Adaptive Misallocation, Minimal Aid and Nash Bargaining Failure in Post-Disaster Economies.

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Abstract

This paper examines how firms adapt their operations following the 2005 Pakistan earthquake, with a particular focus on the role of government aid expectations in shaping firm behavior. Using a difference-in-differences methodology on a panel of 390 firms, I explore three key dimensions: the immediate disruption caused by the earthquake, short-term adaptive strategies employed by firms, and the forward-looking actions taken to build resilience. Firms over-adapt due to minimal expected government aid, while the government further reduces its intervention, exacerbating inefficiencies. This cyclical failure reinforces itself and leads to a reducation in trust and eventual breakdown of the social contract between firms and the government, where both sides act sub-optimally, resulting in slower recovery and reduced overall productivity. These findings highlight the critical role of coordinated public-private responses in disaster resilience.

Keywords: earthquake, firms, adaptation, resilience, Pakistan, natural disasters, manufacturing, recovery, diversification, aid.

JEL Codes: H84, L25, O12, O14, O53, Q54, R11.

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1 Introduction

Natural disasters, as framed by Neo-Classical Growth Theory, inherently disrupt production by impairing the functionality of capital, setting the stage for significant economic challenges. On the other hand, Schumpeter (Schumpeter 1942) puts forth the ideas that while immediate impacts are largely destructive, the subsequent period of recovery can catalyse opportunities for innovation, business formation, and technological advancements. In this paper, I reconcile these ideas with the concept of resilience to explore how firms can transform disasters into opportunities for development and growth. I will string together these ideas as I evaluate the impact of Pakistan's 2005 earthquake on micro-firm level outcomes.

This paper is motivated by several stylised facts. In Pakistan's emerging economy, the share of the manufacturing sector as a percentage of its Gross Domestic Product has remained relatively static over the past several decades. The manufacturing sector operates within a challenging policy context, exacerbated by the country's unique geographic and environmental positioning that make it highly vulnerable to natural disasters.

Located at the intersection of the Eurasian and Indian tectonic plates, Pakistan is one of the most seismically active countries in the world. This vulnerability is compounded by the presence of over 7,253 glaciers, the largest number outside the polar regions, making the country more prone to large scale flooding. In view of the country's susceptibility to natural disasters, it is important to understand firm's existing adaptive capacity in order to determine the optimal firm and government response.

Despite the clear need to understand this impact and response of firms that can aid governments in developing robust response frameworks and policies, there is little to no literature of impact of natural disasters on firm-level output and the efficacy of various adaptation and resilience strategies. On the other hand hand, literature of the impact of disasters on household-level outcomes (Andrabi and Das (2017); Andrabi, Daniels, and Das (2023); Frankenberg et al. (2011)) is fairly well-developed. A few papers such as those by Balboni, Boehm, and Waseem (2023) and Huppertz (2023) have begun to explore aggregate firm-level dynamics. However, this current literature does not focus on the micro-level response and adaptation measures.

This paper aims to fill this gap by providing a detailed analysis of how manufacturing firms in Pakistan respond to the challenges posed by natural disasters. Using a panel dataset, this paper explores the immediate reactions of firms to disaster events, their short-term adaptations in operations and strategy, and the longer-term actions they undertake to build resilience. By doing so, it contributes to a more nuanced understanding of the intersection between environmental challenges and economic resilience in emerging economies.

Furthermore, by examining the specific responses and innovations that firms deploy to navigate the aftermath of disasters, this paper offers insights into policy measures that could support these firms in not just surviving but growing in the face of adversity. The ultimate goal is to propose policies that can be adopted by policymakers and business leaders to expand the manufacturing base amidst challenges posed by natural disasters in a changing global climate.

In the aftermath of the 2005 Kashmir earthquake, the economic landscape for Pakistani firms near the epicenter was significantly altered. The capital stock of firms was destroyed, supply chains were disrupted and national supporting infrastructure destroyed. This destruction resulted in a notable decline in sales among affected firms. The decline, in turn, lead to strategic adaptations that facilitate recovery and build resilience.

Traditional economic models often treat government aid as a important tool in post-disaster recovery, but firms operating in environments with weak government support tend to adapt independently, leading to adaptive misallocation.

Building on the framework of Neo-Classical Growth Theory and the concept of creative destruction (Schumpeter, 1942), this paper explores the dynamics of firm resilience, incorporating the expectation-based model that highlights the interaction between firm adaptation and government complacency. Firms, foreseeing reduced future government aid, over-invest in self-protective measures. This behavior, while aimed at safeguarding their operations, results in a distortion of resources that could have otherwise been directed toward productive investment, a phenomenon I will refer to as adaptive misallocation.

