A Framework for Detecting Short-Run Financial Contagion and Identifying Transmission Channels

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Problem Statement

- Traditional models assume linearity and cannot capture short-run crisis dynamics.
- Lack of insights into specific **transmission channels**.
- **To investigate pure contagion among major global economics and measure the strength of pure contagion channels in meditating the transmission**

Dataset Description

- **Time Period:** January 5, 2004 – June 4, 2025
- **Total Duration:** Over 21 years of data

Return Data (Markets)

- Date
- S&P 500
- S&P/TSX
- Nikkei 225
- DAX
- CAC 40
- FTSE 100
- FTSE MIB

Contagion Channel Data

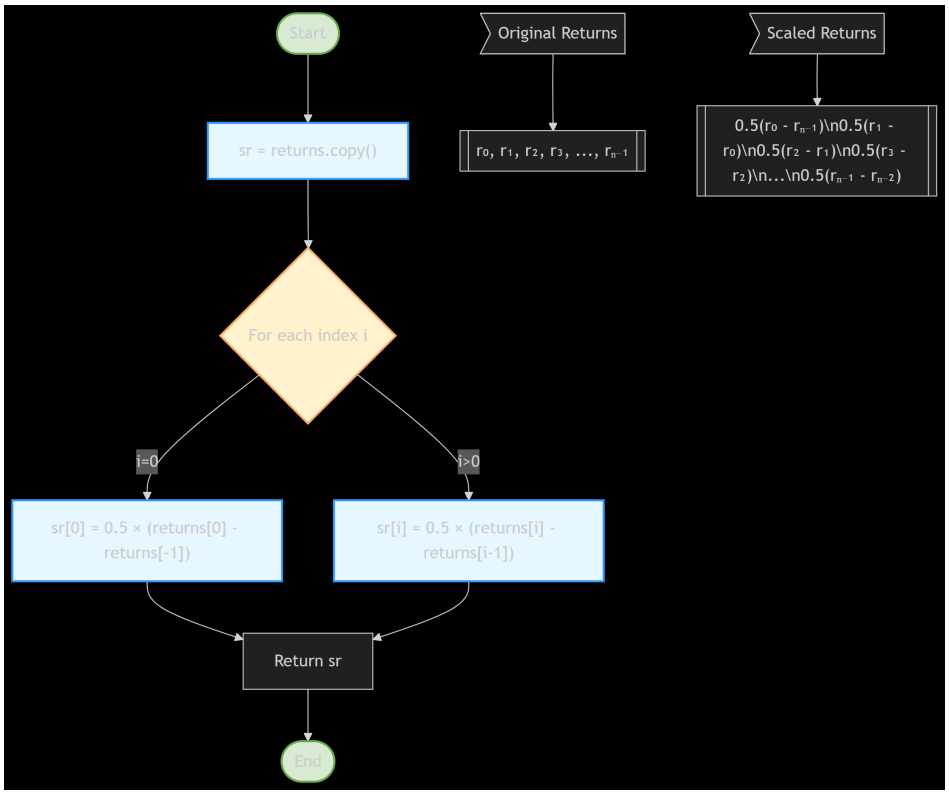
- Date
- GPRD (Geopolitical Risk)
- VIX (Volatility Index)
- Bid-Ask Spread – S&P 500
- Bid-Ask Spread – S&P/TSX
- Bid-Ask Spread – Nikkei 225
- Bid-Ask Spread – DAX
- Bid-Ask Spread – CAC 40
- Bid-Ask Spread – FTSE 100
- Bid-Ask Spread – FTSE MIB

Proposed Framework: Overview

1. Use **wavelet decomposition** to isolate short-run contagion effects.
2. Apply **Minimum Spanning Tree (MST)** for detecting topological contagion.
3. Identify dominant transmission channels using:
   - Elastic Net Regression (linear)
   - Random Forest (non-linear)

