Proposal 1: Firm adaptation and production networks: Structural evidence from extreme weather events in Country x

SUMMARY

Climate change presents a global threat to human populations and economic growth. One important manifestation of climate change is through the increased likelihood of extreme weather events. In this project we aim to understand the response of firms and their supply networks to extreme weather events, more specifically floods, in Country X. We seek to estimate impacts on firms that are directly affected, firms indirectly affected through disruptions to vertical linkages or factor markets, and the structure of firm supply networks themselves. A particular focus of our analysis is the extent to which firms make adaptive decisions in the aftermath of extreme weather events that may help to limit their exposure to future such events.

The project's approach combines a micro-founded structural general equilibrium model with novel datasets. To measure firm outcomes, we have obtained and georeferenced monthly microdata on the near-universe of formal firm-to-firm sales transactions of firms from VAT data. To measure firms' exposure to floods, we combine three datasets: (i) satellite flood maps; (ii) georeferenced flood risk measures based on state-of-the-art hydrological models; (iii) high-frequency geospatial data from GPS trackers installed on over commercial trucks, which yields accurate data on supply routes, traffic conditions and flood-related road closures.

We will first use these datasets to provide reduced-form evidence on the responses of firms and their supply network structures to natural disaster events. We will then interpret the elasticities estimated from these regressions in a structural spatial general equilibrium model to understand the general equilibrium impacts of shocks on all firms in the network and run counterfactuals to understand the importance of different adaptation margins for firm-level and aggregate outcomes. Understanding the magnitude of these adaptation decisions is crucial in trying to anticipate how costly climate change will be and in designing appropriate policy responses.

RESEARCH DESIGN

The proposed methodology for the project combines micro-founded structural econometric models with a series of novel datasets, georeferenced at a fine geographical resolution, described below:

1. To measure firm sales outcomes and disruptions to supply chains, we have obtained and georeferenced microdata on the near-universe of formal firm-to-firm sales transactions of local firms. These data are available from the government [source details anonymized by the IGC for this example]. These data provide monthly transaction-level data reported by VAT-registered firms containing sales, purchases, imports, exports, VAT amounts paid and key characteristics of the transacting firms. The full data span the period 20XX to 20XX, with VAT amounts paid also available dating back to 20XX. Importantly, the data also contain detailed information on each firm's registered address and business premises, which we have used to geocode firms in the data at a fine geographical resolution.

2. To measure the extent to which supply routes are affected by extreme weather events, we have purchased high-frequency geospatial data from GPS trackers installed on over 15,000 commercial trucks from an original equipment manufacturer. These data show the location and speed of the vehicles travelling on country's road network at a very high frequency from 20XX to the present, comprising 6 billion observations. These allow us to construct accurate data on supply routes, traffic conditions, flood disruptions, and adaptation of firms' shipping routes from these data.

3. Georeferenced data on extreme weather and natural disaster events in Country X over our study period have been obtained from publicly available sources. These geospatial datasets can be combined with the georeferenced data on firm locations and supply routes as above to identify at a high geographical resolution firms and infrastructure that were exposed to extreme weather events over the study period. Our primary source of flooding data is georeferenced satellite data on flood events and extents from the UNOSAT Flood Portal of the United Nations Institute for Training and Research. Areas affected by earthquakes are obtained by combining USGS earthquake data with georeferenced 'ShakeMaps', a product of the USGS Earthquake Hazards Program in conjunction with regional seismic networks which allow for estimation of affected areas by providing maps of ground motion and shaking intensity. The fine geographical resolution of the datasets allows us to construct the extent of flood- and earthquake-related disruptions to firms and road networks.

We have now collected and georeferenced these datasets. The proposed activities over the period covered by this proposal focus on analysis of these datasets to understand the response of firms and their networks to natural disasters, and important margins of adaptation. There are two key components of this analysis: (i) examining reduced form evidence on the responses of firms and their supply network structures to natural disaster events in Country X; and (ii) interpreting the elasticities estimated from these regressions in a structural spatial general equilibrium model to understand the general equilibrium impacts of shocks on all firms in the network and run counterfactuals to understand

the importance of different adaptation margins. The methodologies proposed for each of these sections are described in more detail below.

