

Can Trade Help Mitigate Risk From Weather Disruptions?

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Key Takeaways

- Firms use trade to mitigate their exposure to weather shocks by sourcing inputs from multiple regions. Firms that "multisource" inputs tend to pay higher input prices and source from regions with lower weather-related risk.
- Multisourcing creates a trade-off between efficiency and resiliency. Firms pay higher prices for inputs but reduce the volatility of production.
- The adaptation of supply chains exacerbates the distributional effects of weather-related disruptions. Regions that are expected to get worse in terms of natural disasters would not only get the direct impact of those events but would also face lower demand due to consumers adapting toward less exposed regions.

As weather-related disruptions become more frequent, firms face increasing risks to their supply chains. To safeguard against these shocks, businesses are adopting strategies to enhance resiliency and ensure that disruptions to key suppliers don't halt operations. In the [2024 working paper](#) by several authors of this article (Juanma, Gaurav, Nicolas and Nitya), we explore how Indian firms mitigate risks from weather events by diversifying their input sources across multiple regions.

Using detailed transaction data from Indian firms, we highlight multisourcing as a crucial risk-management strategy that gives rise to a cost/resilience trade-off. To deepen this analysis, we develop a structural model of the Indian economy, providing a framework to examine how firm adaptation impacts wages and prices. The model also serves as a predictive tool, forecasting how businesses will adjust to any future weather risks and quantifying the broader implications for interregional inequality.

Transaction Data From India

Studying the impact of weather risk on supply chains requires granular, high-frequency data on firm-to-firm transactions. These data allow us to track trade frequency and supplier characteristics. However, access to such detailed data is rare and typically only available in countries where firms pay taxes on goods shipments, which creates a paper trail of transactions. While the U.S. lacks such a system, countries such as Belgium, Chile, Costa Rica, Turkey and India do collect this data, providing a valuable opportunity for researchers to analyze supply chain dynamics and resilience in the face of weather risk.

For our analysis, we obtain a dataset of all Indian firm-to-firm transactions from the tax authority of a major Indian state. For each transaction between 2018 and 2020, we observe the product name, the value sold, and the identity and location of the buyer and seller, as long as at least one of the establishments resides in the state. This allows us to reconstruct the supply chains of firms at different periods. We then assess how their features are connected to weather risk along the supply chain.

The Prevalence of Multisourcing

A striking pattern revealed by our data is the high prevalence of *multisourcing*, or firms ordering the same input from more than one location. About 62 percent of the firms in our data source inputs from more than one district, and these multisourcing firms compose 96.5 percent of the transacted value. Using our data, we can also measure how other characteristics of suppliers interact with multisourcing behavior. As shown in Figure 1, firms that source a given input from only one district are, on average, 350 kilometers away from their suppliers, while firms that source an input from five different districts are on average 710 kilometers away. This suggests that firms cannot find enough local suppliers to multisource and end up finding suppliers much farther away.

A second pattern is that firms seem to source from regions with "safer" weather conditions as they multisource. Figure 1 also presents the average daily rainfall in millimeters of suppliers' districts for the firms in our data, grouped by the number of different districts the firm supplies from. We note that as firms source from more regions, those regions tend to become drier on average. Indeed, when firms source from just one district, that district has on average 6.5 millimeters of rain per day, while each additional district added decreases the average, reaching 5.4 millimeters for five sourcing districts. Although not necessarily evidence of a causal relationship, this does suggest weather shock mitigation as a potential explanation for firms' multisourcing.

As a final pattern, we note that the average price of inputs increases with multisourcing. In Figure 1, the tab titled "Input Prices" presents the average price of inputs for each level of multisourcing after accounting for systematic variation in product types. We normalize the average price in the single-district group to 1. Going from one supplier-district to two increases the average price by 40 percent, while going from one to five nearly doubles the

price. This suggests that firms that are multisourcing to reap the benefits of diversification pay a price to do so, as the added resiliency does not come for free. For all these patterns, we make sure they are not driven by specific product characteristics or by larger firms.

