THE COMPLEX FOOD NETWORK AND ASSOCIATED RISKS

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INTRODUCTION

Globalised trade → wider food supply, but higher risk

Unsafe food: 600M illnesses / 420k deaths each year

125k children under 5 die annually (WHO)

EU imports a wide range of foods → increased exposure to risks

RASFF: EU's rapid alert system for food/feed safety

Traditional monitoring (reactive)

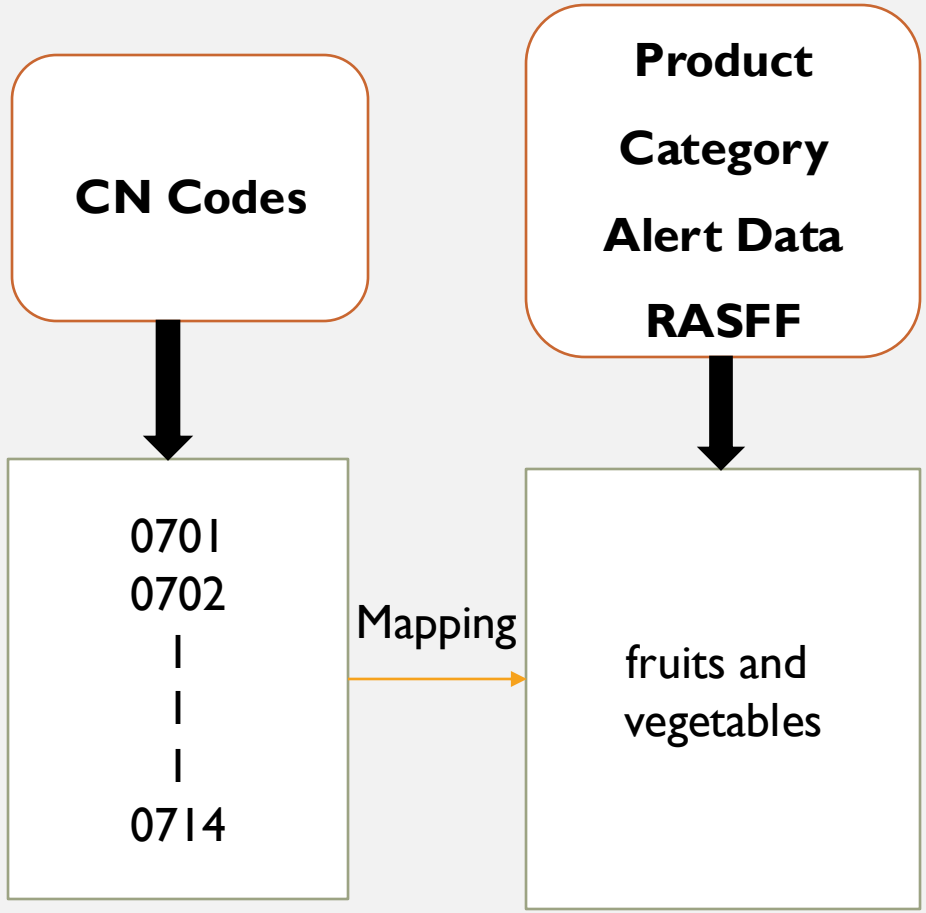
Need for proactive early-warning

BACKGROUND FROM LITERATURE

- **RASFF data** is widely used in food safety studies and EFSA monitoring of emerging risks
- **Predictive models applied:**
  1. Deep learning with categorical embeddings on RASFF (Nogales et al., 2020)
  2. Prophet, ARIMA, and deep learning compared for food price forecasting (Menculini et al., 2021)
- **Network science** applied to study resilience, trade links, and risk spread in food systems
- **Research Gaps:**
  1. Forecasting of food safety alerts underexplored compared to food prices/consumption
  2. Prophet/TBATS not yet applied to RASFF alerts
  3. Integration of alerts with trade/network features is limited

DATA SOURCES

- **RASFF alerts (2000–2024)**
  - Fields: Date, Product category, Country of origin, Risk decision, Notifying country
- **CN → RASFF mapping**
  - Manual mapping of product categories to CN codes using CN 2025 reference
- **Eurostat Comext trade data (2000–2024)**
  - Monthly EU-27 imports by CN code



SCOPE OF ANALYSIS

1. **Network Analysis (5-year blocks)**
   - Trade networks built per product category
   - Based on alert counts + trade values
   - Focus: resilience, exporter risk, structural properties
   - Special attention to Ireland's position in EU network
2. **Forecasting (monthly time series)**
   - Combines: number of alerts, trade volumes and out-degree of exporter countries
   - Models: Prophet, TBATS

METHODOLOGY – NETWORK ANALYSIS

- Trade networks in 5-year intervals (2010–2024)
- Nodes = countries; Edges = trade flows
- Exporter risk scores = alerts / trade
- Layout: force-directed → countries with more trade move closer, less trade pushes them apart
- Structural metrics:
  - Out-degree (export partners per country)
  - In-degree (exporters per importer)
  - Density

