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Timing Tracing and Multidimensional Modelling Risk Assessment and Strategy Analysis of Cross-Border Flow of Financial Data based on Risk Quantification

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Abstract: In the context of accelerating digital transformation of the global economy, financial data cross-border flows are large in scale but frequent in risk events, and existing static research methods are difficult to capture the dynamic correlation of risks. This study aims to construct a dynamic risk assessment framework to provide decision support for relevant subjects. The ARIMA model, rolling time window regression and event study method are adopted to integrate the risk factors of technical, legal and political dimensions, and to construct a dual-driven early warning model and dual-cycle comparative analysis method. The results show that the framework can effectively identify the temporal fluctuation pattern of data flow and quantify the dynamic influence of risk factors and policy impact effects. The study fills the gap of quantitative assessment of cross-border data flow risk dynamics, provides methodological support and strategic references for regulators, fintech companies and multinational banks, and helps improve the risk prevention and control capability of cross-border financial data flow.

Keywords: Cross-Border Flow of Financial Data; Time Series Modelling; Dynamic Risk Assessment; Risk Quantification.

1. Introduction

1.1 Background of the Study

In the context of the era of deepening digital transformation of the global economy, cross-border flow of financial data is becoming the core driving force for the efficient operation of the international financial system. According to the International Monetary Fund (IMF, 2023), the scale of global cross-border financial data flow will exceed USD 850 trillion in 2023, which is more than eight times of the global GDP, with an average annual growth rate of more than 25%, and will deeply penetrate key financial business areas such as payment and settlement, cross-border investment and financing, and anti-money laundering monitoring. However, the exponential expansion of data flows is accompanied by serious risk challenges: according to the EU Financial Supervisory Authority (2022) report, cross-border data breaches have led to an average annual loss of $42 billion for global financial institutions, and risk events such as data leakage, compliance conflicts and geopolitical games are frequent, and may even threaten regional financial stability through systemic risk transmission. In traditional research, fixed risk indices constructed based on static weight allocation methods such as principal component analysis are difficult to capture the dynamic correlation between changes in the policy environment and market fluctuations, resulting in financial institutions not being able to accurately identify the temporal and sequential fluctuation patterns in the chain of data flows, and regulators lacking tools to predict the market reaction to the implementation of policies such as data localisation legislation. In this context, the construction of a quantifiable and traceable dynamic risk assessment framework that transforms abstract "data security threats" into concrete time-sequence risk indicators has become a key breakthrough in solving the problem of cross-border data flow risk governance[1].

1.2 Overview of Research

In the field of risk assessment of cross-border flow of financial data, scholars at home and abroad have conducted research from the perspectives of legal regulation, risk characteristics, dynamic modelling and regulatory strategies. Focusing on the perspective of international trade law, Huang Linlin (2023) proposes that the compliance risk of financial data flow needs to be dynamically balanced through the coordination of international rules and the convergence of domestic legislation, but his study does not quantify the risk transmission path in depth. Ni Jianhan (2024) further constructs a risk identification framework for cross-border data flow from the legal regulation level, emphasising the compound risk of data sovereignty conflict and privacy leakage, which provides a theoretical basis for risk classification. In terms of risk typology analysis, Liu Sheng and Zhao Dawei (2023) point out that the cross-border flow of financial data under digital trade scenarios faces new types of risks such as "data localisation policy differences" and "market manipulation triggered by algorithmic blackboxes", but their empirical analysis of the dynamic evolution of risks is insufficient. However, their empirical analysis of the dynamic evolution of risks is insufficient. Zhong Hong and Yang Xinyu (2022), on the other hand, put forward a "technology-institution" collaborative governance strategy from the perspective of security regulation, and advocate the reduction of risk exposure through blockchain deposits and cross-border regulatory sandboxes, but they lack the discussion of quantitative risk thresholds and dynamic early warning mechanisms[2].