Wavelet-Based Short-Run Return Transformation

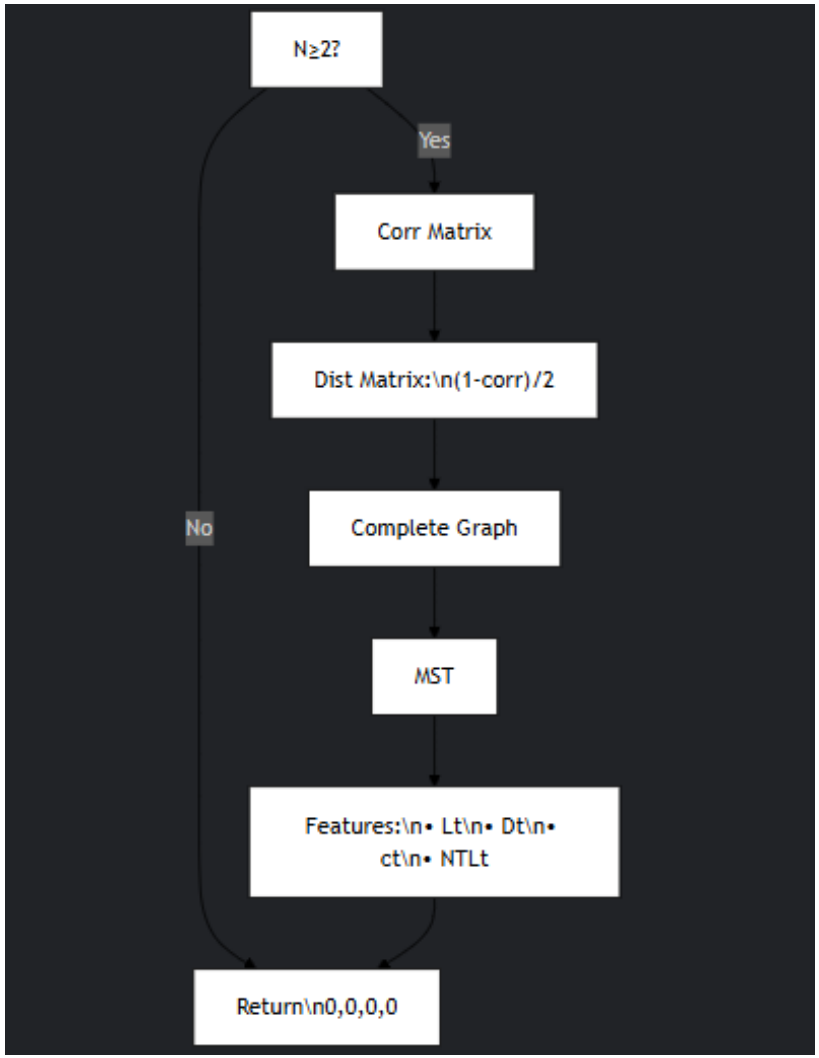
- The short-run return component is isolated using a first-level wavelet approximation.
- Captures high-frequency fluctuations most likely due to contagion rather than fundamentals.
- Forms the input for MST and channel identification stages.



4.2 MST Topological Features

To detect contagion in market structure, we compute the following four topological features from the Minimum Spanning Tree (MST):

- **Average Path Length (Lt)**: Mean shortest path across all node pairs in the MST.
- **Diameter (Dt)**: Longest shortest path in the MST; indicates maximum separation.
- **Degree Centralization (Ct)**: Measures hub dominance; higher values indicate centralized contagion.
- **Normalized Tree Length (NTLt)**: Total MST length normalized by maximum possible edge length.



4.3 Contagion Detection Rule

We define a contagion indicator I_t^{MST} based on MST thresholds:

Conditions:

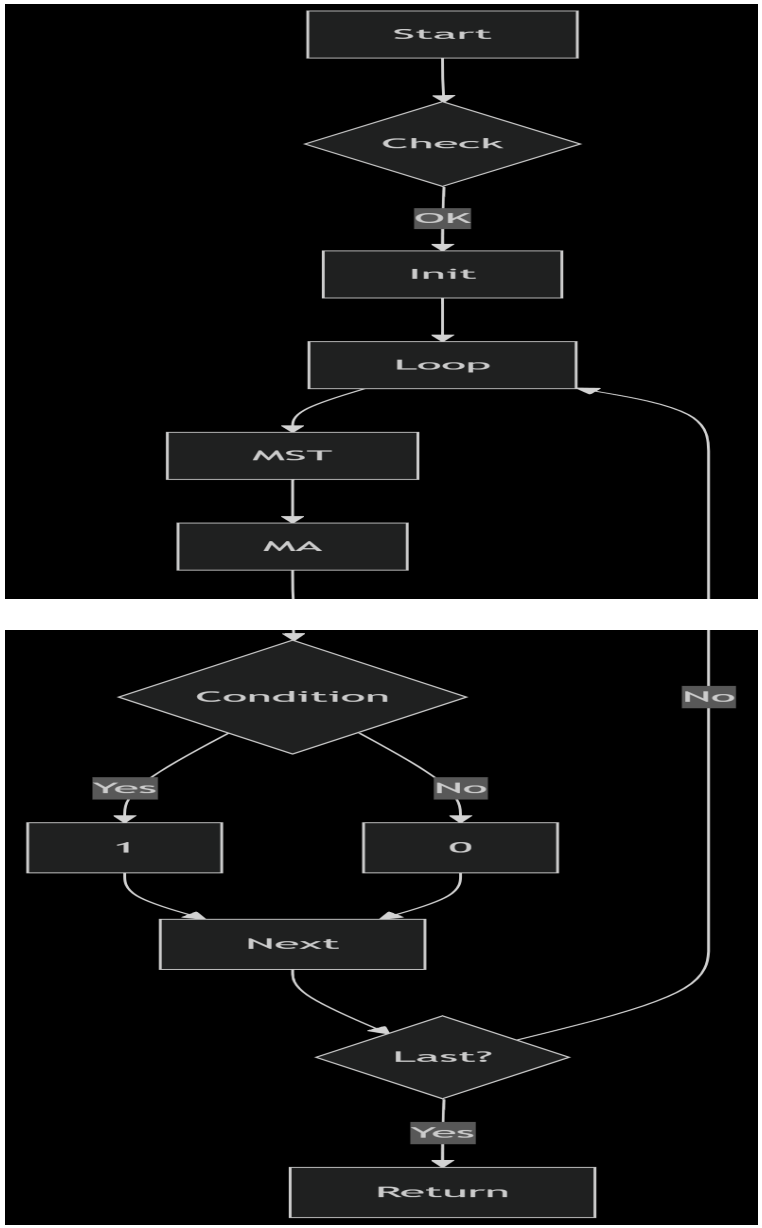
$$\frac{L_t}{\bar{L}_{t-w:t-1}} < \theta_L$$

$$\frac{D_t}{\bar{D}_{t-w:t-1}} < \theta_D$$

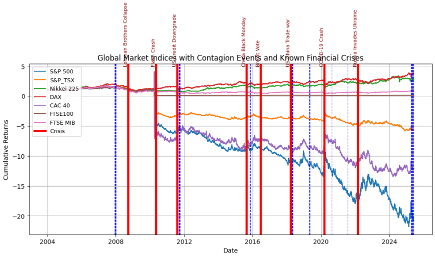
$$C_t > \theta_C$$

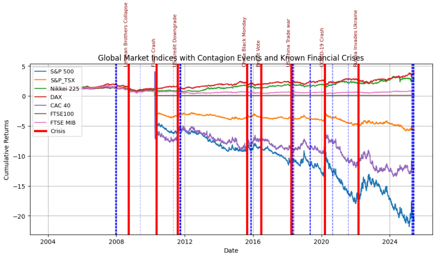
If all conditions hold, then:

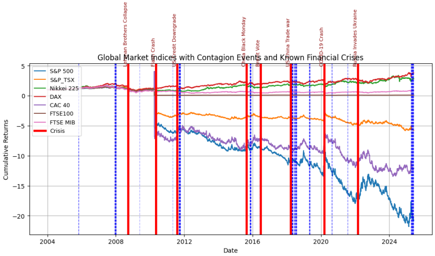
$$I_t^{\text{MST}} = 1 \quad \text{(Contagion Detected)}$$



MST Trees at Different Threshold Combinations







Contagion Summary:

- Case 1 $\theta_L = 0.85$, $\theta_D = 0.85$, $\theta_C = 0.75$.
- Case 2 $\theta_L = 0.90$, $\theta_D = 0.90$, $\theta_C = 0.75$.
- Case 3 $\theta_L = 0.95$, $\theta_D = 0.95$, $\theta_C = 0.75$.

