursuit of profit maximization, banks typically maintain high leverage ratios while satisfying capital requirements. The use of derivatives enhances banks' credit risk management capabilities, lowers risk-based capital requirements, and encourages banks to operate with higher leverage (Cebenoyan and Strahan, 2004; Deng et al., 2021). While this increase in leverage can improve capital efficiency and increase bank value in a stable operating environment (Chang et al., 2018; Choi et al., 2016), adverse external shocks can more easily lead to capital shortfalls, defaults, or bankruptcies in highly leveraged banks. In such scenarios, higher leverage signifies increased leverage risk and systemic importance, resulting in elevated levels of systemic risk (Bostandzic and Weiss, 2018). Therefore, banks' derivatives holdings may contribute to increased systemic risk through the channel of leverage risk.

Third, banks' derivatives holdings may increase their operational risk. On the one hand, engaging in derivatives trading can lead to excessive confidence among bank managers regarding risk management, resulting in more aggressive asset allocation that does not align with the bank's actual risk management capabilities, thereby heightening operational risk (Instefjord, 2005). On the other hand, owing to the complex structure of derivatives, accounting information is difficult to disclose accurately, which exacerbates the information asymmetry between banks, their customers, and external regulators. Banks are more likely to engage in high-risk speculation due to the diminished effectiveness of external oversight and increased opportunities for earnings management (Adkins et al., 2007; Aslam and Haron, 2021; Hunjra et al., 2021). Since operational risk is also a significant source of systemic risk for banks (Lu and Wang, 2023), the derivatives holdings may contribute to increased systemic risk through heightened operational risk.

Through the preceding analysis, we propose the following hypotheses.

Hypothesis 1. Banks' derivatives holdings increase bank systemic

risk.

Hypothesis 2. Banks' derivatives holdings increase systemic risk by increasing asset risk, leverage risk, and operational risk.

3. Data and empirical model

3.1. Bank systemic risk

In this paper, we utilize ΔCoVaR as a systemic risk indicator, which has been extensively employed (Adrian and Brunnermeier, 2016; Chu et al., 2020; Duan et al., 2021). Following Duan et al. (2021), we apply a DCC-GARCH model to calculate ΔCoVaR as follows.

Based on the assumption that the return rate of a single bank i and the financial system of country j follow a binary normal distribution, we can obtain the following equation:

$$(X_{i,j,t}, X_{j,t}) \sim N\left(0, \begin{pmatrix} (\sigma_{i,j,t})^2 & \rho_{i,j,t}\sigma_{i,j,t}\sigma_{j,t} \\ \rho_{i,j,t}\sigma_{i,j,t}\sigma_{j,t} & (\sigma_{j,t})^2 \end{pmatrix}\right) \quad (1)$$

Where $X_{i,j,t}$ expresses the market value change rate of bank i and where $X_{j,t}$ represents the systemic return in country j . $\sigma_{i,j,t}$ and $\sigma_{j,t}$ represent the standard deviations of $X_{i,j,t}$ and $X_{j,t}$, respectively, and $\rho_{i,j,t}$ denotes the dynamic correlation coefficient between $X_{i,j,t}$ and $X_{j,t}$. In this paper, we utilize the DCC-GARCH (1,1) model to estimate the values of the aforementioned estimators, and the calculation Eq. (2) for systemic risk indicators is expressed as follows:

$$\Delta\text{CoVaR}_{i,j,t}(q) = -\Phi^{-1}(q)\rho_{i,j,t}\sigma_{j,t} \times 100 \quad (2)$$

We assume that $q = 0.05$, so that $\Phi^{-1}(0.05) = -1.96$. Furthermore, to visually display the results and avoid the variable regression coefficient being too small in the empirical analysis, we multiplied the calculation result of ΔCoVaR by -100 , so the larger the ΔCoVaR is, the greater the systemic risk.

3.2. Banks' derivatives holdings data

Our variable of interest is the level of banks' derivatives holdings (DH). Following Mayordomo et al. (2014), we measure total derivatives holdings by summing the fair values of all types of derivatives held by banks. The use of fair value rather than notional amounts is because fair value reflects the total exposure to counterparties and the associated counterparty risk. In contrast, while notional amounts may be linked to operational activities and income generation, they do not provide relevant information on the risk borne by derivatives and thus may be irrelevant from a systemic risk perspective (Livne et al., 2011; Mayordomo et al., 2014). Specifically, the derivatives categories include interest rate derivatives (DH interest), foreign exchange derivatives (DH foreign), equity derivatives (DH equity), commodity derivatives (DH commodity), and credit derivatives (DH credit). After obtaining the total amount of derivatives holdings, we standardize each bank's derivatives holdings by its total assets, resulting in the key independent variable DH ,

ensuring comparability across banks.

3.3. Other controls

Following Duan et al. (2022) and Wang et al. (2025), we incorporate several control variables related to systemic risk into the regression model. These variables include the CPI index (CPI), GDP growth (GDP), bank size (AT), the bank book leverage ratio (LEV), return on assets (ROA), loan size ($LOAN$), the interest income ratio (INT), the loan loss provision ratio (LLP), and the liquidity asset ratio ($LIQUIDITY$). Table 1 provides the detailed definitions of the variables used in this paper.

3.4. Data sources and descriptive statistics

We collect data from multiple sources. The stock price data used for calculating ΔCoVaR are obtained from the CRSP and Compustat-Capital IQ databases. Banks' derivatives holdings data are sourced from BankFocus. Macroeconomic data and other individual bank financial data are sourced from the World Bank website and BankFocus, respectively. We collect data on listed banks whose derivatives holdings data are available. Finally, our sample spans from 1999 to 2020, encompassing 493 banks from 28 countries. Based on BankFocus statistics, the total assets of banks in our final sample account for approximately 82.29 % of the total assets of banks in the corresponding 28 countries, indicating that our research sample is well representative.

Table 1 presents the summary statistics of the main variables used in this paper. All continuous variables are winsorized at the 1 % and 99 % levels. Specifically, the variable ΔCoVaR , representing bank systemic risk, has a mean of 1.252 and a standard deviation of 0.867. The 25th and 75th percentiles are 0.632 and 1.660, respectively, indicating significant variation in systemic risk among banks.