International studies provide important references in methodology and dynamic risk modelling. The rolling time window regression model proposed by Pesaran and Timmermann (2005) provides a methodological basis for capturing the time-varying characteristics of risk parameters in the presence of sudden structural changes, but its application scenario is limited to the traditional financial markets. The event study approach framework proposed by Fama et al. (1969) and MacKinlay (1997) provides a tool for quantifying the short-term impact of policy shocks or data breaches, but needs to be combined with a dynamic model for high frequency data scenarios. MacKinlay's (1997) event study methodological framework provides tools to quantify the short-term impact of policy shocks or data breaches on cross-border flows, but needs to be combined with dynamic modelling to cope with high-frequency data scenarios. At the level of risk theory, Bauer et al. (2014) empirically test the economic costs of data localisation policies, revealing the non-linear character of risk transmission; Cory and Dascoli (2021) further point out that geopolitical games exacerbate the spatio-temporal heterogeneity of cross-border data flow risks. In terms of dynamic modelling, Engle's (2002) Dynamic Conditional Correlation Model (DCC-GARCH) and Diebold and Yilmaz's (2014) Volatility Spillover Network approach provide technical paths for the analysis of multidimensional risk contagion effects, but their adaptability in data cross-border scenarios remains to be verified[3].

Overall, existing research presents two main features: first, domestic literature focuses on qualitative risk analysis and static governance frameworks, with insufficient exploration of dynamic quantitative methods; second, although international literature is more mature in terms of methodology, it mostly focuses on traditional financial risk or isolated event analysis, and has yet to systematically integrate rolling window regression and event study methodology in dynamic risk assessment scenarios of cross-border data flows. This provides room for this study to innovate by constructing a dynamic quantitative risk assessment model and then proposing a strategy optimisation scheme based on real-time monitoring data[4].

1.3 Research Questions and Research Objectives

To address the above research gaps, this study is committed to solving the following core questions: How to accurately identify long-term trends and abnormal fluctuations in cross-border data flows through time series analysis? How to quantify the dynamic coupling effect and time-varying characteristics of multi-dimensional risk factors? How to verify the short-term inhibitory effect of sudden policies on data flow based on time series data? How to build a dynamic risk assessment and response mechanism that is both predictive and adaptive?

The goal of the study is to break through the limitations of traditional static analysis, and to build a three-dimensional assessment framework covering technical, legal and political dimensions by integrating time-series prediction, dynamic correlation test and policy shock decomposition methods, so as to provide scientific basis for financial institutions to optimise their data routing strategies and for regulators to improve their governance rules, and to help reduce the risks of data retention and systemic risk conduction[5].

1.4 Research Methodology and Technology Pathway

The study adopts a multi-method technical approach: first, based on IMF cross-border payments data, an ARIMA model is used to strip out long-term trends and seasonal fluctuations in data flows, forecast baseline flows for 2025 and identify periods of abnormal fluctuations, and correlate them with geo-political or policy events to explain the causes of the fluctuations; second, the dynamic correlation coefficients between risk factors such as technical vulnerability index and intensity of legal conflicts and data traffic are calculated over a 3-year rolling window to reveal the time-ordered evolution of the influence of risk factors; furthermore, policy nodes such as GDPR and China's Data Security Law are selected, and t-tests and regression analyses of independent samples are used to quantify the difference in the mean value of data traffic before and after the implementation of the policies, as well as the association between the severity of the policies and the traffic drop; finally, the prediction thresholds and the dynamic correlation coefficients are integrated, and a dual trigger warning of "traffic threshold-Finally, we integrate the prediction thresholds and dynamic correlation coefficients to design a dual-trigger early warning strategy of "policy sensitivity", and introduce the Delphi method to achieve the quarterly dynamic calibration of the threshold parameters[6].

The whole paper follows the logic of "Problem Orientation-Theoretical Construction-Methodological Innovation-Empirical Test-Strategy Design": firstly, we sort out the types of risks and transmission mechanisms in the literature review, and construct a three-dimensional analytical framework; secondly, we describe the integration logic and data processing process of ARIMA model, rolling window regression and event study method; we carry out empirical analysis through 2015-2024 IMF data to verify the dynamic association of risk factors and the effect of policy shocks; we propose three dimensions from regulators, fintech companies and multinational banks. Then, it details the integration logic of ARIMA model, rolling window regression and event study method and the data processing process; conducts empirical analyses through the 2015-2024 IMF data to verify the dynamic correlation of risk factors and the effect of policy shocks; puts forward the strategy of "prediction-response-irritation" from the three dimensions of regulators, FinTechs, and multinational banks; and finally sums up the research conclusions and looks forward to the future research direction. The study concludes and looks forward to future research directions. Through this structural design, the study will systematically present a dynamic risk assessment system for cross-border financial data flows, and provide solutions with both theoretical depth and practical value for financial governance in the digital era[7].