The paper via its theoretical model also introduces the concept of Nash bargaining failure in post disaster economics, where firms and governments fail to reach an optimal balance in contributing to disaster recovery efforts. Instead of cooperating to distribute recovery costs efficiently, firms over-adapt due to minimal expected government intervention, while the government further reduces its aid, exacerbating inefficiencies. This failure leads to a breakdown in the social contract between firms and the government, where both sides act sub-optimally, resulting in slower recovery and reduced overall productivity.

This paper simulates different policy interventions to explore how strategic government spending can mitigate the inefficiencies caused by firm misallocation and restore firm productivity to pre-disaster levels. The analysis highlights that without adequate government intervention, firms' excessive adaptation results in misallocation, underlining the importance of coordinated public-private efforts in disaster recovery.

The paper is organised as follows: Section 2 summarises the literature that motivates the research questions, Section 3 provides the conceptual framework and Section 4 summarises the context and data. Methodology is outlined in Section 5, Section 6

summarises data while presenting descriptive statistics and Section 7 provides a discussion on the empirical results and 8 reports the Robustness Checks. Section 9 presents the theoretical model in light of the empirical results, while section 10 simulates optimal government response and Section 11 concludes.

2 Related Literature

The theoretical framework of this research borrows from Neo-Classical Growth Theory and Joseph Schumpeter's theory of creative destruction (Schumpeter 1942) later asserting that entrepreneurial activities are vital for long-term economic growth and can be stimulated by crises such as natural disasters. This perspective underpins the notion that while disasters pose significant risks, they also offer opportunities for firms to innovate and adapt, potentially leading to enhanced resilience and economic development.

A review of the empirical literature reveals mixed results regarding the overall impact of disasters on firms. Hallegatte and Ghil (2008) note that the impact of natural disasters on macroeconomic dynamics remains ambiguous, often varying by the context and type of disaster. Meanwhile, studies by Cole, Elliott, and Zhang (2017) suggest that firms with prepared disaster resilience strategies tend to sustain less damage in their asset prices during disasters. Further research by Fan and Stevenson (2018) and Balboni, Boehm, and Waseem (2023) highlights the importance of supply chain diversification and flexibility in building resilience against disruptions caused by disasters.

Recovery and resilience mechanisms are also critically analyzed in the literature. Hochrainer-Stigler et al. (2014) and Kunreuther and Michel-Kerjan (2009) discuss the role of public-private partnerships and government aid in supporting short-term recovery and fostering long-term resilience Hochrainer-Stigler et al. (2014). The importance of financial tools such as insurance is underscored in the paper by Gurenko et al. (2006), which examines the effectiveness of earthquake insurance in Turkey as a model for financial resilience Gurenko et al. (2006).

Despite the breadth of research, there remain gaps in understanding the specific impacts of disasters at the firm level, particularly in contexts like Pakistan, where geographic and economic vulnerabilities present unique challenges. This paper tries to address these gaps by aiming to dissect the immediate impacts on firms, their short-term adaptations, and the strategic actions taken to enhance resilience post-disaster.

The interaction between firm adaptation and government response to natural disasters has been widely explored, particularly in the context of public good provision, mitigation strategies, and the role of government intervention. However, the model we build in this paper following our empirical results provides a novel perspective by introducing a framework where firms increasingly adapt to disasters in response to expectations of

minimal government aid, thereby creating a misallocation of resources and leading to suboptimal resilience outcomes.

The literature on moral hazard in disaster response, such as Kahn 2005, has emphasized how government aid can distort firm behavior, leading to insufficient mitigation efforts. However, this view presupposes that governments provide consistent and reliable aid. Our model breaks from this by considering a situation where firms expect low government aid, leading them to increase their own adaptive measures. In this context, government complacency emerges not as a response to over-reliance by firms but as a consequence of firms overcompensating for expected under-provision of aid. This feedback loop fundamentally alters the typical moral hazard narrative.

Empirical studies, such as those by Cavallo and Noy 2011b, have shown that government responses to disasters are often delayed and inconsistent, which can create an environment where firms must rely on self-help strategies. This aligns with our assumption that firms act with forward-looking expectations regarding government response, adapting their strategies accordingly. By including these expectations in our model, we expand on the idea that firms' anticipatory actions can lead to systemic inefficiencies.

Firm adaptation in the face of external shocks has been studied extensively, particularly in the context of climate change and disaster preparedness. The work of Hsiang and Jina 2014 demonstrates that firms and economies can suffer long-term productivity losses due to climatic shocks. Our model, which incorporates a non-linear mitigation cost and the expectation of minimal government aid, further contributes to this literature by highlighting the cumulative costs of over-adaptation, as firms divert resources from productive uses to defensive measures. This dynamic is akin to the findings of Dell, Jones, and Olken 2012, where firms in vulnerable regions demonstrate slower economic growth due to higher disaster-related costs.