METHODOLOGY - PROPHET (FORECASTING)

- **Captures trend + seasonality**
- **Decomposes into:**

$$y_t = g_t + s_t + h_t + \sum_{k=1}^{K} \psi_k \, x_{k,t} + \varepsilon_t$$

  - g_t : Trend Component
  - s_t : Seasonality Component
  - h_t : Holiday Component (not used in here)
  - $x_{k,t}$: external regressor (e.g., trade, network degree)
  - ψ_k : impact (weight) of each regressor
  - ε_t : Error term

METHODOLOGY - TBATS(FORECASTING)

- **Captures multiple seasonality + trends**
- **Decomposes into:**

$$y_t^{(\omega)} = l_t + \phi b_t + \sum_{i=1}^{S} s_t^i + \sum_{k=1}^{K} \psi_k \; x_{k,t} + d_t$$

  - l_t : Local level
  - ϕb_t : Trend with damping
  - s_t^i : Seasonal component (i = 1,…,S)
  - $x_{k,t}$: external regressor (e.g., trade, network degree)
  - ψ_k : impact (weight) of each regressor
  - d_t : ARMA error term

APPLICATION – TIME SERIES FORECASTING

Model A: RASFF alerts only

Model B: Alerts + trade (lagged values)

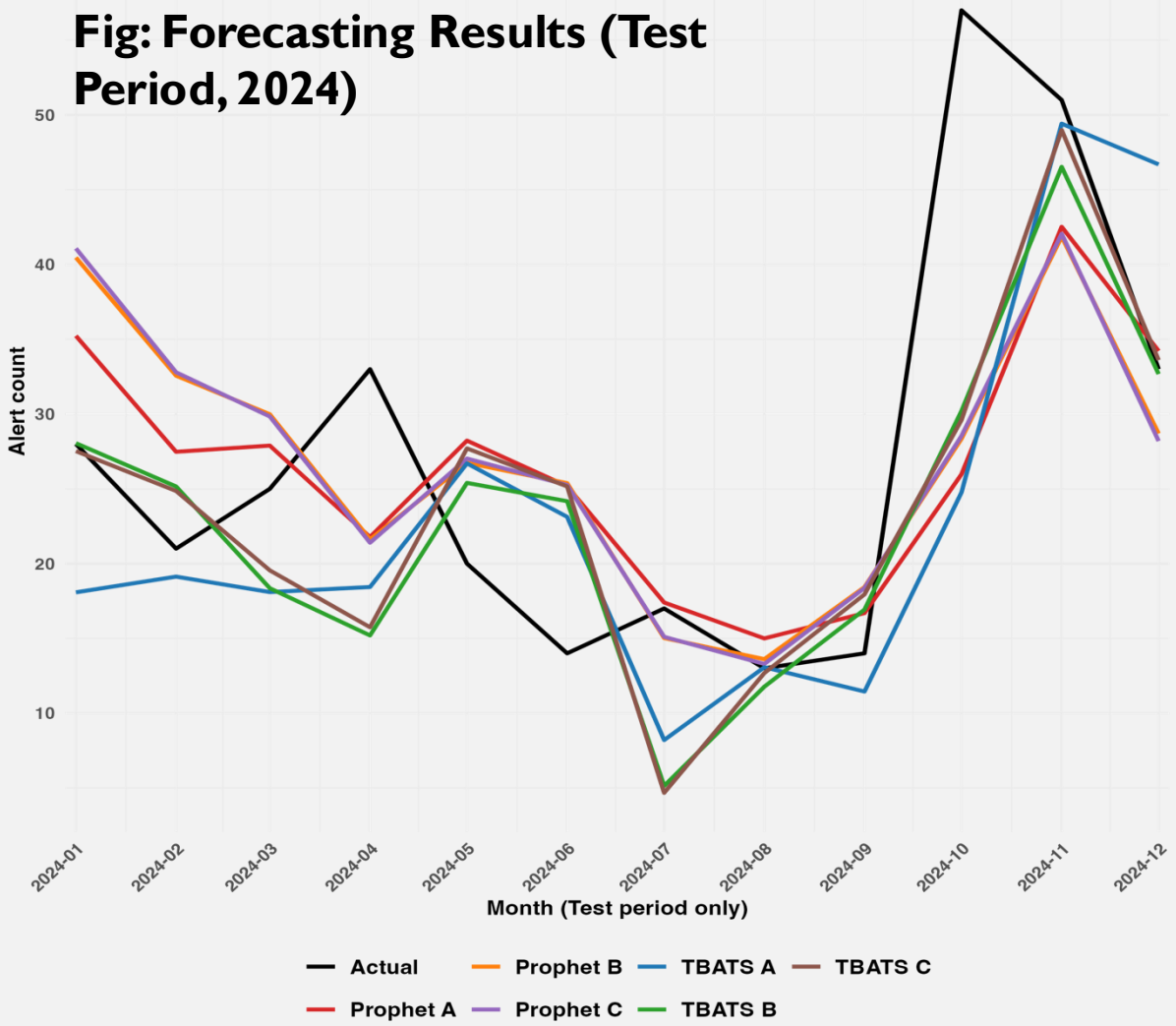
Model C: Alerts + trade (lagged) + out-degree (lagged) (network structure)