2. Research Methodology

2.1 Research Theory

This study takes information asymmetry theory, risk management theory and dynamic capability theory as the core theoretical foundation to construct a theoretical analysis framework for risk assessment of cross-border flow of financial data.

The information asymmetry theory was proposed by Stiglitz (2000), which points out that the market participants will lose the efficiency of resource allocation due to the difference in information acquisition. In the cross-border financial data flow scenario, there are significant information barriers between regulatory bodies and financial institutions. It is difficult for regulators to grasp complete information about financial institutions' data transfers in real time, and there is a lag in financial institutions' knowledge of regulatory policy changes in different countries. This information asymmetry makes risk identification and prevention and control significantly more difficult. Bauer et al. (2014) reveal the internal mechanism of information barriers exacerbated by data localisation policies based on this theory, which provides theoretical support for this study to analyse the risk perception bias among subjects in cross-border data flows[8].

Risk management theory emphasises the systematic process of risk identification, assessment and response (COSO, 2017). In the study of financial data cross-border flow risk, the theory guides this study to construct the research logic chain of "characterisation →

factor quantification → strategy design". Through the comprehensive identification of data flow risks, multi-dimensional risk factors such as technical, legal, and political are quantified, and then targeted risk response strategies are designed. Cory and Dascoli (2021) apply the framework to analyse the transmission path of geopolitical risks on data flows, confirming its effectiveness in integrating multi-dimensional risk factors, which provides theoretical references for this study[9].

Dynamic capability theory, proposed by Teece (1997), advocates that organisations need to adapt to environmental changes by continuously adjusting their resource allocation. In the field of cross-border financial data flow, the policy environment and market conditions are changing rapidly, and the traditional static risk assessment methods are difficult to meet the actual needs. Based on this theory, Zhong Hong and Yang Xinyu (2022) propose a "technology-institution" collaborative governance strategy, which provides a theoretical reference for this study to design a dynamic risk assessment and response mechanism, and ensures the timeliness and adaptability of the proposed strategy[10].

2.2 Specific Experimental Methods

2.2.1 Time Series Trend Analysis and ARIMA Benchmark Flow Forecasts

The information asymmetry theory states that the loss of efficiency in resource allocation can occur due to differences in information access between regulatory bodies and financial institutions (Stiglitz, 2000). In the field of cross-border flow of financial data, accurate time-series forecasting can help to narrow the information gap and improve risk identification (Bauer et al., 2014). The data in this study are obtained from the IMF Balance of Payments Statistics database, and the quarterly cross-border payment data from 2015-2024 are selected to cover the scale of financial data flows among major economies around the world. After data cleaning, the quarterly flow series for 28 countries and regions (n=400+) are retained[11].

In the specific implementation process, firstly, the seasonal decomposition module of SPSS is used, and the multiplicative model $Y_t = T_t \times S_t \times I_t$ is adopted to separate the data series into long-term trend (T), seasonal fluctuation (S) and irregular component (I), and the trend component of 2015Q1-2024Q4 is extracted to identify the cyclical pattern of data flow, such as seasonal fluctuation brought about by the settlement peak at the end of the quarter. Then, the series smoothness is analysed by autocorrelation function (ACF) and partial autocorrelation function (PACF), and the non-smooth data are processed with first-order difference (d=1), and the autoregressive order p=3 and moving average order q=2 are determined based on the truncated tail feature, and the ARIMA (3,1,2) model is constructed. Then, using the 2015-2024 data as the training set, the baseline flow is predicted for 4 quarters in 2025$\hat{Y}_{2025Q1-Q4}$

In addition, a 95 per cent confidence interval is computed, with actual values exceeding the confidence interval by ±2σ considered to be an abnormal volatility interval. Finally, periods with forecast deviations of more than 15% are matched with geopolitical events and regulatory policy implementation over the same period to qualitatively analyse the path of external shocks on data flows. The time series decomposition and ARIMA modelling are done with SPSS 28.0, and Python 3.9 is used for event matching and visualisation.

2.2.2 Time-varying correlation test of risk factors

Risk management theory emphasises the need for risk assessment to integrate multidimensional factors and dynamically adjust the weights in response to environmental changes (Cory & Dascoli, 2021). The rolling window technique is able to capture the time-varying characteristics of parameters and overcome the limitations of traditional static correlation analysis. This study constructs risk indicators from three dimensions: technical risk adopts the "Data Security Breach Index" from the World Bank's Global Information Technology Report. This index is mainly composed of three core indicators: (1) the default frequency of financial data per unit time (per 10,000 transactions per day), (2) the average resolution time of security incidents (in hours), and (3) the weighted score of vulnerability severity (graded according to the CVSS 3.0 standard), which converts annual data into quarterly series through linear interpolation; legal risk selects the "Cross-Border Data Compliance Conflict Index" published by the EU's ESMA ", reflecting differences in data localisation policies across countries; political risk uses the EIU Geopolitical Risk Index, covering trade barriers, policy stability and other dimensions.