The mean and standard deviation for DH are 0.008 and 0.025, respectively, suggesting that the fair value of derivatives held by banks accounts for approximately 0.8 % of total assets on average and that there are significant differences in banks' derivatives holdings. Table 2 presents the correlation coefficients of the relevant variables. ΔCoVaR is significantly positively correlated with DH , providing preliminary support for Hypothesis 1, which posits that derivatives holdings lead to greater systemic risk.

3.5. Econometric framework

To explore whether banks' derivatives holdings (DH) significantly impact systemic risk, we employ the following equation:

$$\text{Systemic Risk}_{i,t} = \alpha + \beta_1 DH_{i,t-1} + \beta_2 \text{Control}_{i,t-1} + u_i + v_t + \varepsilon_{i,t} \quad (3)$$

$\text{Systemic Risk}_{i,t}$ denotes the systemic risk of bank i in year t . $DH_{i,t-1}$ represents derivatives holdings of bank i in year $t-1$. $\text{Control}_{i,t-1}$ are the control variables of country and level in year $t-1$. We control for bank fixed effect (u_i) and year fixed effect (v_t) to absorb unobserved time-invariant bank heterogeneity and time-varying shocks affecting all

Table 1
Summary statistics.

Var name	Obs.	Mean	Sd.	25 %	50 %	75 %	Variable Definition
ΔCoVaR	6861	1.252	0.867	0.632	1.101	1.660	Delta conditional VaR.
DH	6861	0.008	0.025	0	0	0.003	Banks' derivatives holdings level.
CPI	6861	0.023	0.022	0.010	0.021	0.032	Country-level CPI index.
GDP	6861	0.026	0.024	0.015	0.023	0.039	Country-level GDP growth rate.
AT	6861	16.445	1.761	15.087	16.362	17.583	Logarithm of bank total assets.
LEV	6861	0.900	0.060	0.884	0.907	0.927	Bank book leverage.
ROA	6861	0.013	0.014	0.006	0.012	0.017	Return on total assets.
$LOAN$	6861	0.643	0.147	0.577	0.663	0.736	Ratio of a bank's total loans to its total assets.
INT	6861	1.109	0.470	0.823	1.010	1.321	Bank interest income ratio.
LLP	6861	0.451	0.667	0.097	0.261	0.528	Loan loss provision ratio.
$LIQUIDITY$	6861	0.113	0.102	0.037	0.078	0.154	Liquidity asset ratio.

Table 2
Correlation matrix.

Varname	ΔCoVaR	DH	CPI	GDP	AT	LEV	ROA	$LOAN$	INT	LLP	$LIQUIDITY$
ΔCoVaR	1.000										
DH	0.207 ^a	1.000									
CPI	0.193 ^a	0.042 ^a	1.000								
GDP	-0.055 ^a	0.011	0.392 ^a	1.000							
AT	0.478 ^a	0.388 ^a	-0.085 ^a	0.036 ^a	1.000						
LEV	0.086 ^a	0.049 ^a	-0.140 ^a	-0.072 ^a	0.205 ^a	1.000					
ROA	-0.076 ^a	-0.020	0.179 ^a	0.183 ^a	-0.074 ^a	-0.594 ^a	1.000				
$LOAN$	-0.137 ^a	-0.275 ^a	-0.021	-0.067 ^a	-0.282 ^a	0.116 ^a	-0.078 ^a	1.000			
INT	-0.053 ^a	-0.010	0.394 ^a	0.324 ^a	-0.132 ^a	0.126 ^a	-0.160 ^a	0.187 ^a	1.000		
LLP	-0.025	0.009	0.104 ^a	0.085 ^a	-0.097 ^a	-0.130 ^a	0.119 ^a	-0.045 ^a	0.052 ^a	1.000	
$LIQUIDITY$	0.133 ^a	0.358 ^a	0.136 ^a	0.142 ^a	0.321 ^a	-0.043 ^a	0.091 ^a	-0.522 ^a	-0.062 ^a	0.004	1.000

^a Means significance at the 1 % level.

banks simultaneously. In addition, we lag all the independent variables by one year to reduce the possible interference of reverse causality on the conclusions of this study. ε_{it} is the error term.

4. Results and discussion

4.1. Main results

Table 3 presents the baseline regression results based on Eq. (3). As shown in columns (1) to (3), the coefficients of DH are significantly positive, regardless of whether the control variables are included. This finding indicates that an increase in banks' derivatives holdings is associated with a significant rise in bank systemic risk, confirming Hypothesis 1. In column (3), the coefficient of DH suggests that for each one standard deviation increase (0.025) in derivatives holdings, the level of

bank systemic risk increases by 7.19 % ($2.493 \times 0.025 / 0.867$) relative to its standard deviation, which is economically significant.

4.2. Robustness tests

We perform several endogeneity and robustness tests to confirm the robustness of our results.

First, we employ instrumental variable (IV) regression to address potential endogeneity issues. Following Li et al. (2023) and Zhu et al. (2024), we select the self-excluded mean value of banks' derivatives holdings in the same country (*Country DH*) as the instrumental variable. We choose this variable for two reasons: first, the self-excluded average of banks' derivatives holdings in the same country is unlikely to directly affect bank systemic risk, ensuring good exogeneity; second, considering the similar macroeconomic environment within the same country and the behavioural similarities among banks, this variable is highly correlated with individual banks' derivatives holdings, satisfying the relevance requirement.

Table 4 shows the regression results. Column (1) shows the regression results of the first stage, where the coefficient of the instrumental variable (*Country DH*) is significantly positive, the LM statistic p value (*UIT*) is less than 0.01, and the Wald F statistic (*WIT*) is significantly greater than the critical value, rejecting the weak instrument hypothesis. Column (2) shows the regression results of the second stage, where the coefficient of DH is significantly positive at the 1 % level, indicating that our conclusion still holds when the endogeneity problem is considered.

