AI-Driven Financial Market Dynamics and Cross-Market Spillovers: A Comparative Research Framework for Emerging and Developed Stock Markets and Sustainable Development

Dr. Chokkamreddy Prakash[1], Prof. Otilia MANTA [2]

[1] LGPR Postdoctoral Research Scholar, Lincoln Global Postdoctoral & Researcher Programme, Lincoln University College, Malaysia; [2] Professor, Romanian-American University, Bucharest, Romania;

Email ID pdf.PrakashChokkamreddy@lincoln.edu.my;drcprakashreddy@gmail.com; otilia.manta@rgic.ro

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Abstract: Financial integration has risen and shocks are increasingly transmitted to and from emerging other developed stock markets around the globe. Previous literature is also disjointed in the fields of AI-based prediction, nonlinear market dynamics, cross-market spillovers, financial contagion, sustainability issues and AI. This study proposes an AI/ML-powered research platform that integrates AI/ML with market, macroeconomic, volatility, liquidity, sentiment and sustainability variables including the ESG, green finance and carbon markets and climate related risks, to model financial market dynamics and cross market spillovers. Eight significant gaps were found in the reviewed research thriving the methodology, cross-asset analysis, sustainability, nonlinear modelling, explainability, crisis prediction, SDG integrability and overall. Seven testable hypotheses are formulated and used to direct further empirical research. This framework can be used to aid investors, portfolio managers, financial institutions, regulators and policymakers in predictivity, contagion risk identification, risk management and sustainable financial decision making.

Keywords: Artificial Intelligence; Financial Market Dynamics; Cross-Market Spillovers; Emerging Markets; Developed Markets; Financial Connectedness; Sustainable Finance; Explainable AI

Introduction

Financial markets have become increasingly interconnected because of cross-border capital flows, financial liberalisation, technological advancement, institutional investment, and the rapid dissemination of information. This integration improves international capital allocation and diversification but also increases the potential for financial shocks to transmit rapidly across countries. Evidence from major crises, including the global financial crisis and COVID-19 pandemic, demonstrates that disturbances originating in one market can generate significant effects in other markets through international financial connectedness and contagion [2], [5], [37]. Consequently, understanding the direction, intensity, and time-varying nature of cross-market spillovers has become important for investors, financial institutions, regulators, and policymakers.

The issue is particularly important when comparing emerging and developed stock markets. Differences in market depth, liquidity, institutional development, regulatory structures, investor participation, and dependence on international capital flows can produce asymmetric responses to external financial shocks. At the same time, financial connectedness is influenced by economic uncertainty, liquidity conditions, investor behaviour, geopolitical risk, and crisis periods. These characteristics indicate that international spillovers are dynamic and potentially nonlinear rather than stable relationships that can be adequately represented through conventional approaches alone.

The increasing availability of high-dimensional financial data has created opportunities to apply Artificial Intelligence (AI) and Machine Learning (ML) techniques to financial forecasting, risk analysis, and spillover prediction. AI/ML models can identify complex and nonlinear relationships that may be difficult to capture using traditional econometric approaches. However, existing research remains fragmented across financial connectedness, AI-based prediction, emerging–developed market comparisons, and sustainable finance. In particular, the integration of ESG, green finance, carbon-market, and climate-related variables into AI-based international spillover analysis remains limited. Moreover, the interpretability of AI models is important because investors and policymakers require not only predictions but also an understanding of the factors driving financial-risk transmission.

Against this background, the present study proposes an AI-driven comparative research framework for analysing and predicting dynamic cross-market spillovers between emerging and developed stock markets, while incorporating financial, macroeconomic, and sustainability-related factors. The framework integrates financial connectedness analysis, AI/ML-based prediction, nonlinear modelling, sustainability variables, and Explainable AI (XAI) to identify important determinants of financial-risk transmission. The study is therefore motivated by the need for a unified and interpretable framework that can support financial risk management, investment decision-making, market resilience, and sustainable financial development.

Related Work and Literature Review

Financial Spillovers and Connectedness.

The increasing integration of global financial markets has strengthened the transmission of shocks across countries and financial systems. Previous studies demonstrate that financial contagion can intensify during periods of crisis and that spillover effects are not constant over time. Evidence from major international markets indicates that financial connectedness varies with market conditions, uncertainty, and crisis periods, highlighting the importance of analysing spillovers as dynamic rather than static relationships [2], [5], [34], [37]. Although these studies provide substantial evidence on international contagion and connectedness, much of the existing literature focuses on identifying historical spillovers rather than developing integrated predictive frameworks for future spillover dynamics.