For the implementation step, a 3-year

(12-quarter) rolling window is set and the formula $r_t = \frac{\sum_{i=t-11}^{t}(X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=t-11}^{t}(X_i - \bar{X})^2 \sum_{i=t-11}^{t}(Y_i - \bar{Y})^2}}$ is applied to calculate the Pearson correlation coefficients r_t between each risk factor and the cross-border data flows, where x_i is the normalised risk factor and y_i is the normalised flow data. The window was slid from 2018Q1 to 2024Q4 to generate 24 sets of time-varying correlation coefficient series. Then, Excel plots the correlation coefficients from 2018 to 2024, identifies key turning points, such as the change in the correlation of legal risk factors after the implementation of China's Data Security Law in 2021, and analyses the drivers of the correlation changes in the context of the policy text. The rolling calculations and visualisations are done with the help of Excel 365, and Stata 17 is used for standardisation and significance testing.

2.2.3 Comparison of means and regression validation of policy events

The event study method (Fama et al., 1969) can quantify the short-term effects of policy shocks by assessing abnormal fluctuations within the event window period, while the dynamic capability theory requires organisations to be agile and responsive to policy changes, which requires clarifying the quantitative relationship between policy stringency and risk transmission. In this study, two landmark policy events, GDPR implementation (May 2018) and China's Data Security Law implementation (September 2021), are selected. For GDPR, monthly flow data from May 2017-April 2019 (12 months before and after the event) are intercepted to analyse the changes in data flows between the EU and non-EU countries; for China's Data Security Law, data from September 2020-August 2022 are selected to focus on the fluctuations in cross-border data flows between China and the US.

During the implementation process, the flow means (μ1,μ2) and standard deviations (σ1,σ2) of the flows before (T1 period) and after (T2 period) the implementation of the policy were firstly calculated, and the significant differences between μ1 and μ2 were verified by using the SPSS independent samples t-test, and according to the chi-square situation, either the Levene's test or the Welch's corrected t-test was chosen. The Levene's test or Welch's corrected t-test was chosen according to the chi-square. Second, a policy stringency index containing five secondary indicators, such as data localisation requirements and cross-border transmission approval process, was constructed, assigned values by expert scoring method, and tested for reliability (Cronbach's α=0.85). Finally, a univariate linear regression model Drop rate=$\beta_0+\beta_1\times H$arshness+ϵ was constructed with flow rate reduction as the dependent variable and policy stringency as the independent variable, revealing the quantitative relationship between policy intensity and data flow inhibition effect through scatter plot fitting and coefficient significance test ($p<0.05$). The t-test and regression analyses were conducted using SPSS 28.0, and the reliability and validity of the indicators were verified with the help of AMOS 26.

2.2.4 Design of dynamic risk assessment and graded response mechanisms

Dynamic capability theory emphasises the need for organisations to adapt to environmental changes by continuously adjusting their resource allocation (Teece, 1997). Based on this, this study builds a closed loop of "Monitoring-Early Warning-Response-Iteration" to achieve dynamic and intelligent risk prevention and control.

With regard to the implementation framework, a dual-trigger early warning mechanism was first established. The flow threshold is based on ARIMA prediction results and is set at ±20% of the baseline value (historical data shows that this interval covers 90% of normal fluctuations); the correlation coefficient threshold is set at a correlation coefficient of >0.5 for the technical risk factor and >0.4 for the legal risk factor, and high-level warnings are initiated when the actual flow rate breaks through the thresholds for two consecutive quarters and the correlation coefficient of any risk factor exceeds the standard. Second, formulate preset response strategies. For financial institutions, set up automatic switching of data routing, activate cross-border transmission encryption protocols, and trigger the accelerated process of regulatory reporting; for regulators, activate the policy sandbox tool, and dynamically adjust the pace of data localisation legislation according to the deviation of the ARIMA prediction, e.g., delaying the implementation of the new regulation when the deviation of the prediction is >15%. Finally, the thresholds are dynamically calibrated. Every quarter, 10-15 experts in the fields of financial regulation and data security are organised to score the threshold parameters using the Delphi method, screen the valid opinions through the coefficient of variation method, and apply the formula New threshold=Historical thresholds×(1+k×Expert to update the thresholds (k=0.3, determined by backtesting the historical data). This session collects expert opinions with the help of Delphi method online research platform (Questionnaire Star) and develops the threshold algorithm using Python 3.9.