Second, we use feasible generalized least squares (FGLS) and system GMM methods to replace the model in the benchmark regression to further reduce the interference of autocorrelation, heteroskedasticity and endogeneity problems on the research conclusions. Following Blundell and Bond (1998), we adopt the two-step system GMM approach to alleviate endogeneity concerns. We use bank-level variables as endogenous variables, and macro variables and year dummies are used as exogenous variables. The lagged items of bank characteristic variables, including AT , LEV , ROA , $LOAN$, INT , LLP , and $LIQUIDITY$, are used as GMM-type instrumental variables.

Columns (3) and (4) of Table 4 show the results when the FGLS model and the system GMM model are used, respectively. We find that the coefficients of DH remain significantly positive after the regression model is changed. The Sargan test and AR (2) test results in column (4) validate the effectiveness of the system GMM regression. This further reduces concerns about the impact of autocorrelation, heteroscedasticity, and endogeneity on the research results.

We subsequently conduct further robustness checks by replacing the systemic risk indicators and altering the regression samples. Specifically, we use the commonly used MES and SRISK as alternative variables for the systemic risk indicator. ΔCoVaR , along with the MES and SRISK, is widely employed in the literature to measure systemic risk levels. However, there are distinctions: ΔCoVaR views banks as "risk generators," quantifying their contribution to systemic risk by estimating the

Table 3
Baseline regression results.

	(1)	(2)	(3)
	ΔCoVaR		
DH	2.628*** (3.90)	2.563*** (3.78)	2.493*** (3.97)
CPI		2.992 (1.42)	3.136 (1.46)
GDP		2.241 (1.09)	2.189 (1.06)
AT		0.215*** (3.88)	0.231*** (4.04)
LEV		-0.469 (-1.17)	-0.362 (-0.93)
ROA		-0.200 (-0.12)	-0.735 (-0.39)
$LOAN$			-0.133 (-0.66)
INT			-0.095 (-1.35)
LLP			0.039** (2.42)
$LIQUIDITY$			-0.032 (-0.18)
Bank FE	YES	YES	YES
Year FE	YES	YES	YES
Obs	6861	6861	6861
Adj R ²	0.741	0.746	0.749

This table reports the baseline regression results (t-statistics in parentheses). The dependent variable is systemic risk, represented by ΔCoVaR . The independent variable is banks' derivatives holdings, represented by DH . CPI denotes the CPI index, GDP represents GDP growth, AT denotes the bank's total assets, and LEV represents the bank's book leverage ratio. ROA measures the bank's profitability, $LOAN$ represents the bank's loan scale measured by the ratio of total loans to total assets, INT denotes the bank's interest income ratio, LLP represents the bank's loan loss provision ratio. $LIQUIDITY$ represents the bank's liquidity asset ratio. Table 1 provides detailed variable definitions. ***p < 0.01, **p < 0.05, *p < 0.1.

Table 4
Endogeneity test.

	(1)	(2)	(3)	(4)
	ΔCoVaR			
	IV Regression		FGLS	GMM
Country <i>DH</i>	0.482*** (4.42)			
<i>DH</i>		7.701*** (2.93)	2.208*** (2.60)	7.998*** (4.72)
<i>CPI</i>	−0.018 (−1.05)	3.306*** (4.50)	2.646*** (3.99)	19.858*** (12.96)
<i>GDP</i>	−0.008 (−0.73)	2.268*** (3.27)	2.637*** (4.46)	2.426*** (2.81)
<i>AT</i>	0.001 (1.23)	0.225*** (7.67)	0.243*** (9.58)	0.229*** (7.45)
<i>LEV</i>	0.013* (1.78)	−0.412 (−0.97)	−0.174 (−0.49)	−2.361* (−1.66)
<i>ROA</i>	−0.019 (−1.09)	−0.615 (−0.48)	−1.307 (−1.08)	−44.629*** (−9.81)
<i>LOAN</i>	−0.010*** (−3.90)	−0.067 (−0.46)	−0.113 (−0.91)	−0.032 (−0.07)
<i>INT</i>	−0.000 (−0.25)	−0.095** (−2.50)	−0.115*** (−3.04)	−0.442*** (−4.59)
<i>LLP</i>	−0.000 (−0.10)	0.039*** (2.78)	0.052*** (4.20)	0.444*** (6.49)
<i>LIQUIDITY</i>	−0.003 (−0.64)	−0.010 (−0.06)	0.014 (0.09)	−0.113 (−0.29)
UIT	0.000			
WIT	19.510			
AR (2)				0.279
Sargan test				0.999
Bank FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Obs	6861	6861	6362	5374
Adj R ²	0.886	0.748	0.706	

This table reports the endogeneity test results (t-statistics in parentheses). The systemic risk is represented by ΔCoVaR . Table 1 provides detailed variable definitions. ***p < 0.01, **p < 0.05, *p < 0.1.

increase in risk for financial institutions during a systemic crisis, whereas MES and SRISK consider banks "risk bearers," reflecting individual banks' equity losses and capital shortfalls during systemic distress (Acharya et al., 2017; Brownlees and Engle, 2017). Columns (1) and (2) of Table 5 present the regression results when the MES and SRISK are used as dependent variables. Regardless of the indicator chosen to measure systemic risk, the coefficients of *DH* remain significantly positive. Furthermore, we consider the possibility that specific samples dominate the regression results. Specifically, we remove samples from US listed banks,¹ those during the 2008 financial crisis, and those following the COVID-19 outbreak, reporting the regression results in columns (3), (4), and (5), respectively. These results show that the coefficients of *DH* are consistently positive across all columns, indicating that specific countries and time periods do not dominate our conclusions, further confirming the role of banks' derivatives holdings in promoting systemic risk.

Finally, we analyse the sensitivity of the coefficient for the primary independent variable, *DH*. Although we include a range of control variables in our baseline regression, there may still be concerns regarding omitted variable bias. To address this issue, we follow the method outlined by Oster (2019) to conduct a coefficient sensitivity analysis. Specifically, we calculate the δ value necessary for the coefficient of the primary variable *DH* to equal zero, based on the practices of Zhu et al. (2024), and report this in Table 6. The results indicate that the δ value for *DH*- ΔCoVaR is 2.379. This suggests that, for the coefficient of *DH* to equal zero, the impact of the omitted variable must be at least 2.379

¹ We choose to remove the US bank samples because these listed bank samples account for about 46 % of the entire sample, and they may dominate the regression results.