Emerging and Developed Markets and Crisis Effects.

Emerging and developed markets differ in terms of market depth, liquidity, institutional structures, regulatory environments, and exposure to international capital flows, which may result in asymmetric responses to external shocks. Studies of BRICS, ASEAN and global foreign-exchange markets provide evidence of significant international transmission and interconnectedness between emerging and developed economies [24], [27], [33]. Recent evidence also indicates that energy and foreign-exchange market relationships differ across developed and emerging economies, reflecting differences in their financial structures and risk characteristics [31]. However, existing studies are frequently limited to particular countries, regions, assets, or bilateral relationships, indicating a need for a systematic comparative framework for examining spillovers across emerging and developed markets.

Cross-Asset, Liquidity and Geopolitical Factors.

Financial spillovers extend beyond equity markets to commodities, energy, foreign exchange, and other asset classes, particularly during periods of financial stress. Research on stock, oil and gold markets demonstrates significant changes in cross-asset connectedness during the COVID-19 period, while broader evidence confirms the importance of commodity and other financial markets in international risk transmission [8], [17]. In addition, liquidity conditions can act as an important

channel for transmitting financial disturbances across markets, while geopolitical risk can influence volatility spillovers and international financial connectedness [14], [19]. These findings suggest that a comprehensive analysis of financial spillovers should consider multiple financial and risk-related factors rather than focusing exclusively on stock-market relationships.

AI/ML and Nonlinear Prediction.

The increasing availability of high-dimensional financial data has encouraged the application of Artificial Intelligence (AI) and Machine Learning (ML) techniques to financial forecasting and risk analysis. Recent studies demonstrate the potential of neural networks and other machine-learning approaches for predicting financial spillovers, extracting useful information from noisy financial data, and identifying nonlinear determinants of spillover movements [20], [21], [30]. Since financial relationships may change across market regimes and crisis conditions, nonlinear approaches such as Markov-switching models further highlight the limitations of assuming stable linear relationships [26]. However, the comparative application of AI/ML for predicting spillovers between emerging and developed markets, particularly within a unified framework, remains relatively limited.

ESG, Sustainability and Explainable AI.

Sustainability-related financial factors have become increasingly relevant to international financial-market analysis. Evidence indicates that ESG regulation, ESG portfolios, green bonds, carbon markets, and environmental factors can influence financial connectedness and spillover dynamics [4], [12], [22], [23], [40], [41]. However, the integration of these sustainability-related variables into AI-based cross-market spillover prediction remains underdeveloped. Furthermore, although AI/ML models can improve predictive performance and capture complex relationships, their limited interpretability can restrict their practical usefulness for investors, financial institutions, and policymakers. Therefore, incorporating Explainable AI (XAI) alongside financial, macroeconomic, and sustainability variables provides an important direction for developing a more comprehensive and decision-oriented framework.

Critical Research Gap

From this literature review, it is noted that the current research findings have provided significant underpinnings, yet the research has yet to fully integrate these into a single research construct. Five critical gaps in particular come to the fore.

The first one is the methodological gap, as the financial-spillover literature continues to rely on the conventional econometric, connectedness and network-based methods, and the AI-driven predictive ones are comparatively new [20], [21].

Second, a comparative gap turns out to be there, as the emerging and developed markets are typically discussed separately or regionally or in the context of particular bilateral relationships and not in the context of a comparative framework [24], [27], [31], [33].

Thirdly, there is a gap in the nonlinear modeling due to these financial spillovers being potentially regime-dependent while the number of nonlinear financial models is limited [26], [30].

Fourth, there is a capacity gap for sustainability, with ESG, green finance, carbon markets, and climate-related financial risks becoming increasing central elements of financial connectedness, but yet there is lack of integration with AI based prediction of these spillovers [4], [22], [23], [40], [41].

Fifth, the explainability gap should exist as predictive AI technologies need to be interpretable for financial managers, investors and policymakers to be practically useful [20], [30].

