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Estimating the Impact of Physical Risks on Firm Defaults: a Supply-Chain Perspective

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Disclaimer

The following presentation is joined work with **Jan De Spiegeleer**, **Gregory van Kruijsdijk**, and **Wim Schoutens**. The project has been partially funded by the Flemish government and RiskConcile, a fintech company based in Leuven, Belgium, through a Baekeland Mandate awarded to Ruben Kerkhofs.

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The results shown today are subject to changes and should not be referenced.

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Introduction

- Due to the increasing complexity and global reach of supply chains, researchers have identified significant increases in the number of supply chain shocks experienced by firms. [1]
- Literature in finance has linked supply chain shocks to financial impacts:
  - CDS spreads significantly increase following a client's credit rating downgrade [2]
  - CDS jumps result in significant changes in the CDS spreads of suppliers and customers [3]
  - Supplier firms experience negative abnormal returns during the announcement of customer credit rating downgrades; Supplier firms experience significantly higher probabilities of rating downgrades when customers are downgraded [4]
  - These effects are approximately twice as large for adverse credit shocks originating from natural disasters [4]
- Research Gap
  - These study show that supply chains are an important information channel for financial risks; but they do not provide any framework for modelling how these financial risks propagate.
  - Models required for quantitative scenario analysis

[1] Kathryn E. Stecke and Sanjay Kumar. Sources of supply chain disruptions, factors that breed vulnerability, and mitigating strategies. 16(3):193–226.
[2] Jung-Hsien Chang, Mao-Wei Hung, and Feng-Tse Tsai. Credit contagion and competitive effects of bond rating downgrades along the supply chain. 15:232–238.
[3] Senay Agca, Volodymyr Babich, John R. Birge, and Jing Wu. Credit shock propagation along supply chains: Evidence from the CDS market. 68(9):6506–6538
[4] Dallin M. Alldredge, Yinfei Chen, Steve Liu, and Lan Luo. The effect of credit rating downgrades along the supply chain. 21(1):1–31

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Methodology

Modelling Framework

Climate Model

Simplified version in which climate events are simulated on a per country basis. Based on data from the EM-DAT and climate analytics research. [5]

storms, droughts, floods, wildfire, extreme temperatures

Structural Credit Risk Model

Barrier version of the Merton model calibrated using market data (if available) or sector averages. [6]

Default events (endogenous shocks)

Agent-Based Model

Virtual Representation of real supply chains in which firms produce goods based on fixed input recipes. Based on state-of-the-art research around Supply Chain Resilience and the Ripple Effect. (Literature review: [7], main model: [8])

[5] Hossein Tabari and Patrick Willems. Trivariate analysis of changes in drought characteristics in the CMIP6 multimodel ensemble at global warming levels of 1.5°, 2°, and 3°c. 35(18):5823–5837
[6] Petra Andrĭıkov a. Is barrier version of merton model more realistic? evidence from europe.
[7] Niels Bugert and Rainer Lasch. Supply chain disruption models: A critical review. 11(5):1–35.
[8] C. Otto, S. N. Willner, L. Wenz, K. Frieler, and A. Levermann. Modeling loss-propagation in the global supply network: The dynamic agent-based model acclimate. 83:232–269