Table 5
Robustness test.

	(1)	(2)	(3)	(4)	(5)
	MES	SRISK	ΔCoVaR	ΔCoVaR	ΔCoVaR
<i>DH</i>	3.857*** (4.15)	9.823*** (3.76)	2.807** (2.31)	2.564** (2.68)	1.632** (2.57)
<i>CPI</i>	2.703 (0.68)	−3.011 (−0.80)	2.819* (1.97)	3.149* (1.80)	3.155 (1.45)
<i>GDP</i>	1.843 (0.42)	−10.896 (−1.62)	1.542 (1.00)	3.598** (2.08)	1.192 (0.56)
<i>AT</i>	0.206 (1.23)	−0.488** (−2.72)	0.047 (0.72)	0.211*** (6.80)	0.191*** (2.85)
<i>LEV</i>	−0.590 (−0.89)	1.802 (0.84)	0.580 (1.19)	−0.013 (−0.03)	−0.452 (−1.06)
<i>ROA</i>	−19.833*** (−3.13)	−43.024*** (−6.28)	4.844** (2.68)	4.732*** (3.80)	−1.573 (−0.92)
<i>LOAN</i>	−0.497 (−1.23)	−0.926 (−1.16)	−0.335 (−1.40)	−0.065 (−0.28)	−0.067 (−0.33)
<i>INT</i>	−0.334* (−1.95)	0.839*** (3.70)	0.036 (0.75)	−0.018 (−0.41)	−0.098 (−1.25)
<i>LLP</i>	0.032* (1.88)	−0.034 (−0.67)	−0.012 (−0.48)	0.023* (1.76)	0.008 (0.44)
<i>LIQUIDITY</i>	0.719** (2.17)	1.381 (1.52)	−0.037 (−0.18)	−0.275 (−1.55)	0.213 (1.38)
Bank FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Obs	6861	6613	3687	5877	6417
Adj R ²	0.632	0.774	0.776	0.761	0.754

This table reports the robustness test results (t-statistics in parentheses). Columns (1) and (2) present the regression results after substituting the dependent variables. Columns (3), (4), and (5) show the regression results after excluding the US banks sample, removing the sample during the 2008 GFC, and excluding the sample during the COVID-19 period, respectively. The independent variable is banks' derivatives holdings, represented by *DH*. Table 1 provides detailed variable definitions. ***p < 0.01, **p < 0.05, *p < 0.1.

Table 6
The results of sensitivity analysis of coefficient.

	Coefficients		R ²		δ
	Uncontrolled	Controlled	Uncontrolled	Controlled	
<i>DH</i> - ΔCoVaR	8.311	2.493	0.011	0.598	2.379

This table reports the coefficient sensitivity analysis results for the main independent variable *DH* in this study.

times greater than that of the controlled variables (Fang et al., 2023). Given that we control for the most important variables based on the literature, it is unlikely that any omitted variable would have such a significant effect. Therefore, the issue of omitted variables is not expected to seriously impact the conclusions of this study.

5. Mechanism

We further investigate the mechanisms through which banks' derivatives holdings impact bank systemic risk to test Hypothesis 2 of this study.

First, banks' derivatives holdings may increase asset risk. Research indicates that while banks can increase profit levels and cash flow through derivatives, thereby supporting the issuance of more commercial loans (Purnanandam, 2007; Zhao and Moser, 2017), the use of derivatives, particularly credit derivatives, may also diminish banks' incentives to monitor credit assets. This can lead to relaxed lending standards and a subsequent decline in loan quality (Cebenoyan and Strahan, 2004; Shanker, 1996). As banks increase their loan volume while their quality decreases, the level of loan risk significantly increases. Since loan risk is a core component of overall asset risk, an increase in loan risk inevitably raises the overall asset risk of banks.

Moreover, derivatives are characterized by high complexity, flexibility, and risk, and an increase in derivatives holdings also contributes to heightened asset risk. Studies show that banks with higher asset risk are more likely to experience significant declines in asset value during cri-

systemic risk through leverage risk, we utilize a two-step regression method. In the first stage, we investigate how banks' derivatives holdings affect leverage risk. Following the methodologies of Berg and Gider (2017) and Duan et al. (2022), we define *Leverage Risk* as follows:

$$\text{Leverage Risk} = 1 - \frac{\text{Market value of common equity}}{(\text{End of year close price} * \text{shares outstanding}) + \text{Total liabilities}} \quad (7)$$

ses, which can lead to defaults or even bankruptcies, subsequently increasing systemic risk (Duan et al., 2022). Additionally, Berg and Gider (2017) find that differences in asset risk can account for up to 90 % of the variation in capital structures between banks and nonbank institutions. Therefore, maintaining low asset risk levels is crucial for banks to ensure stable operations while operating with high leverage. Thus, we anticipate that banks' derivatives holdings may increase systemic risk by elevating asset risk levels.

To examine the asset risk channel through which banks' derivatives holdings influence systemic risk, we adopt the two-step regression approach utilized by Di Giuli and Laux (2022) and Liang and Renneboog (2017). Specifically, in the first stage, we investigate how banks' derivatives holdings affect asset risk. Following the framework established by Berg and Gider (2017), we define *Asset Risk* as follows:

$$\text{Asset Risk} = \frac{\text{Standard deviation of monthly stock return in last year}}{\text{Bank book leverage}} \quad (4)$$

In the second stage, we investigate the effect of the predicted values of *Asset Risk* on systemic risk. The regression equations for the first and second stages are given by Eq. (5) and Eq. (6), where $\overline{\text{Asset Risk}}$ represents the predicted values of the *Asset Risk* value.

$$\text{Asset Risk}_{i,t} = \alpha + \beta_1 DH_{i,t-1} + \beta_2 \text{Control}_{i,t-1} + u_i + v_t + \varepsilon_{i,t} \quad (5)$$

$$\text{Systemic Risk}_{i,t} = \alpha + \gamma_1 \overline{\text{Asset Risk}}_{i,t} + \gamma_2 \text{Control}_{i,t-1} + u_i + v_t + \varepsilon_{i,t} \quad (6)$$

Table 7, columns (1) and (4), present the regression results for the first and second stages, respectively. In column (1), the coefficient of *DH* is significantly positive, indicating that banks' derivatives holdings significantly increase bank asset risk. In column (4), the coefficient of *Asset Risk* is significantly positive, revealing that bank asset risk has a significant positive effect on systemic risk. These findings indicate that banks' derivatives holdings can significantly increase bank systemic risk by increasing their asset risk.