Evaluation: **walk-forward validation**

Comparison: Prophet vs TBATS

RESULTS – TIME SERIES (TURKEY → EU, FRUITS & VEGETABLES)

Fig: Forecasting Results (Test Period, 2024)



Insights

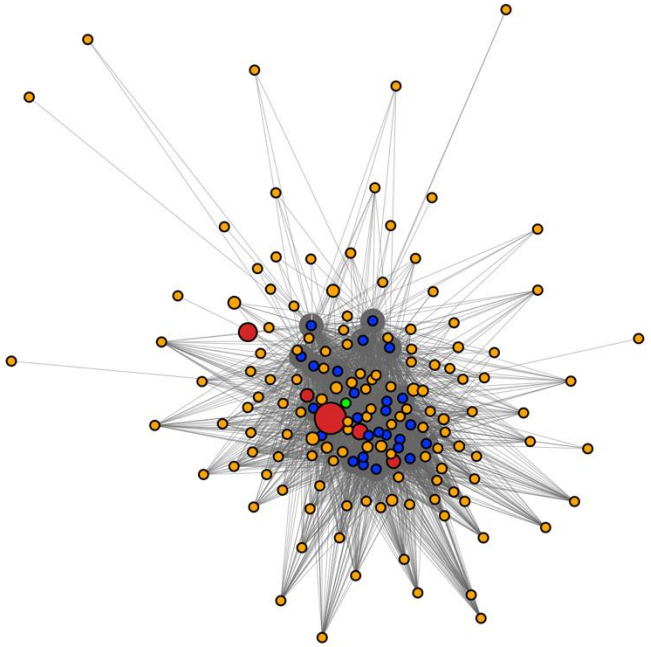
- **Prophet:** Alerts-only model performed best; adding trade did not improve forecasts.
- **TBATS:** Trade-based model outperformed all others, including Prophet.
- **Out-degree:** Adding network degree gave only marginal improvement in both models.

RESULTS – NETWORK ANALYSIS (FRUITS & VEGETABLES)

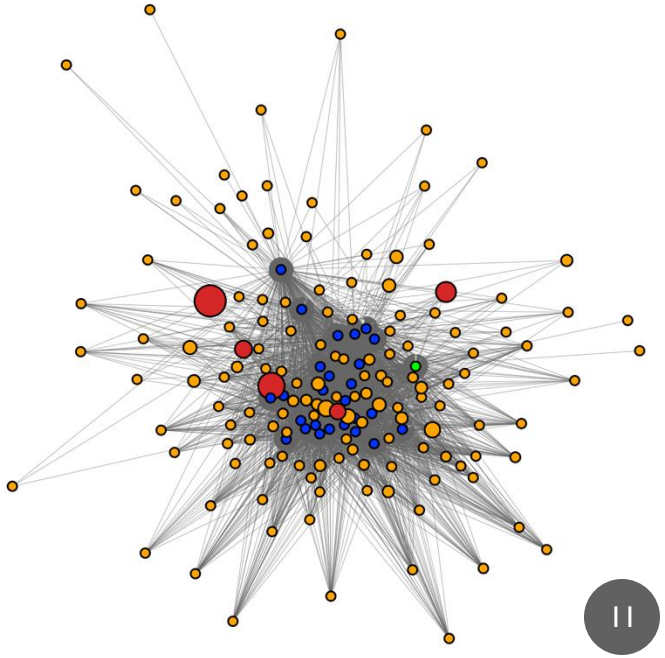
Insights

- Network density increased, showing more interconnected trade.
- In-degree grew, meaning EU importers diversified their sourcing.
- Out-degree also grew, with exporters reaching more markets.
- Ireland moved towards the network edges.
- Risky exporters (red nodes) also shifted towards the periphery.

2015 - 19



2020 - 24



CONCLUSION & FUTURE WORK

- Time series models show mixed performance: Prophet worked best with alerts-only, while TBATS performed better with trade data.
- Adding out-degree gave only limited improvement in forecasting.
- Some country–product pairs had many **zero-alert months**, which reduced forecasting accuracy.
- Zero-alert months were still retained to ensure consistency and avoid bias.
- Network analysis shows increasing connectivity in trade.
- Ireland and high-risk exporters have shifted towards the edges of the network.
- **Future Work:**
  - Apply methods to a **wider range of product categories**.
  - Develop methods to handle **sparse alert data** more effectively in forecasting.