Contagion Detection Validation (Event-wise)

Historical Crisis Periods and Detected Contagion Events:

Period / Crisis	Approx. Timestamps
2007–2008 Global Crisis	15
2011 European Debt Crisis	20
2015 Market Turbulence	10
2016 Brexit referendum	4–5
2018 Trade War	30
2020 COVID-19	3–4
2025 Events (Forecasted)	20+

Validation Summary:

- **Detected Timestamps:** 129
- **Justified by Known Events:** 95–100
- **Percentage Justified: 79.2% – 83.3%**
- **Conclusion:** Majority of detections align with actual global/economic shocks, validating the contagion framework's effectiveness.

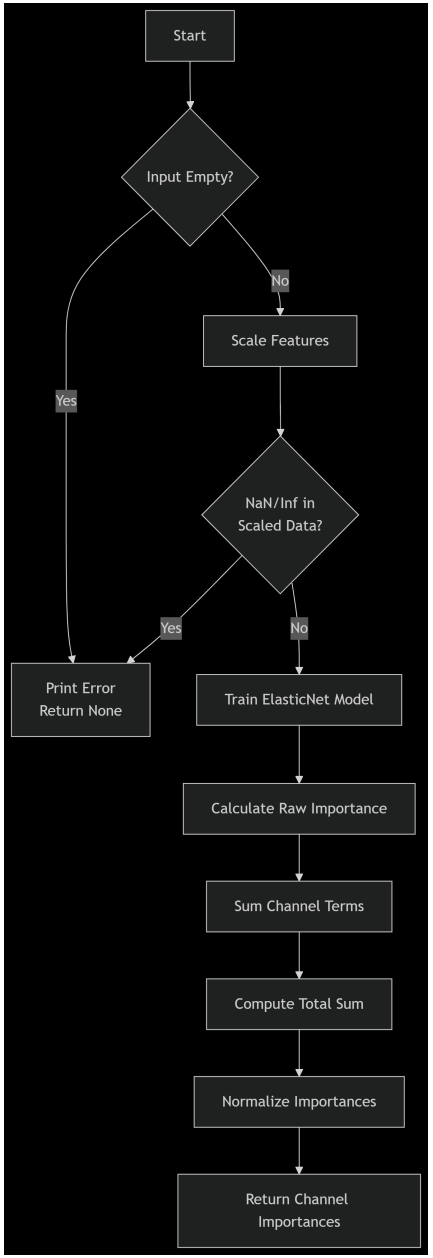
Elastic Net Regression

- **Objective**: Estimate short-run returns $r_{i,t}^{SR}$ using uncertainty channels.
- **Model**:

$$r_{i,t}^{SR} = \alpha_i + \beta_i^f f_t + \beta_i^g g_t + \beta_i^p p_t + \epsilon_{i,t}$$

- **Elastic Net** = Lasso (L1) + Ridge (L2)

$$IEN_{i,x} = \frac{\sum |\hat{\beta}_{i,j}^x| \cdot \sigma(x_j)}{\text{Total Sum}}$$



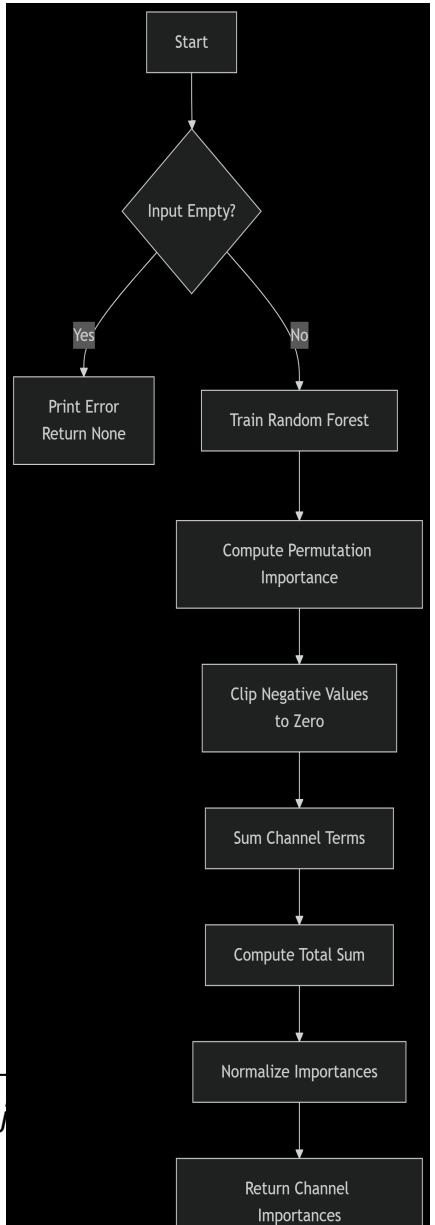
Random Forest Variable Importance — Summary Slide