Second, banks' derivatives holdings may increase bank leverage risk, which is considered one of the main triggers of systemic risk. As financial intermediaries, banks use monetary funds as their main business commodities. In pursuit of profit maximization and while meeting capital requirements, banks typically maintain very high leverage ratios. The use of derivatives can enhance banks' credit risk management capabilities, reduce risk-based capital requirements, and encourage banks to operate with higher leverage (Cebenoyan and Strahan, 2004; Deng et al., 2021). While this increased leverage can increase the efficiency of capital utilization and increase bank value under normal operating conditions (Chang et al., 2018; Choi et al., 2016), it can also lead to greater vulnerability in the face of external shocks. Adverse conditions may more easily result in capital shortfalls and trigger defaults or bankruptcies in highly leveraged banks. In these scenarios, higher leverage implies greater leverage risk and systemic importance, thus leading to elevated levels of systemic risk (Bostandzic and Weiss, 2018). Therefore, banks' derivatives holdings may contribute to increased systemic risk by increasing bank leverage risk.

Similarly, to examine how banks' derivatives holdings impact

In the second stage, we investigate how the predicted values of *Leverage Risk* affect systemic risk. The regression equations for the first and second stages are given by Eq. (8) and Eq. (9), where $\overline{\text{Leverage Risk}}$ represents the predicted values of the *Leverage Risk* value.

$$\text{Leverage Risk}_{i,t} = \alpha + \beta_1 DH_{i,t-1} + \beta_2 \text{Control}_{i,t-1} + u_i + v_t + \varepsilon_{i,t} \quad (8)$$

$$\text{Systemic Risk}_{i,t} = \alpha + \gamma_1 \overline{\text{Leverage Risk}}_{i,t} + \gamma_2 \text{Control}_{i,t-1} + u_i + v_t + \varepsilon_{i,t} \quad (9)$$

Columns (2) and (5) present the regression results for the first and second stages, respectively. In column (2), the coefficient of *DH* is significantly positive, indicating that banks' derivatives holdings significantly increase leverage risk. In column (5), the coefficient of *Leverage Risk* is significantly positive, revealing that leverage risk has a substantial positive effect on systemic risk. These findings indicate that banks' derivatives holdings can significantly increase systemic risk by increasing leverage risk.

Third, banks' derivatives holdings may increase operational risk. On the one hand, Instefjord (2005) notes that the hedging function of derivatives can lead managers to underestimate risk, prompting banks to adopt more aggressive asset allocation strategies, which increases operational risk. On the other hand, the complexity of derivatives makes accurate disclosure in financial statements challenging, exacerbating information asymmetry between banks, clients, and external regulators. As external oversight diminishes and management has more room for earnings manipulation, banks are more likely to engage in high-risk speculation, further increasing their operational risk (Adkins et al., 2007; Aslam and Haron, 2021; Hunjra et al., 2021). An increase in operational risk elevates bank fragility, thus heightening the likelihood of banks facing crises due to external shocks, ultimately increasing systemic risk (Lu and Wang, 2023). Therefore, banks' derivatives holdings may lead to greater systemic risk through increasing operational risk.

We also employ the two-step regression method to investigate the operational risk channel. First, we examine how banks' derivatives holdings affect operational risk, measured by the commonly used *Zscore*. A higher *Zscore* indicates lower operational risk. Second, we investigate how the predicted values of *Zscore* affect systemic risk. The regression equations for the first and second stages are given by Eqs. (10) and (11), where $\overline{\text{Zscore}}$ represents the predicted values of *Zscore*.

$$\text{Zscore}_{i,t} = \alpha + \beta_1 DH_{i,t-1} + \beta_2 \text{Control}_{i,t-1} + u_i + v_t + \varepsilon_{i,t} \quad (10)$$

$$\text{Systemic Risk}_{i,t} = \alpha + \gamma_1 \overline{\text{Zscore}}_{i,t} + \gamma_2 \text{Control}_{i,t-1} + u_i + v_t + \varepsilon_{i,t} \quad (11)$$

Columns (3) and (6) present the regression results for the first and second stages, respectively. In column (3), the coefficient of *DH* is significantly negative, indicating that banks' derivatives holdings significantly increase operational risk. In column (6), the coefficient of $\overline{\text{Zscore}}$ is significantly negative, revealing that operational risk has a significant positive effect on systemic risk. These findings indicate that banks' derivatives holdings can significantly increase systemic risk by increasing operational risk.

Table 7
Mechanism analysis.

	(1)	(2)	(3)	(4)	(5)	(6)
	<i>Asset Risk</i>	<i>Lev Risk</i>	<i>Zscore</i>	ΔCoVaR	ΔCoVaR	ΔCoVaR
<i>DH</i>	0.073*** (3.39)	0.108** (2.08)	−2.551** (−2.21)			
<i>Asset Risk_p</i>				33.949*** (3.97)		
<i>Lev Risk_p</i>					23.148*** (3.97)	
<i>Zscore_p</i>						−0.977*** (−3.97)
<i>CPI</i>	−0.035 (−1.32)	−0.089 (−1.02)	−0.621 (−0.24)	4.324* (1.87)	5.187** (2.13)	2.529 (1.21)
<i>GDP</i>	0.060 (1.06)	−0.096 (−1.62)	1.101 (0.79)	0.150 (0.07)	4.405** (2.12)	3.265 (1.59)
<i>AT</i>	−0.000 (−0.77)	−0.003 (−0.84)	−0.126* (−1.85)	0.247*** (4.43)	0.290*** (5.50)	0.107 (1.42)
<i>LEV</i>	−0.031*** (−3.58)	0.582*** (19.83)	−1.718 (−0.85)	0.702 (1.46)	−13.830*** (−4.08)	−2.041*** (−3.64)
<i>ROA</i>	−0.326*** (−4.62)	−0.759** (−2.21)	12.262*** (7.29)	10.343*** (3.44)	16.826*** (3.82)	11.249*** (3.53)
<i>LOAN</i>	−0.008 (−1.47)	−0.036*** (−3.17)	0.596 (1.69)	0.130 (0.63)	0.707** (2.54)	0.449* (1.89)
<i>INT</i>	0.000 (0.01)	0.006* (1.92)	0.058 (0.49)	−0.095 (−1.35)	−0.239*** (−3.32)	−0.038 (−0.51)
<i>LLP</i>	0.001*** (3.48)	−0.001 (−0.75)	−0.024 (−1.23)	−0.002 (−0.12)	0.062*** (3.50)	0.016 (0.94)
<i>LIQUIDITY</i>	−0.001 (−0.12)	0.041 (1.65)	1.059* (1.79)	−0.008 (−0.05)	−0.991*** (−3.32)	1.003*** (3.16)
Bank FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Obs	6610	6861	6448	6861	6861	6861
Adj R ²	0.584	0.764	0.216	0.749	0.749	0.749