2.3 Methodological Soundness and Innovations

The methodological system of this study has significant innovative features. At the theoretical level, it is the first time that information asymmetry theory and dynamic capacity theory are introduced into the risk assessment of cross-border data flow, which provides a solid theoretical support for the "prediction bias-policy response" mechanism. At the technical level, it breaks through the limitations of a single model and realises the leap from static classification to dynamic quantification of risk factors through the dual-driven modelling of ARIMA benchmark prediction and rolling correlation coefficient. At the practical level, we design a dual-trigger mechanism that can be embedded into the IT system of financial institutions, and combine it with the Delphi method to form an adaptive threshold calibration system, which greatly improves the feasibility of the research results on the ground. This methodology will systematically reveal the risk dynamics of cross-border financial data flow, and provide a new methodological paradigm for constructing a risk governance system that is both predictive and agile.

3. Findings

3.1 Summary of Results

With the core objective of constructing a dynamic risk assessment framework for cross-border financial data flows, this study reveals the long-term trend of data flows, the dynamic mechanism of risk factors, and the short-term impacts of policy interventions through time-series analyses, time-varying correlation tests of risk factors, and validation of the effects of policy shocks. The research results are presented in the following four dimensions: baseline flow prediction, risk factor evolution, quantification of policy shocks and response mechanism effectiveness.

3.2 Cross-Border Data Flow Time-Series Characteristics and Baseline Flow Prediction Results

A time-series decomposition based on quarterly IMF data from 2015-2024 shows significant quarterly cyclicality in cross-border flows of global financial data (seasonal index reaches 1.23 in Q4 compared to 0.89 in Q1), which is highly coincident with the international trade settlement cycle. The ARIMA (3,1,2) model fits the historical data with a goodness of fit of R^2 = 0.92 and a root-mean-square error (RMSE) of \$42.3 trillion. = 0.92, with a root-mean-square error (RMSE) of US\$42.3 trillion, and predicted baseline flows in 2025 of Q1 210 trillion, Q2 225 trillion, Q3 238 trillion, and Q4 255 trillion (Table 1). The analysis of the deviation of the actual flows from the forecasts shows that the forecasts for Q2 2022 (the outbreak of the Russia-Ukraine conflict) and Q4 2023 (the pilot of the new EU data localisation regulation) have deviations of 28% and 21% respectively, significantly exceeding the 95% confidence interval (±18%), which validates the sudden impact of geopolitics and regulatory policies on data flows.

It should be noted that the ARIMA model has inherent limitations in capturing structural breaks—its linear assumptions and fixed parameters struggle to adapt to volatility clustering induced by extreme events. The 28% prediction error during the 2022 Russia-Ukraine conflict serves as definitive evidence: the conflict triggered bidirectional extremes with energy transaction data flows surging (+34%) while payment data collapsed (-41%) due to SWIFT sanctions, yet ARIMA's constant variance assumption failed to capture such heteroskedasticity.

Table 1. Benchmark Forecasts of Cross-Border Data Flows in 2025 (in Trillions of US Dollars)

season (sports)	projected value	95% confidence interval	Historical average for the same period
Q1	210	[195, 225]	182
Q2	225	[208, 242]	199
Q3	238	[220, 256]	215
Q4	255	[235, 275]	231

To enhance adaptability to extreme events, subsequent studies should adopt GARCH-family models to quantify volatility persistence in risk contagion or introduce LSTM neural networks to capture nonlinear linkage mechanisms between policy shocks and geopolitical crises.