- **Objective**: Estimate $r_{i,t}^{SR}$ using a non-parametric model.
- **Model Form**:

$$r_{i,t}^{SR} = f_i(f_t, g_t, p_t) + \epsilon_{i,t}$$

- **Variable Importance**:
  - Based on increase in MSE when permuting variables
  - Higher ΔMSE $\rightarrow$ Higher channel importance

$$IRF_{i,x} = \frac{\sum \Delta MSE(x_j)}{\sum \Delta MSE(f_j) + \sum \Delta MSE(g_j) + \sum \Delta MSE(p_j}$$



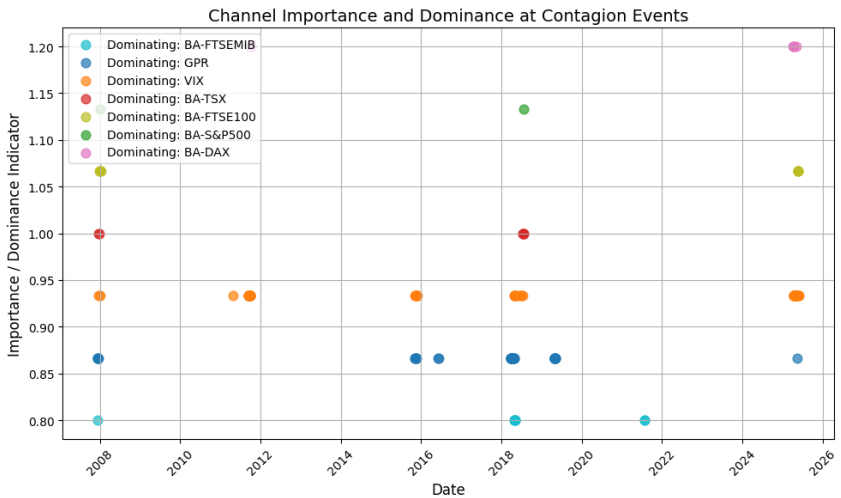
Feature Importance Analysis – Process Overview

1. **Prepare Data**
   - Define market return columns (e.g., S&P 500, Nikkei 225)
   - Define contagion channels (e.g., GPR, VIX, Bid-Ask spreads)
2. **Loop Over Each Event Date**
   - Extract nearby return and channel data
   - Merge returns with channel indicators
3. **Apply Models**
   - For each market: apply Elastic Net and Random Forest
   - Estimate importance of each channel
4. **Aggregate Importance Scores**
   - Compute average importance from both models
   - Combine scores to get unified measure
5. **Identify Dominating Channel**
   - Select channel with highest combined importance
6. **Determine Best Method**
   - Compare EN, RF, and Combined scores
   - Choose method giving strongest signal

Dominating Channel Summary

Dominating Channel Count

Channel	Count
VIX	53
GPR	43
Bid-Ask TSX	9
Bid-Ask DAX	8
Bid-Ask S&P 500	8
Bid-Ask FTSE MIB	6
Bid-Ask FTSE 100	2



Example: Scatter plot of dominating channel

Event-wise Channel Validation

Period / Crisis	Approx. Timestamps	Dominant Channels
2007–2008 Global Crisis	15	gpr, vix, ba-s&p500
2011 European Debt Crisis	20	vix, ba-dax, gpr
2015 Market Turbulence	10	ba-ftsemib, gpr
2016 Brexit referendum	4–5	vix, ba-ftsemib
2018 Trade War	30	gpr, ba-tsx, ba-s&p500
2020 COVID-19	3–4	vix, gpr, ba-s&p500
2025 Events	20+	vix, gpr, ba-dax

Validation Result: *Percentage Justified:* **80–83%**

Conclusion

- Novel, modular, and robust contagion detection framework
- Integrates non-linear learning and network theory
- Offers interpretable, actionable crisis insights
- Fully implemented in Python and validated with Real-time Data

Thank You!