To this end, the present study aims to develop an integrated framework where macroeconomic and financial conditions and sustainability factors influence emerging and developed stock markets, which in turn generate dynamic cross market spillovers; AI/ML models can predict the behaviour of financial-

risk transmission; and explainable AI can pinpoint the underlying main factors of the financial-risk transmission. Distilleries created from the results can help with financial risk management, financial market resilience and sustainable financial development.

Research Problem

Over the past years, the connection between global financial markets has intensified with the transmission of financial shocks between emerging markets and developed ones getting stronger. There is strong and time variant spillover effect from previous research, especially in times of crisis and uncertainty [2], [37]. But traditional methods do not offer much in terms of capturing complex nonlinear interrelationships and forecasting spillover dynamics in the future.

AI/Machine learning techniques have greater capabilities of modelling complex financial relationships [20] and [21] while only a limited research has been undertaken in which context one can apply it to the prediction of spill over effects between emerging and developed markets. Moreover, current AI-based financial models have not adequately considered the impact of ESG, green finance and carbon markets [4] as well as climate factors on international spillovers [40] [41]. AI models also have low interpretability, complicating the identification of key determinants for the transmission of financial risk.

Hence, the study asks the following question(s):

No unified AI-based, explainable scheme exists to analyse and predict the dynamic financial spillovers between emerging and developed stock markets and has been built based on financial, macroeconomic, and sustainability factors.

The study therefore aims to create a framework that will involve financial connectedness, AI/ML prediction, emerging market—developed market context, sustainability concerns, and explainable AI for better financial risk management and sustainable financial development.

Research Questions

Table 1. Research Questions

Code	Research Question
RQ1	What is the nature and direction of financial spillovers between emerging and developed stock markets?
RQ2	Are financial spillovers dynamic and significantly different across emerging and developed markets?
RQ3	Do financial crises and uncertainty significantly amplify cross-market spillovers?
RQ4	Can AI/ML models improve spillover prediction compared with conventional approaches?
RQ5	Can AI models capture nonlinear financial relationships more effectively than conventional models?
RQ6	Do ESG and sustainability-related factors influence international financial spillovers?
RQ7	Can explainable AI identify the major determinants of cross-market spillover risk?

Research Objectives

General Objective

To develop an AI-driven comparative framework for analysing dynamic cross-market spillovers between emerging and developed stock markets while incorporating sustainability-related financial factors.

Specific Objectives

1. To critically review international financial-spillover literature.
2. To examine the conceptual differences between emerging and developed markets.

3. To examine the role of crisis and uncertainty conditions in spillover dynamics.
4. To establish the potential contribution of AI/ML to spillover prediction.
5. To examine nonlinear relationships in international financial markets.
6. To integrate ESG and sustainability-related financial factors.
7. To establish the role of explainable AI in identifying spillover determinants.

Theoretical Foundation

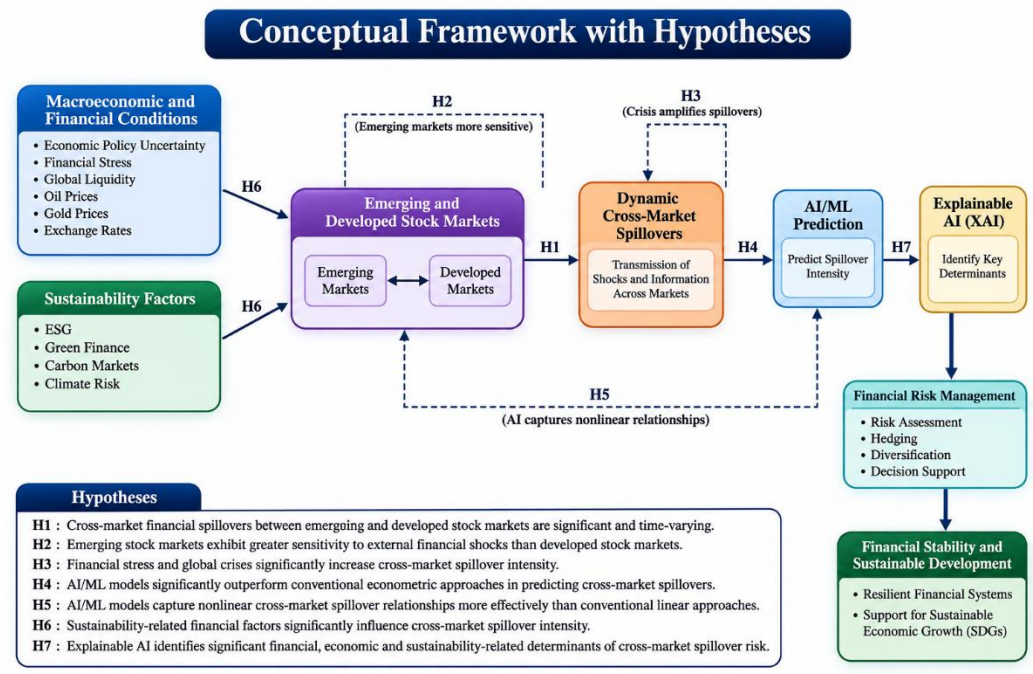
Table 2. Theoretical Perspectives Underpinning the Study