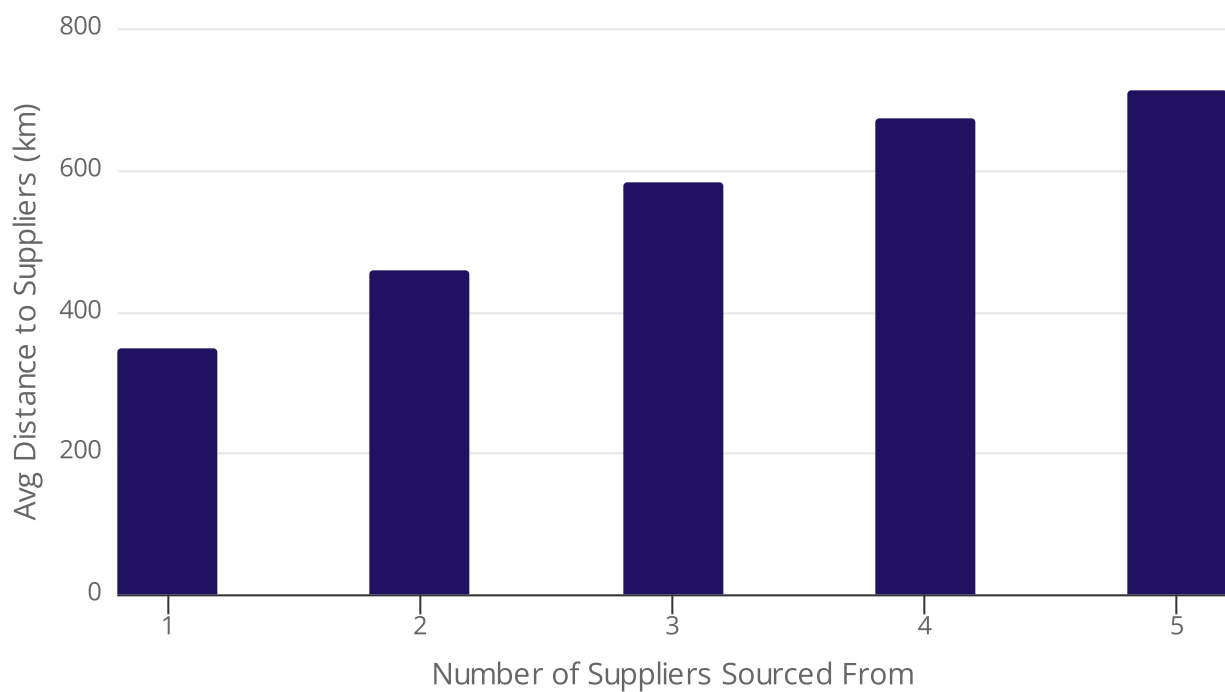
Figure 1: Supply Chain Features

< Distance >

Distance



■ Avg Distance to Suppliers



Note: We compute the average distance between the firm and each of its suppliers from our transaction data. We then compute the average distance across firm-product pairs sourcing from one to five districts.

Source: Authors' calculations from the 2024 working paper "Weathering the Storm: Supply Chains and Climate Risk."

The high prevalence of multisourcing inputs is intriguing from an economic standpoint. In the absence of risk, a firm should source a given input from the most cost-effective supplier. Hence, multisourcing is a puzzle that needs to be explained: What motivates firms to buy from more than one supplier at further distances and higher prices?

A potential explanation is that multisourcing firms have, on average, less rainfall in their suppliers' districts than single-sourcing firms. Thus, firms might be diversifying their supply chains to be resilient to weather risk. If a firm has relationships with suppliers in different regions, then a weather shock in one supplier's region need not wipe out their operations. Instead, they can turn to other suppliers to pick up the slack. The firm might be willing to pay higher prices to protect themselves from shocks to their suppliers and build more resilience into their supply chains.

Understanding How Firms Adapt Their Sourcing Strategies

To more rigorously analyze this trade-off — as well as assess its implications for the economy at large — we turn to formal economic modeling. The goal is to use our model as a laboratory of the economy and simulate how firms' sourcing behavior may change as weather conditions evolve over time.

We build a model of the Indian economy with regions subjected to varying degrees of climate risk. Each district is divided into two sectors:

- Intermediate goods producers that use labor to produce materials
- Final goods producers that use labor and the materials from the first sector to produce final goods for consumption

Intermediate inputs can be traded between districts subject to a cost that increases in the distance between the districts. The final goods producers must decide from where to source their inputs.