3.3 Dynamic Evolution of Time-Varying Correlations of Risk Factors

Rolling window analysis shows that the correlation coefficient of the technology risk factor (data security vulnerability index) with traffic flows shows a "V-shaped" fluctuation between 2020-2024, and rapidly rises to 0.62 (2022Q2) after the implementation of the Data Security Act in 2021, indicating that the inhibitory effect of technology vulnerabilities on data flows increases with the change of regulatory environment; The legal risk factor (Compliance Conflict Index) correlation continues to be higher than 0.5 after the implementation of the GDPR, with an average correlation coefficient of 0.58 in 2023, significantly higher than 0.32 before 2018 (t-test, p<0.01); the political risk factor (Geopolitical Index) correlation plummets to 0.45 in 2022Q1, which is directly related to the reconfiguration of cross-border payment links due to the conflict in Russia-Ukraine directly related to the reconfiguration of cross-border payment links due to the Russian-Ukrainian conflict. The ranking of the influence of the three types of risk factors changes dynamically over time, with legal risk dominating before 2020 (average correlation coefficient of 0.48), and technological risk jumping to the top after 2021 (average of 0.55), reflecting the significant impact of the iterative global data security technological architecture on cross-border flows.

3.4 Short-Term Shock Effects of Policy Events on Data Flows

An analysis of incidents against the GDPR and China's Data Security Law shows (Table 2):

GDPR implementation effect: The average monthly traffic between EU and non-EU countries decreased from 12.5 trillion before implementation to 10.2 trillion after implementation, a decrease of 18.4%. The independent samples t-test shows a significant difference between the means (t=-3.27, p=0.002), and the regression coefficient of the policy stringency and the decrease of the traffic is -1.85 (p<0.05), that is, the decrease of traffic is 1.85% larger for every 1 unit of increase of the stringency. unit increase in stringency, the rate of traffic reduction increases by 1.85%.

Data Security Law implementation effect: the average value of cross-border data flows between the US and China decreased from 8.3 trillion before implementation to 6.7 trillion after implementation, a decrease of 19.3 per cent, with a significant t-test (t=-2.89, p=0.005), and a regression analysis showing that the coefficient of stringency was -2.12 (p<0.01), suggesting that the inhibitory effect of China's data compliance requirements on high-frequency data flows was slightly higher than that of the EU policies.

Table 2. Comparison of Data Traffic Averages Before and After Policy Implementation

Policy events	phase	Average value (trillion)	(statistics) standard deviation	t-value	p-value
Pre-GDPR	2017.05-2018.04	12.5	1.8	-3.27	0.002**
After GDPR implementation	2018.05-2019.04	10.2	1.5		
Pre-Data Security Act	2020.09-2021.08	8.3	1.2	-2.89	0.005**
After the Data Security Act	2021.09-2022.08	6.7	1.1		

*Note: ** indicates p<0.01, *indicates p<0.05 (two-tailed test).*

3.5 Validation of the Effectiveness of Dynamic Risk Assessment Mechanisms

Backtesting of the double-trigger warning mechanism through the actual data in 2023 shows that when the traffic exceeds the threshold for two consecutive quarters (e.g., the actual traffic in 2023Q3 and Q4 is 265 trillion and 280 trillion, respectively, which exceeds the 20% thresholds of the baseline value of 238 trillion and 255 trillion) and the technical risk correlation coefficient is >0.5, the system accurately triggers a high-level warning, prompting financial institutions to switch The system accurately triggers a high-level warning, prompting financial institutions to switch data routing to low-risk areas, reducing the risk of data retention by 37 per cent. The Delphi method threshold calibration mechanism has increased the accuracy of the warning rate from the initial 82% to 89%, showing that the combination of expert experience and data models has effectively enhanced the adaptability of the system.

3.6 Summary of Results

This study was confirmed by quantitative analyses:
The cross-border flow of financial data shows significant time-order regularity, and the ARIMA model can effectively capture long-term trends and identify abnormal fluctuations; the influence of technical, legal, and political risk factors dynamically evolves with the policy environment, and rolling window technology is needed to track their correlation changes in real time; the short-term inhibitory effect of data localisation policies on cross-border flows is significant, and the severity of the policies is negatively correlated with the rate of flow decline; the dual-trigger early warning mechanism and dynamic calibration system can improve the accuracy of risk response, providing operational decision-making tools for financial institutions and regulators. The dual-trigger early warning mechanism and dynamic calibration system can improve the accuracy of risk response and provide operational decision-making tools for financial institutions and regulators.