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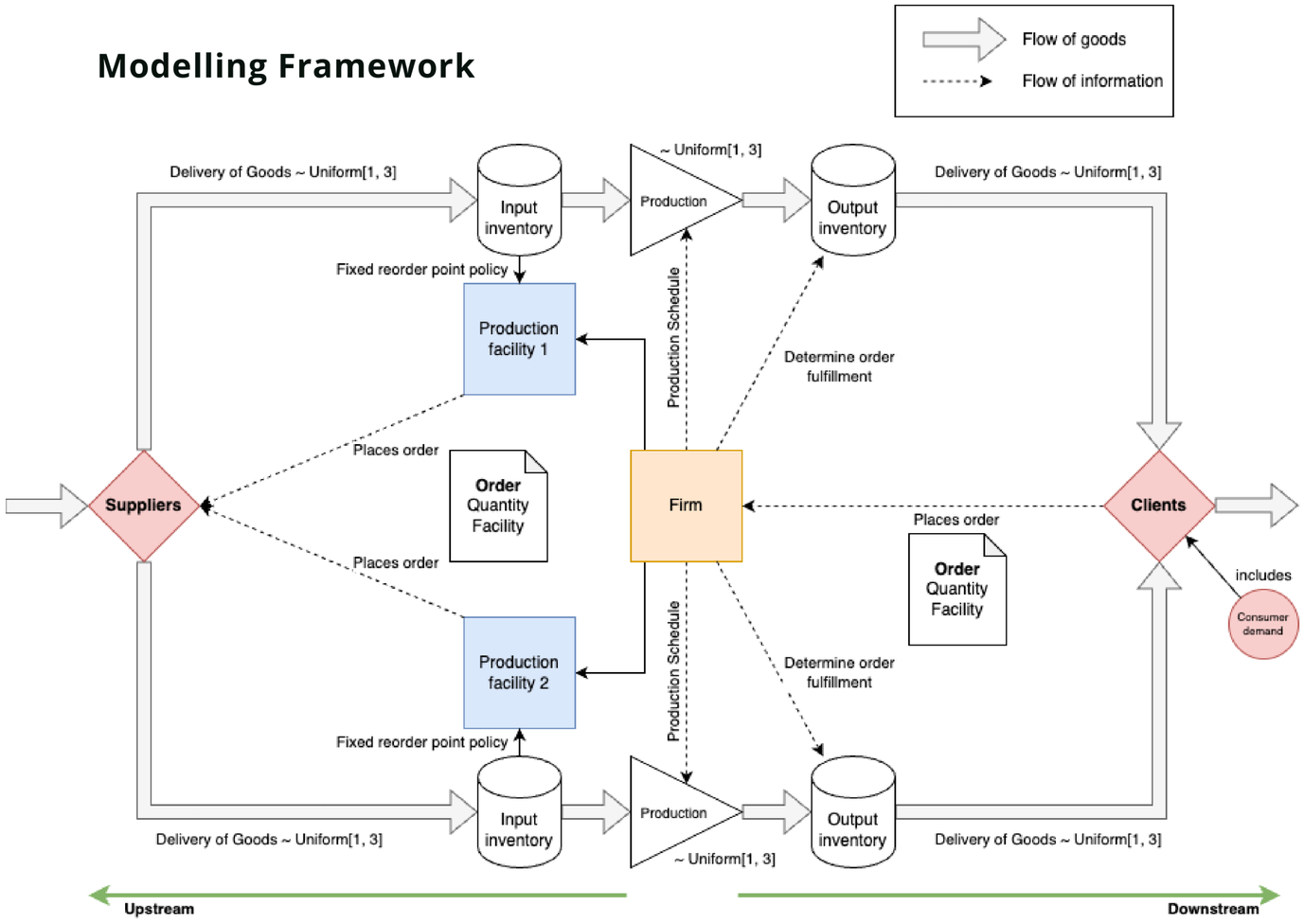
Methodology

Modelling Framework



Main Model Features

- Firms can consist of multiple production facilities; Production is performed at these facilities, but the coordination of these facilities is centrally handled by the firm.
- **Climate shocks temporarily reduce a facility's ability to produce goods**
- **When firms are unable to fulfil consumer demand, they experience a jump in the structural credit risk model.**
- Natural disasters can temporarily increase the probability that other types of disasters occur (e.g., long periods of drought increase likelihood of wildfires)
- Firms have input and output inventories as buffers against shocks
- Consumer demand, production times, and transportation times are stochastic

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Results - Case Studies

Scenario Analysis

Investigate the impact of increases (decreases) in the frequency and economic impact of natural disasters. Four hypothetical scenarios where developed.

Extreme Event	Current World	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Droughts	×1	×1.5	×3	×1.5	×0.7
Extreme Temperatures	×1	×5	×10	×5	×0.5
Floods	×1	×1.5	×1.5	×1.5	×0.8
Storms	×1	×1.5	×3	×1.5	×0.75
Wildfires	×1	×1.5	×2.5	×1.5	×0.5

Table 2: Increase in frequency of extreme weather events for the different scenarios.

Extreme Event	Current World	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Droughts	×1	×1.25	×2.5	×0.75	×0.75
Extreme Temperatures	×1	×1.1	×1.25	×0.9	×0.9
Floods	×1	×1	×1	×0.75	×0.75
Storms	×1	×1.075	×1.25	×0.8	×0.8
Wildfires	×1	×1.25	×1.75	×0.6	×0.6

Table 3: Increase in economic impact of extreme weather events for the different scenarios.

Scenario 1
Moderate increases in both frequency and economic impact of natural disasters

Scenario 2
Extreme increases in both frequency and economic impact of natural disasters

Scenario 3
Moderate increases frequency of natural disasters but a moderate decrease in economic impact thanks to the implementation of adaptation measures

Scenario 4
Decreases in both the frequency and economic impact of natural disaster

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Results - Case Studies

Scenario Analysis - Impact on firm defaults

The metric of interest for these scenarios is the increase in median default probability of the firms. The baseline metric for this increase is the default probability in the current world scenario. Bootstrapping is used to obtain an interval estimate of this increase:

Scenario	Point estimate	Confidence interval (90%)
Current world	-	-
Scenario 1	18.84%	[16.24%, 21.55%]
Scenario 2	42.36%	[39.00%, 45.31%]
Scenario 3	1.04%	[-2.38%, 5.52%]
Scenario 4	-14.16%	[-15.98%, -12.30%]

Key insights, according to the model:

- Increases in climate events do result in material increases in default risks
- Reductions in economic impact (e.g., adaptation measures) can offset increases in the frequency of natural disasters

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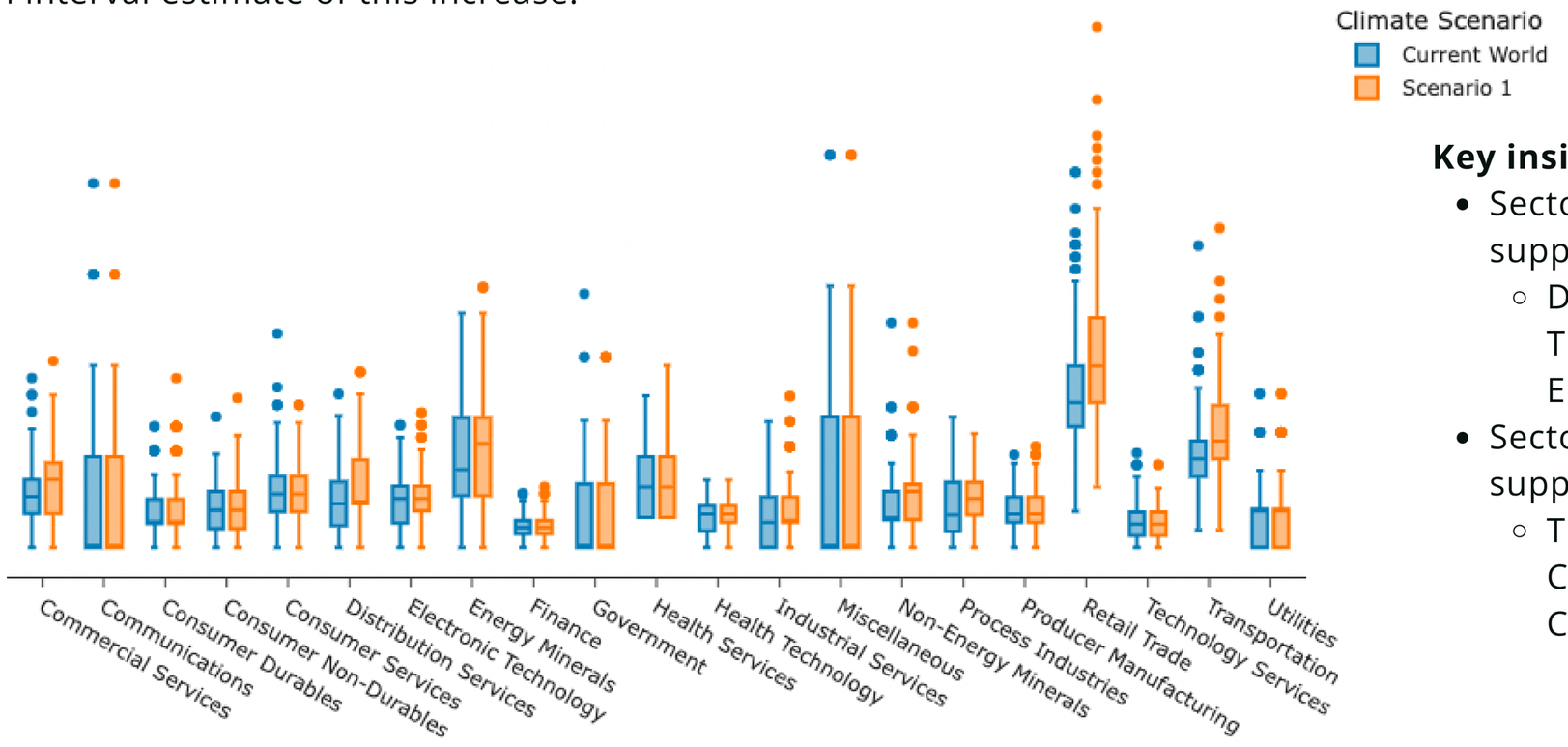
Results - Case Studies

Scenario Analysis - Impact on sectors

The metric of interest for these scenarios is the increase in median default probability of the firms. The baseline metric for this increase is the default probability in the current world scenario. Bootstrapping is used to obtain an interval estimate of this increase:



Key insights, according to the model:

- Sectors at highest risk for climate-induced supply chain disruptions:
  - Distribution services, Retail Trade, Transportation, Industrial Services, Energy Minerals
- Sectors at lowest risk for climate-induced supply chain disruptions:
  - Technology Services, Finance, Communications, Health Technology, Consumer Non-Durables

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Conclusions

Conclusions

- Researchers have identified supply chains as an information channel for financial risks; but the current body of research lacked frameworks to actually model how supply chains transmit financial risks.
- This study introduces a modelling framework to study the propagation of credit shocks induced by natural disasters and their subsequent impact on firm defaults.
- The model behaviour was demonstrated using two case studies:
  - Scenario analysis
  - Sensitivity analysis (not discussed in this presentation)

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