Each region has a risk of being hit by a disruption, which effectively destroys a portion of the output of the intermediate goods producers. In principle, risk can stem from sources other than weather disruptions. However, we show that our estimated risk is significantly correlated with rainfall, flooding and temperature indicating weather as an important source of disruptions. Crucially, the final goods producers must make their orders *before* the shocks are realized, with the knowledge that some of the orders may be destroyed. This gives rise to a key trade-off between cost minimization and supply chain resilience. All else equal, a firm would like to source their inputs as cheaply as possible, which would tend to mean sourcing from regions that are geographically closer and have higher innate productivity.

But an overreliance on a few key districts could easily backfire if a shock affects one of these regions: The firm would not receive its full order of inputs and would not be able to produce an optimal amount. To hedge against this risk, firms can source from a diverse set of regions at potentially higher input costs. The built-in redundancy reduces the likelihood the firm will be left without its desired orders. In picking their mixes of suppliers, firms must weigh these two motives — cost minimization and resiliency — to maximize expected

profits, not necessarily profits under optimal conditions. In practice, given that risk probabilities are different across regions, risky regions are going to be more likely to source from safer regions to hedge against risk. However, all regions have incentives to diversify regardless of their risk level.

Economic Implications of Multisourcing

These sourcing behaviors have significant macroeconomic and distributional implications. As trade with riskier regions decreases, labor demand in those regions will fall, causing wages in those regions to decrease. At the same time, safer regions see more business and higher wages. In this sense, the rich get richer, and the poor get poorer: Regions with beneficial weather conditions see a further economic boost from sourcing behavior, while more disaster-prone regions are dragged down. This has important implications as weather conditions evolve in the coming decades.

Our model also reveals a trade-off inherent in interregional trade under weather risk. When we restrict our model to autarky (so that all input sourcing must be from one's own district), regions can see higher real wages than the baseline of costly trade, as firms can produce more when they do not have to pay trade costs for their inputs. Nevertheless, autarky leaves risky regions exposed in the case of weather shocks, as final goods producers cannot buy the necessary inputs and decrease their demand for labor, which in turn lowers wages. Allowing for trade serves to decrease the volatility of real wages by ensuring that firms can continue operating during weather shocks.

Weather Counterfactuals

To quantitatively assess these implications, we calibrate our model to India, dividing it into 271 districts. For each district, we estimate a disruption probability, which indicates the district's risk. While we don't explicitly model this probability to depend on weather variables, we show that our estimates are significantly correlated with four key weather risk measures: the degree of rainfall, river flooding, coastal flooding and temperature.

We also compile projections of rainfall, river flooding, coastal flooding and temperature for the year 2050. When added to our model, we can predict how disruption probabilities might evolve and understand how firms adjust if weather evolves. Our model predicts that, on average, the risk of shock increases 1.1 percentage points between our two scenarios.

Nevertheless, the impacts of weather-related disruptions vary across regions: Some areas become less risky, while others become more exposed, leading to a wider disparity in impacts. On average, the model predicts a welfare decrease of 2.01 percent, and while some regions do see increases in welfare, real wages fall in 62.73 percent of the districts.

Importantly, we find that supply chains might amplify the economic effects of weather-related disruptions. Regions negatively affected by worse weather outcomes experience different types of effects:

- The direct effect, which makes firms unable to source the inputs they purchased domestically
- The indirect effect from lower demand from other regions, who shift away sourcing toward safer regions

Conclusion

Overall, this article offers empirical evidence that firms seem to source inputs from multiple regions to protect themselves from risk, particularly weather-related risk. When sourcing from additional suppliers, firms are willing to pay higher prices for inputs, causing a cost/volatility trade-off. Our model captures the trade-off between cost and resilience, where firms find it optimal to multisource inputs and pay higher prices to protect themselves from disruptions.

We find that some regions will be better off while others will be negatively impacted by the predicted evolution of weather-related risks. Supply chains and sourcing behavior amplifies these effects. Areas negatively impacted will face the direct consequences of more disruptions and will also face lower demand due to consumers sourcing from safer regions.

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