4. Talk Over

4.1 Summary of Findings and Core Values

This study constructs a dynamic risk assessment framework for financial data cross-border flows by integrating the ARIMA model, rolling window correlation analysis and event study method, and achieves important findings in multiple dimensions. First, the analysis based on quarterly IMF data from 2015-2024 shows that global financial data cross-border flows show significant quarterly cyclicality, which is highly consistent with the international trade settlement cycle, and the prediction accuracy of the ARIMA model for the baseline flow in 2025 reaches $R^2=0.92$, and it can effectively identify the abnormal fluctuations caused by external shocks, such as geopolitical conflicts, regulatory policies, and so on. It can also effectively identify abnormal fluctuations caused by external shocks such as geopolitical conflicts and regulatory policies. For example, the new EU data localisation pilot in 2023 makes the prediction deviation rate of the current quarter reach 21%. Second, the influence of technical, legal and political risk factors dynamically evolves with the policy environment, with the correlation coefficient of the technical risk factor (data security vulnerability index) rising to 0.55 after 2021, surpassing the legal risk factor (0.52) to become the dominant factor, reflecting a significant increase in the shaping of cross-border flows by the technical compliance requirements for data security. The quantitative results of the policy impact effect show that after the implementation of the GDPR and China's Data Security Law, the relevant regional data flows dropped by 18.4% and 19.3% respectively, and for every 1-unit increase in policy stringency, the flow drop expanded by 1.85%-2.12%, verifying the linear negative correlation between regulatory intensity and flow size. In addition, the double-trigger early warning system reduces the risk of data retention by 37%, and the Delphi method calibration improves the accuracy of early warning to 89%, which proves that the dynamic assessment framework is of significant value for the prevention and control of actual risks. These findings break through the limitations of traditional static assessment methods and provide new perspectives for understanding the dynamic transmission mechanism of data flow risk, especially in the context of the increasing trend of global data localisation, which fills the gap of quantitative research on the time-series dimension of risk.

4.2 Theoretical and Practical Interpretation of Research Findings

From a theoretical perspective, this study finds that the correlation of the technology risk factor shows a "V-shaped" fluctuation and reaches 0.62 in 2021, which echoes the "technology-institution" synergistic governance theory proposed by Zhong Hong and Yang Xinyu (2022). This echoes the "technology-institution" synergistic governance theory proposed by Zhong Hong and Yang Xinyu (2022), which suggests that the improvement of data security technology standards can have a positive effect in the long run by enhancing the stability of data flow, although it increases the compliance cost in the short term. Unlike Huang (2023), who focuses on the static compliance risk balance, this study reveals the time-varying priority of risk factors through the rolling-window technique: the legal risk factor dominates before 2020 due to the differences in the data sovereignty legislation of each country (average correlation coefficient of 0.48), and technical compliance becomes the core threshold of cross-border flows after 2021 with the implementation of the new regulations of the Data Security Law and the Personal Information Protection Law, with technical risk factors becoming the core threshold of cross-border flows, and technical risk factors becoming the core threshold of cross-border flows. After 2021, with the implementation of new regulations such as the Data Security Law and other personal information protection laws, technical compliance becomes the core threshold of the flow, and the influence of the technical risk factor rises significantly, which is consistent with the theory of "policy heterogeneity exacerbates spatial and temporal differences in risk" put forward by Cory & Dascoli (2021), and further quantifies the dynamic process of shifting the influence of factors.

An international comparison of policy shock effects shows that the dampening effect of China's Data Security Law on cross-border data flows between China and the US (19.3% drop) is slightly higher than the impact of the GDPR on EU flows (18.4%), which is in line with Bauer et al.'s (2014) finding that "the economic costs of data localisation policies are higher in emerging markets " which is consistent with Bauer et al.'s (2014) finding that "the economic costs of data localisation policies are higher in emerging markets," and may be attributed to the fact that cross-border data flows between China and the US are dominated by high-frequency transactional data, which is more sensitive to compliance reviews. The regression results show that the policy stringency coefficients are-2.12 and-1.85 for the China and EU scenarios, respectively, indicating that the complexity of the regulatory framework (e.g., the cross-border transmission whitelisting system) has a more significant impact on the flows than the stringency of the policy text per se, which complements the limitations of the application of the event study methodology in low-frequency policy scenarios of Fama et al. (1969) by demonstrating that the dynamic time-series analyses can more accurately capture the long-tail effects of policy implementation.

Compared with existing studies, this study, in contrast to the static risk identification framework constructed by Ni Jianhan (2024), upgrades the risk assessment from "classification identification" to "dynamic tracking" through the dual-driver model of ARIMA and rolling correlation, effectively solving the Compared with the DCC-GARCH model of Engle (2002) in international studies, this study combines the event study method and the expert calibration mechanism, which better fits the complex scenario of "policy shock-market response-mechanism iteration" in the cross-border flow of data. This study combines the event study method and expert calibration mechanism to better fit the complex scenario of "policy shock-market response-mechanism iteration" in cross-border data flows, which significantly improves the explanatory power of the model.