(i) Reduced form analysis

We first explore firms' responses to extreme weather events by running reduced-form regressions of firm decisions (in particular adaptive decisions such as exit, location, industry, supplier choice, supply routes, but also total sales and purchase values) on variables capturing the direct and indirect exposure to floods. The granular spatial and temporal resolution of our data allow us to run these regressions at the level of individual firms and firm pairs at the monthly, quarterly and annual level. The availability of the firm-to-firm transaction data over a time period spanning 20XX-20XX also allows us to consider the persistence of effects over several years (longer than is generally possible in the extant literature), an effect of particular interest since persistent responses may be indicative of changes in firms' expectations about future natural disaster events. As part of this proposal, we are also asking for resources to investigate extending the data to more recent time periods to study the impact of and adaptation to a more recent natural disaster in Country X.

Our main set of reduced-form regressions are event study regressions, i.e. regression of outcome variables (at the firm x month level) on a set of time-to-event dummies, as well as cross-sectional and time fixed effects. To capture the role of the degree of treatment intensity, we will interact the time-to-event dummies with a measure of flood severity in the local vicinity of the firm's location. Equivalent specifications will also be run using earthquake rather than flood exposure.

These specifications allow us to test, for instance, how far firms in affected areas experience differential rates of exit; lower sales; and/or move to a different location in the aftermath of extreme weather events. We will also be able to investigate potential adaptive responses by examining, for instance, how far firms that move to a different location move to areas characterized by a lower risk of extreme weather events.

Corresponding specifications that draw on the network structure of the transaction-level data will then be used to examine network-level adaptive responses. For instance, for seller- (buyer-) level regressions, we can consider whether flood exposure results in changes in the shares of sales to (expenditures from) buyers (sellers) in flooded or flood-prone regions, as well as how such effects impact firm outcomes such as total sales and survival probability. This will also allow us to analyse indirect impacts, for instance whether firms that have customers or suppliers in affected locations undertake adaptive responses such as moving to safer locations or shifting the balance of firms' customers or suppliers towards those that are less susceptible to extreme weather events.

By combining the firm data with the GPS data on supply routes and transport network disruptions, we will also be able to examine impacts when the road to a supplier or customer is disrupted by the extreme weather events, even though neither the firm nor their trading partners are in an affected area. Another set of regressions will look at heterogeneity in responses; particularly whether firms in poorer areas or rural areas exhibit different adaptation behaviour. Interactions of flood severity with ex-ante flood risk will inform us about the mechanisms at play.

(ii) Structural analysis

The second part of the analysis will then interpret the different elasticities estimated from these reduced form regressions in a structural spatial general equilibrium model. This will allow us to investigate the quantitative importance of different margins of firm responses and to run counterfactuals. The exact margins of firms' choices and adjustments to be included in the model will depend on those margins that we find to be operational according to the reduced-form regressions. Firms may, for instance, potentially face a location choice, a choice of industry, a choice of suppliers and customers and a choice of supply routes. Trade is costly and extreme weather events may affect labour productivity in flooded areas as well as these trade costs. Our structural spatial general equilibrium model will allow us to quantify the importance of changes in firm expectations for mitigating the cost of future extreme weather events. Through the lens of the model and using the elasticities calibrated from the extreme weather shocks, we would also be able to use counterfactual simulations to assess the importance of and interactions with other types of transport network disruptions, for instance resulting from conflict and other frictions, for aggregate economic activity.

Our structural model-based approach allows us to study questions that it is not possible to address using reduced-form analysis. Such questions include, for instance: Do the observed adaptation patterns point to the presence of frictions that could be corrected through policy? How far does observed adaptation reduce the economy's exposure to subsequent extreme weather events? How sensitive is the aggregate economy to bottlenecks in the supply chain network, and how exposed are these bottlenecks to disruptions caused by climate change? What is the impact of policies that protect key segments of the road network or increase supply chain diversification among key firms in the firm network? The answers to these questions are key when attempting to make supply chains more resilient to the threats imposed by climate change.

IGC EVALUATION

This is a very strong proposal with a good question, great data, and a careful plan for analysis with the potential to produce knowledge that will garner interest from policymakers.