Theory/Perspective	Core Proposition	Application
Financial Contagion Theory	Financial shocks can spread across markets	Cross-market spillovers
Information Transmission Perspective	Information is rapidly reflected across markets	International market interaction
Network Perspective	Financial markets operate as interconnected nodes	Transmitters and receivers
Sustainable Finance Perspective	ESG and environmental information influence financial decisions	Sustainability integration

The combination of these perspectives provides a theoretical foundation for analysing financial markets as dynamic, interconnected, nonlinear, and sustainability-sensitive systems.

Figure1: Conceptual Research Framework

The proposed conceptual framework follows the sequence:



Hypothesis Development

Table 3. Proposed Hypotheses

Hypothesis	Proposed Relationship
H1	Emerging–developed market spillovers are significant and time-varying.
H2	Emerging markets are more sensitive to external financial shocks than developed markets.
H3	Crisis and financial stress conditions increase spillover intensity.
H4	AI/ML models outperform conventional approaches in spillover prediction.
H5	AI/ML models capture nonlinear spillover relationships more effectively.

H6	Sustainability-related factors significantly influence spillovers.
H7	Explainable AI identifies significant spillover determinants.

Table 4. Proposed Empirical Analysis Framework

Research Dimension	**Variables / Indicators**	**Proposed Analysis**	**Expected Purpose**
Market Dynamics	Stock returns, volatility, trading volume	Descriptive statistics, correlation analysis	Examine basic market characteristics
Financial Connectedness	Emerging and developed market returns	Diebold–Yilmaz spillover index	Measure total and directional spillovers
Direction of Spillovers	Net transmitters and receivers	Total Connectedness Index, Net Spillover Index	Identify transmission direction
Time-Varying Spillovers	Rolling/rolling-window connectedness	Dynamic connectedness analysis	Examine changes over time
Crisis Effects	Crisis-period dummy / stress periods	Pre-crisis vs. crisis comparison	Examine whether crises amplify spillovers
Nonlinear Relationships	Market returns and spillover measures	Nonlinear/regime-dependent modelling	Identify nonlinear transmission patterns
AI/ML Prediction	Spillover indicators and explanatory variables	LSTM, XGBoost, Transformer/ML models	Predict future spillover dynamics
Model Comparison	Predicted vs. actual spillovers	RMSE, MAE, MAPE, \(R^2\)	Compare predictive performance
Sustainability	ESG, green bonds, carbon-market indicators	Regression/ML feature analysis	Examine sustainability-related effects
Explainability	Important predictive variables	SHAP/XAI analysis	Identify major determinants of spillovers

Table 5. Proposed Variables and Data Structure

Category	**Variable**	**Measurement / Proxy**	**Role in Analysis**
Market	Stock Market Return	Log return of daily index prices	Dependent/market variable
Market	Volatility	Realized/conditional volatility	Risk indicator
Market	Trading Activity	Trading volume	Liquidity/activity indicator
Macroeconomic	Interest Rate	Policy/benchmark interest rate	Explanatory variable
Macroeconomic	Exchange Rate	Local currency/USD	Explanatory variable
Macroeconomic	Economic Policy Uncertainty	EPU indicator	Uncertainty variable
Financial	Global Market Condition	Global stock-market indicator	Control variable
Sustainability	ESG	ESG index/score	Sustainability factor
Sustainability	Green Finance	Green bond/green asset indicator	Sustainability factor
Sustainability	Carbon Market	Carbon price/index	Environmental financial factor
Sustainability	Climate Risk	Climate-related risk indicator	Risk factor