4.3 Research Limitations and Future Directions

Although the study has achieved some milestones, there are still some aspects that need to be improved. In terms of sample coverage, the current data mainly come from the 28 major economies published by IMF, and insufficient attention is paid to small high-frequency data flows in emerging markets such as Southeast Asia and Latin America, which may lead to a shift in the weights of the risk factors, and the future study can incorporate the subdivided regional data from the World Bank's Global Payments Database (GPDB) in order to enhance the model's general applicability. In terms of extreme event adaptability, the ARIMA model relies on the assumption of smoothness of historical data, and the prediction of unexpected geopolitical events such as the Russia-Ukraine conflict in 2022 has a large deviation (28%), and GARCH-like models or machine learning algorithms (e.g., LSTM) need to be introduced in the future to enhance the ability to fit non-smooth sequences. In terms of indicator construction, the policy stringency index adopts the expert scoring method, although it passes the reliability test (Cronbach's α=0.85), but the difference in the understanding of "data localisation" by experts in different fields may affect the accuracy of the indicator, and in the future, it can be combined with the Natural Language Processing (NLP) technology to quantify and encode the policy text. coding to reduce subjective bias.

4.4 Implications for the practical application of research findings

The results of the study have important applications for regulators, financial institutions and international rule harmonisation. For regulators, the significant linear relationship ($p<0.01$) between policy stringency and traffic drop suggests that when formulating data localisation policies, the ARIMA prediction model in this study can be used to preset a tolerance zone for traffic fluctuations, e.g., to allow short-term drops of no more than 20%, to avoid the "one-size-fits-all" policy triggering a systemic risk. Specifically, a dynamic buffer period can be set using the 2025 baseline traffic forecast before the implementation of the new regulation, and when the actual traffic falls below 80% of the baseline for two consecutive quarters, the policy effect assessment and adjustment mechanism will be automatically triggered, which can be used as a reference to optimise the cross-border regulatory sandbox tools by the European Union's ESMA and other institutions.

Financial institutions can build resilient data routing systems in response to the trend of rising correlation of technical risk factors. Multinational banks can develop "Risk Factor-Routing Node" intelligent matching algorithm, when the correlation coefficient of legal risk in a certain region is >0.5 and the traffic exceeds the threshold, it will automatically switch the highly sensitive data to the transit node with higher compliance level, such as the Singapore and Switzerland data centres, which can reduce the transmission delay and compliance cost by 40%. Fintech companies can embed a real-time risk monitoring module in the cross-border payment system, and when the political risk index of a Southeast Asian country has a correlation coefficient of >0.4 with the traffic flow, it will automatically activate the transaction limit strategy, balancing risk control and user experience.

With regard to the coordination of international rules, the time-varying characteristics of risk factors revealed by the study provide a quantitative basis for international organisations to formulate standards for cross-border data flows. It is recommended that rolling window correlation indicators be introduced into the Guidelines on Cross-Border Data Flows, requiring member states to regularly disclose the dynamic correlation data of technical and legal risk factors, and facilitating the transparent assessment of "regulatory intensity-market impact". For example, in the negotiation of RCEP data rules, reference can be made to this study's policy stringency quantification method to establish an early warning mechanism for intra-regional data compliance conflicts, reduce trade barriers caused by policy differences, and promote the construction of a "dynamic compliance" framework.

5. Reach a Verdict

Through methodological innovation and empirical analyses, this study successfully constructs a dynamic risk assessment framework applicable to cross-border financial data flows, confirming the effectiveness of the integration of time-series prediction, factor dynamic quantification and policy shock decomposition. The results of the study not only provide quantitative evidence of the dynamic evolution of risk for academics, but also provide a full-chain solution of "Monitoring-Early Warning-Iteration" for regulatory practice and industry application through the design of a grounded response mechanism. In the context of accelerated reconstruction of global data governance rules, future research can further explore the mitigating effect of AI technology (e.g., federated learning) on cross-border data risks, as well as the risk conduction path of ESG (environmental, social, and governance) factors in data flows, to provide continuous support for the construction of a better risk governance system for cross-border financial data flows.

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