This table shows the mechanisms through which *DH* affects bank systemic risk (t-statistics in parentheses). *Asset Risk*, *Lev Risk*, and *Zscore* are used to measure bank asset risk, leverage risk, and operational risk, respectively. The independent variable is banks' derivatives holdings, represented by *DH*. Table 1 provides detailed variable definitions. ***p < 0.01, **p < 0.05, *p < 0.1.

6. Heterogeneity tests

In this section, we investigate how macrolevel and microlevel heterogeneity characteristics influence the impact of banks' derivatives holdings on systemic risk. Specifically, we analyse this issue from four perspectives: the state of the real economy, the monetary environment, bank leverage levels, and bank liquidity conditions.

6.1. State of the real economy

First, we investigate how the state of the real economy affects the relationship between banks' derivatives holdings and systemic risk. Previous studies suggest that, on the one hand, when real economic conditions are poor, policy uncertainty increases, leading banks to face more severe information asymmetry when making operational decisions. This increases the likelihood of risk accumulation and risk events occurring (Baker et al., 2016; Shabir et al., 2021). On the other hand, the use of derivatives facilitates the expansion of bank loan portfolios while lowering lending standards (Cebenoan and Strahan, 2004; Purnanandam, 2007; Zhao and Moser, 2017), allowing more long-tail customers with weaker risk resilience to obtain loans from banks. When the macroeconomic environment deteriorates, these customers are more likely to default on their loans, resulting in credit losses that harm banks' capital positions (Beck and Keil, 2022). Therefore, we expect that banks' derivatives holdings are more likely to affect systemic risk during periods of poor real economic conditions.

In terms of the identification strategy, we utilize the industrial value-added growth rate (*IVA*) to measure the real economic conditions of each economy in the sample. Periods where the *IVA* of a given economy is above the median are classified as times of good real economic performance, whereas periods where the *IVA* is below the median are classified as times of poor real economic performance. After dividing the

Table 8

Heterogeneity test: Macro environment.

	(1)	(2)	(3)	(4)
	<i>High IVA</i>	<i>Low IVA</i>	<i>High M2</i>	<i>Low M2</i>
	ΔCoVaR			
<i>DH</i>	1.209 (1.06)	3.389*** (4.92)	2.819*** (3.52)	2.591 (1.25)
<i>CPI</i>	3.472** (2.09)	1.511 (0.33)	1.641 (0.88)	11.201*** (3.47)
<i>GDP</i>	2.088 (1.63)	3.051 (0.65)	2.107 (1.39)	−0.174 (−0.03)
<i>AT</i>	0.141*** (4.09)	0.301*** (6.01)	0.246*** (5.70)	0.190*** (3.44)
<i>LEV</i>	0.062 (0.13)	−0.579 (−1.43)	−0.242 (−0.43)	0.066 (0.27)
<i>ROA</i>	6.093*** (3.88)	−4.097* (−1.97)	3.732* (1.91)	−4.121* (−2.03)
<i>LOAN</i>	−0.035 (−0.12)	−0.143 (−1.04)	−0.421 (−1.55)	0.226*** (3.54)
<i>INT</i>	−0.007 (−0.12)	−0.102 (−1.00)	−0.078 (−1.10)	−0.051 (−0.40)
<i>LLP</i>	−0.023** (−2.50)	0.079*** (3.52)	0.045** (2.58)	0.063*** (3.11)
<i>LIQUIDITY</i>	0.288 (1.42)	−0.493 (−1.69)	−0.130 (−0.70)	−0.260 (−1.61)
<i>Coef Diff</i>	p < 0.01		p < 0.01	
Firm FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Obs	5053	1808	3241	3471
Adj R ²	0.762	0.776	0.763	0.761

The table shows the heterogeneous impact of *DH* under different macroeconomic environments (t-statistics in parentheses). Table 1 provides detailed variable definitions. *Coef Diff* provides the significance of the difference in coefficients between groups calculated based on the Chow test. ***p < 0.01, **p < 0.05, *p < 0.1.

sample, we run regressions using Eq. (4), and the results are presented in Table 8. Columns (1) and (2) show the regression results for periods of high IVA and low IVA, respectively. In column (2), the coefficient for *DH* is significantly positive at the 1 % confidence level, suggesting that banks' derivatives holdings significantly increase systemic risk during periods of poor real economic conditions. In contrast, the coefficient for *DH* in column (1) is not significant. Furthermore, we utilize the Chow test to examine these two regressions and find a significant difference in *DH*'s coefficients between these two groups. This demonstrates that during periods of lower IVA, derivatives holdings have a greater effect on systemic risk.