Geopolitical	Geopolitical Risk	GPR indicator	Risk factor
Liquidity	Market Liquidity	Liquidity proxy	Spillover channel
Spillover	Connectedness	Total/directional spillover index	Main dependent construct

Table 6. Hypothesis–Analysis Mapping

Hypothesis	Proposed Relationship	Proposed Analysis	Key Indicator / Criterion
H1	Emerging–developed market spillovers are significant and time-varying.	Dynamic connectedness analysis	Total and directional spillover measures
H2	Emerging markets are more sensitive to external financial shocks than developed markets.	Comparative spillover analysis	Net spillover and shock transmission
H3	Crisis and financial stress conditions increase spillover intensity.	Crisis vs. non-crisis analysis	Difference in spillover intensity
H4	AI/ML models outperform conventional approaches in spillover prediction.	Comparative predictive modelling	RMSE, MAE, MAPE and R^2
H5	AI/ML models capture nonlinear spillover relationships more effectively.	Nonlinear and AI/ML model comparison	Predictive performance and nonlinear relationship measures
H6	Sustainability-related factors significantly influence spillovers.	Regression / machine-learning feature analysis	Statistical significance and feature importance
H7	Explainable AI identifies significant spillover determinants.	XAI / SHAP analysis	Feature-importance ranking

Expected Contribution

The proposed research is expected to contribute to the literature in four principal ways.

First, methodological contribution: It proposes integration of conventional financial connectedness with AI-based predictive modelling.

Second, comparative contribution: It explicitly compares emerging and developed financial markets within a common analytical framework.

Third, sustainability contribution: It incorporates ESG, green finance, carbon-market and climate-related variables into international financial-spillover research.

Fourth, managerial contribution: Explainable AI can potentially provide investors, financial institutions and policymakers with interpretable information concerning the drivers of international financial-risk transmission.

Implications for Management and Sustainable Development

From a management perspective, improved understanding of international spillovers can support portfolio diversification, financial-risk management, asset allocation, stress testing, and strategic investment decisions.

For financial institutions, AI-based spillover prediction may support the identification of emerging systemic-risk conditions. For policymakers, understanding international transmission mechanisms may contribute to financial-stability monitoring and crisis preparedness.

The sustainability dimension further connects the study with sustainable-finance objectives by incorporating ESG, green-finance, carbon-market, and climate-related considerations into financial-risk analysis.

The framework therefore has potential relevance to SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), SDG 13 (Climate Action), and SDG 17 (Partnerships for the Goals).

Conclusion

The growing interdependence in global financial markets has resulted in financial markets that are very dependent on one another, that transfer information quickly, and that are more vulnerable to external shocks from outside the country. For financial contagion, dynamic connectedness, spillovers across different asset classes, emerging-market integration and the transmission of financial crisis, existing studies offer significant evidence [2], [5], [37].

The advent of AI and ML also opens doors to tackle the nonlinear and complex nature of modern financial markets. The recent advances in sustainable finance also suggest that financial-risk analysis of today should incorporate ESG and green finance, carbon markets and climate-related financial risks. However, literature is still fragmented. This study aims to fill this void by defining an integrated conceptual framework that connects AI with the dynamics of financial markets, the SMI bilateral spillovers, sustainability and explainable financial analytics.

Eight major research gaps and seven testable hypotheses were revealed. The proposed research framework is clear, moving the reading and issues to the questions, aims and hypotheses of a research study, and finally to that study's empirical exploration.

Therefore, the results of this paper, which is meant to support the breach and expending of the subsequent empirical phase, have not been reported. Receiving the data and building the benchmark model or AI model can be the next stage of the research, where the indices of emerging and developed markets can be selected, financial and other sustainability-related data can be collected, the benchmark and AI model can be developed, and the H1–H7 can be tested.

The proposed framework thus provides a structured research framework for understanding the dynamic spillover effect, comparisons between emerging and developed stock exchanges, incorporation of sustainability-related financial factors, application of AI/ML in the prediction, analysis for nonlinear relationships, and application of XAI in identifying determinants for the spillover. The resultant empirical study can make a contribution to the enhanced financial risk management, enhanced market resilience and sustainable financial development.

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SGS Initiative, VOL. 1 NO .12 (2026): LGPR