PROPOSAL STRUCTURE

Some of the **strengths of this proposal in terms of its structure and lucidity** are outlined below:

1. **Introduction & rationale:** The proposal starts with a strong introduction, detailing the significance of the refugee situation, and presenting the problem setting the stage effectively for the subsequent sections.
2. **Simplicity of the research question:** The primary research question is clearly stated. It is straightforward and focused and gives a clear direction for the entire research.
3. **Research context:** The choice of Country X and the reasons for this choice are adequately explained, ensuring the reader understands the study's context.
4. **Budgeting & funding:** The financial needs, both from the IGC and other sources, are laid out, offering clarity on how funds will be utilized.
5. **Clarity of approach:** The approach, i.e., conducting an RCT, is elucidated in a structured manner. The step-by-step process, from the skills survey to the endline survey, is presented sequentially.
6. **Use of technical language:** While the proposal does use some technical terms related to RCTs, most of these are well-explained.
7. **Integration of relevant data & references:** The proposal cites relevant data (like statistics from UNHCR) and other essential references. This not only lends credibility but also aids in the clarity of the points being made.
8. **Research design:** This section is comprehensive and covers the methodology in detail. The multi-level randomization is explained, the use of baseline and endline surveys is established, and the strategic selection and placement of refugees is clarified.

RESEARCH DESIGN

Some of the strengths of the research design are outlined below:

1. **Relevance and timeliness:** The topic is of high importance given the current global focus on climate change and its effects on economies and societies.
2. **Comprehensive data collection:** The proposal combines several datasets, both primary and secondary, providing a comprehensive view of the issue.
3. **Rich analysis framework:** The proposal aims to combine reduced-form regressions with structural spatial general equilibrium models, ensuring both a micro and macro analysis of the situation.
4. **Focus on adaptation:** By focusing on adaptive decisions firms take post-weather events, the study offers a forward-looking perspective that is vital for future policymaking.
5. **General equilibrium approach:** This allows the researchers to understand the spillover and systemic effects of extreme weather events on the broader economy.
6. **Consideration of both direct and indirect effects**: The study is not limited to firms directly affected by weather events. It extends its analysis to indirectly affected firms, thereby providing a more comprehensive view of the network and linkage disruptions.
7. **Extensive time span:** With data spanning over multiple years, the research can provide insights into long-term impacts and behavioural changes over time.
8. **Network-level adaptive responses:** The focus on how firms may shift sales to or purchases from other firms based on extreme weather risks is insightful.
9. **Diverse analysis points:** The study plans to compare impacts on rural versus urban firms, richer versus poorer areas, and even the difference in responses based on perceived risk, providing a multi-dimensional view.

AREAS FOR IMPROVEMENT

In conclusion, the research proposal is well-thought-out and ambitious, tackling a highly relevant issue with a multi-faceted approach. However, there could be some areas for improvement such as:

1. **Causality:** While the proposal plans to employ regressions, establishing a clear causality between extreme weather events and firm behaviour could be challenging due to potential confounders.
2. **Unobserved heterogeneity:** Factors outside of the dataset, such as management decisions or global supply chain disruptions, could also play a significant role and need to be controlled for.
3. **Model assumptions:** The assumptions behind the structural spatial general equilibrium model need to be stated and justified. Any model is only as good as its assumptions.
4. **VAT data limitations:** The reliance on VAT-registered firms may exclude the informal sector, which can also be significantly affected by extreme weather events.
5. **External validity:** While the study focuses on Country X, it's unclear how generalizable these results would be to other countries or regions.
6. **Operational challenges:** Implementing GPS trackers or accessing certain datasets in practice could present unforeseen challenges.
7. **Time period expansion:** There is a mention of extending the data to study more recent natural disasters. This could lead to potential project scope creep.

Overall, the proposal is well-structured and offers a lucid explanation of both the research question and the proposed approach. The clarity in the presentation of both the problem and the intended solution makes it accessible for the audience. This research design offers a robust framework for investigating the multifaceted effects of extreme weather events on firms and supply chains, with potential policy implications for enhancing resilience and mitigating climate-related risks in the economy.