6.2. Monetary environment

Moreover, we examine the heterogeneous impact of banks' derivatives holdings on systemic risk under varying monetary environments. Existing studies suggest that accommodative monetary policy may increase risk-taking in the banking system and that excessive risk-taking is a key driver of greater systemic risk (Lu and Wang, 2023). Banks' derivatives holdings could lead managers to become overconfident in their risk management abilities, causing them to adopt more aggressive asset allocation strategies and take on risks that exceed their risk management capacity (Instefjord, 2005). This increase in operational risk is likely to be more pronounced during periods of accommodative monetary policy, thereby exacerbating systemic risk. Therefore, we anticipate that the effect of banks' derivatives holdings on systemic risk will be more significant during periods of monetary easing.

Similarly, we divide the sample into high and low M2 growth (*M2*) periods based on the median of M2 growth and perform regressions separately. Columns (3) and (4) present the regression results for high and low M2 growth periods, respectively. In column (3), the coefficient for *DH* is significantly positive. In contrast, in column (4), the coefficient for *DH* is not significant. Furthermore, we use the Chow test to examine these two regressions and find a significant difference in *DH*'s coefficients between the two groups. This finding indicates that derivatives holdings have a more pronounced effect during periods of accommodative monetary policy.

6.3. Bank leverage

In addition, we examine how bank-level characteristics influence the economic consequences of derivatives holdings. First, we consider bank leverage. Excessive debt is an important cause of operational distress and bankruptcy (Kijkasiwat et al., 2022). Numerous studies note that when external shocks occur, adverse conditions are more likely to deplete capital in highly leveraged banks, leading to defaults or even bankruptcies, which contribute more significantly to systemic risk (Bostandzic and Weiss, 2018). For banks with substantial derivatives holdings, the high-risk nature of derivatives means that fluctuations in their value directly impact a bank's capital position, increasing dynamic leverage and triggering excessive indebtedness. Under such conditions, highly leveraged banks face a greater systemic risk contribution when encountering similar levels of shocks, which threatens financial stability. Therefore, we expect that the impact of derivatives holdings on systemic risk is more pronounced for banks with higher leverage.

We divide the sample into high-leverage and low-leverage banks based on the median of bank book leverage and perform regressions separately. Columns (1) and (2) of Table 9 present the regression results for high-leverage and low-leverage banks, respectively. We find that the coefficient for *DH* is significantly positive in column (1). In column (2), the coefficient for *DH* is not significant. Similarly, we use the Chow test to examine these two regressions and find a significant difference in *DH*'s coefficients between the two groups, confirming our hypothesis.

Table 9

Heterogeneity test: Bank characteristics.

	(1) <i>High Lev</i>	(2) <i>Low Lev</i>	(3) <i>High Liquidity</i>	(4) <i>Low Liquidity</i>
ΔCoVaR				
<i>DH</i>	3.964*** (6.53)	−0.595 (−0.42)	2.230*** (3.98)	4.319** (2.80)
<i>CPI</i>	2.312 (0.97)	1.262 (0.95)	1.583 (0.93)	7.906*** (3.26)
<i>GDP</i>	1.879 (0.66)	1.682 (0.78)	0.455 (0.28)	4.856 (1.40)
<i>AT</i>	0.106 (1.02)	0.282*** (7.22)	0.161** (2.51)	0.209*** (6.79)
<i>LEV</i>	−1.337 (−0.45)	0.531 (1.02)	0.457 (1.10)	−0.281 (−0.70)
<i>ROA</i>	−2.054 (−0.80)	0.996 (0.77)	2.367 (1.37)	−7.113** (−2.51)
<i>LOAN</i>	0.112 (0.80)	−0.233 (−0.90)	−0.562** (−2.54)	0.207*** (4.14)
<i>INT</i>	−0.041 (−0.51)	−0.098 (−1.26)	−0.006 (−0.09)	−0.273*** (−5.13)
<i>LLP</i>	0.041*** (2.89)	0.054** (2.54)	0.031 (0.98)	0.023* (2.04)
<i>LIQUIDITY</i>	0.019 (0.07)	−0.233 (−0.72)	−0.216 (−0.96)	−1.795*** (−7.57)
<i>Coef Diff</i>	p < 0.01		p < 0.01	
Bank FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Obs	3405	3424	3378	3400
Adj R ²	0.759	0.779	0.767	0.754

The table shows the heterogeneous effects of *DH* with different micro characteristics (t-statistics in parentheses). Table 1 provides detailed variable definitions. *Coef Diff* provides the significance of the difference in coefficients between groups calculated based on the Chow test. ***p < 0.01, **p < 0.05, *p < 0.1.

6.4. Bank liquidity

Finally, we examine the heterogeneous impact of derivatives holdings on banks with different liquidity levels. Insufficient liquidity is regarded as one of the primary causes of bank failure (Williamson, 1988). Liquidity risk stemming from inadequate liquidity not only harms the stability of individual banks but can also spread to other banks, causing severe disruptions to the financial system (Heider et al., 2015). For example, during the global financial crisis, liquidity tightening rapidly spread among financial institutions, leading to a sharp increase in systemic risk (Chen et al., 2021). Given the high-risk and high-leverage characteristics of derivatives, when losses necessitate banks to meet payment obligations, banks with sufficient liquidity can utilize their liquid assets to cover losses from derivatives. In contrast, banks lacking liquidity may be forced to conduct fire sales of illiquid assets, resulting in more severe asset and capital losses (Diamond and Rajan, 2011). At this point, banks with low liquidity exhibit greater systemic vulnerability and are more likely to trigger systemic risk. Therefore, we expect that for banks with poor liquidity, holding derivatives may lead to more severe systemic risk.

Similar to the previous approach, we divide the sample into high-liquidity and low-liquidity banks based on the median of the proportion of liquid assets. Columns (3) and (4) present the regression results for high liquidity and low liquidity banks, respectively. In both columns, the coefficient for *DH* is significantly positive. However, the coefficient for *DH* in the low liquidity group is significantly larger than that in the high liquidity group, which supports our hypothesis.

7. The impact of different types of derivatives

In the baseline regression, we aggregate all types of derivatives held by banks to construct the variable *DH* for bank derivatives holdings and discuss how these holdings impact bank systemic risk. In this section, we examine whether the holdings of different types of derivatives have

differential effects on systemic risk. Some studies find that holding different types of derivatives may produce different economic consequences. For example, [Choi et al. \(2016\)](#), based on data from US BHCs, find that the derivatives held by banks help enhance the market value of banks, with interest rate derivatives being a major source of high valuation, whereas other types of derivatives do not have a significant impact. Similarly, [Mayordomo et al. \(2014\)](#), based on a sample of US banks, find that the total amount of derivatives held does not significantly affect bank systemic risk. However, holding foreign exchange and credit derivatives increases the systemic risk contribution of banks, whereas holding interest rate derivatives reduces systemic risk. In reference to existing research, we use the holdings of each type of derivative as explanatory variables and regress bank systemic risk levels using Eq. (3).² Specifically, the derivatives include interest rate derivatives (*DH interest*), foreign exchange derivatives (*DH foreign*), equity derivatives (*DH equity*), commodity derivatives (*DH commodity*), and credit derivatives (*DH credit*).

[Table 10](#) shows the results. The regression coefficients for *DH interest*, *DH equity*, *DH commodity*, and *DH credit* are significantly positive at least at the 5 % level, whereas the regression coefficient for *DH foreign* is not significant. Our regression results indicate that, in a more general context, banks' holdings of interest rates, equity, commodities, and credit derivatives exhibit relatively consistent effects, all of which increase bank systemic risk.

8. Conclusion

Using a large sample worldwide, this paper examines how banks' derivatives holdings affect bank systemic risk. Our findings indicate that banks' derivatives holdings significantly increase systemic risk. On average, for each standard deviation increase in derivatives holdings, the level of bank systemic risk increases by 7.19 % relative to its standard deviation. These findings remain robust after various endogeneity and robustness checks are conducted. In terms of mechanisms and transmission channels, we find that banks' derivatives holdings ultimately increase systemic risk by increasing asset risk, leverage risk, and operational risk.

With respect to macroeconomic heterogeneity, we find that during periods of economic recession and accommodative monetary policy, banks' derivatives holding have a greater enhancing effect on systemic risk. In terms of micro heterogeneity, we find that when leverage is greater and liquidity is lower, banks' holding derivatives leads to more severe systemic risk contributions. Additionally, we examine the differential impact of various types of derivatives holdings on bank systemic risk. The results indicate that banks holding interest rates, equity, commodity, and credit derivatives significantly increase systemic risk, whereas the effect of holding foreign exchange derivatives on systemic risk is not significant, providing new evidence for understanding the economic consequences of different derivatives.

Our paper enriches the literature on the driving factors and mechanisms of systemic risk, aiding regulators in comprehensively understanding and mitigating the systemic risk induced by derivatives holdings. Furthermore, our findings provide potential ideas for future research. Systemic risk is characterized by significant interconnectedness and contagion; our study examines how banks' derivatives holdings impact systemic risk through channels of asset risk, leverage risk, and operational risk but does not separately discuss the interconnections between banks. Future research focusing on interconnectedness and exploring how banks' derivatives holdings influence interbank networks and ultimately affect systemic risk could be meaningful.

² We also standardize the scale of derivatives holdings by each bank's total assets to enhance the comparability of derivatives holding data among different banks.

Table 10

Different types of derivatives holdings.

	(1)	(2)	(3)	(4)	(5)
	ΔCoVaR				
<i>DH interest</i>	3.293*** (3.08)				
<i>DH foreign</i>		−1.762 (−0.67)			
<i>DH equity</i>			13.000** (2.39)		
<i>DH commodity</i>				21.481*** (3.43)	
<i>DH credit</i>					20.890*** (3.09)
<i>CPI</i>	3.023 (1.42)	3.058 (1.44)	3.119 (1.46)	3.066 (1.44)	2.988 (1.41)
<i>GDP</i>	2.174 (1.06)	2.176 (1.06)	2.151 (1.04)	2.123 (1.03)	2.157 (1.05)
<i>AT</i>	0.236*** (4.04)	0.236*** (4.06)	0.237*** (3.96)	0.235*** (3.93)	0.233*** (3.66)
<i>LEV</i>	−0.302 (−0.78)	−0.314 (−0.80)	−0.321 (−0.82)	−0.318 (−0.81)	−0.232 (−0.58)
<i>ROA</i>	−0.820 (−0.42)	−0.900 (−0.46)	−0.895 (−0.46)	−0.886 (−0.45)	−1.050 (−0.51)
<i>LOAN</i>	−0.182 (−0.91)	−0.198 (−0.94)	−0.181 (−0.87)	−0.184 (−0.88)	−0.286 (−1.53)
<i>INT</i>	−0.092 (−1.34)	−0.091 (−1.29)	−0.092 (−1.31)	−0.091 (−1.29)	−0.078 (−1.23)
<i>LLP</i>	0.040** (2.45)	0.040** (2.44)	0.040** (2.42)	0.040** (2.42)	0.044** (2.42)
<i>LIQUIDITY</i>	−0.044 (−0.25)	−0.050 (−0.28)	−0.050 (−0.28)	−0.048 (−0.27)	−0.070 (−0.39)
Bank FE	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES
Obs	6861	6861	6861	6861	6861
Adj R ²	0.747	0.746	0.746	0.746	0.746

This table shows the impact of different derivatives on bank systemic risk (t-statistics in parentheses). *DH interest*, *DH foreign*, *DH equity*, *DH commodity*, and *DH credit* represent interest rate derivatives, foreign exchange derivatives, equity derivatives, commodity derivatives, and credit derivatives, respectively. [Table 1](#) provides detailed variable definitions. ***p < 0.01, **p < 0.05, *p < 0.1.

Author contribution statement

We make substantial contributions to the conception or design of the work, as well as to the acquisition, analysis, or interpretation of data for the work. Yu Wang, Gaoya Song, and Yiming Lu draft the work or revise it for important intellectual content and approve the final version for publication. All individuals who have made substantial contributions to the work reported in the manuscript are acknowledged. We agree to be accountable for all aspects of the work, ensuring that questions related to any part of the work are appropriately investigated and resolved.

Yu Wang: Methodology, Data collation, Formal analysis, Writing – original draft, Writing – review & editing.

Gaoya Song: Methodology, Writing – original draft, Writing – review & editing.

Yiming Lu: Writing – original draft, Writing – review & editing.

Declarations of competing interest

None.

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