Moreover, the introduction of a stochastic element in government response reflects the reality that government aid is often uncertain. As firms build adaptive strategies around this unpredictability, they may become overly resilient to such shocks, leading to an inefficient allocation of resources. This builds on the work of Hallegatte and Przyluski 2010, who argue that excessive adaptation can lead to resource misallocation, exacerbating long-term vulnerability rather than enhancing resilience.

The breakdown of the social contract between firms and governments is a central theme in our model. Classic models of firm-government interaction, such as those by Olson 1996, have explored the role of government in providing public goods that mitigate the risks faced by firms. However, in our framework, the failure of Nash bargaining between firms and the government results in firms internalizing the cost of adaptation, while the government withdraws from its defensive role. This shift creates an imbalance

where firms take on excessive responsibility, further increasing their mitigation costs and reducing overall social welfare.

This is particularly relevant to recent work on disaster recovery and firm dynamics, such as Cohen and Werker 2008, who argue that private sector responses often complement government efforts. However, in our scenario, this complementarity breaks down, leading to a vicious cycle where firms increasingly adapt and the government becomes more complacent. This self-reinforcing loop results in higher adaptation costs for firms and a deterioration of public goods, providing a new angle on the relationship between firm adaptation and government aid.

3 Conceptual Framework

The theoretical framework of this research borrows from Neo-Classical Growth Theory and Joseph Schumpeter's (Schumpeter 1942) theory of creative destruction.

Earthquake decreases the functionality of capital and may disrupt production. We use the Classical Growth framework and using Cobb Douglas production function to demonstrate this:

$$Y = AK^{\alpha}L^{\beta}$$

where Y is the output, A is the total factor productivity (TFP), K is the capital, L is the labor, α and β are the output elasticities of capital and labor, respectively.

An earthquake causes a destruction of capital stock. Let δ represent the fraction of capital destroyed. The post-earthquake capital stock, K', is given by:

$$K' = (1 - \delta)K$$

The earthquake may also reduce TFP due to various disruptions. Let γ represent the reduction factor in TFP. The post-earthquake TFP, A', is:

$$A' = (1 - \gamma)A$$

The adjusted production function after the earthquake becomes:

$$Y' = A'(K')^{\alpha}L^{\beta}$$

Substituting the affected A' and K', we get:

$$Y' = (1-\gamma)A\left((1-\delta)K\right)^{\alpha} L^{\beta}$$

Immediately after the earthquake, output Y' decreases due to the reduced capital stock (K) and potentially reduced total factor productivity (A). In the Long-term firms may implement adaptive strategies to recover or even enhance total factor productivity and rebuild capital stock. These strategies could lead to increased operational hours, market diversification, and innovation, influencing the recovery of A and K.

This is consistent with what Schumpeter posits that economic development is driven by a cyclical process where innovation leads to the transformation of older economic structures, facilitating growth and efficiency. In the wake of natural disasters, while the immediate impacts are largely destructive, the subsequent period of recovery can catalyse opportunities for innovation, business formation, and technological advancements. This paper integrates Schumpeter's ideas with concepts of resilience to explore how firms can transform disaster impacts into opportunities for development and growth.

Schumpeter (1934) suggested that disruptions, while challenging, are vital for evoking entrepreneurial activity that leads to innovation and economic growth. Applying this to natural disasters, the rebuilding phase can stimulate demand in sectors like construction and infrastructure, potentially leading to the emergence of new technologies and business practices.

This framework also explores how firms adapt their operations, supply chains, and product offerings to recover and capitalise on new market opportunities post-disaster. Firms might adopt more sustainable practices, enhance their operational strategies, or tap into emerging markets created by shifts in the economic landscape due to the disaster. Schumpeter's theory, resilience is conceptualized not just as returning to pre-disaster conditions but using the disaster as a catalyst for superior economic and operational effectiveness. This resilience can be broken down into three key types, each reflecting a different aspect of the firm's capacity to withstand and evolve through disasters:

Financial Resilience:
The ability of a firm to secure financial stability post-disaster. This includes accessing emergency funds, loans, and aid to quickly recover operational capabilities. Financial resilience is critical for ensuring that firms can maintain liquidity, manage increased costs due to damages, and invest in recovery efforts.

Operational Resilience:
This type of resilience involves maintaining or quickly restoring core business operations after a disaster. It encompasses strategies such as diversifying supply chains to reduce

dependency on a single source, enhancing flexibility in production processes, and investing in disaster-prepared infrastructure that can withstand future shocks.

Strategic Resilience:
Refers to the ability of firms to adapt their business strategies in response to disasters. This could involve innovating product lines to meet changing customer needs, entering new markets that emerge as a result of economic shifts caused by the disaster, or rethinking business models to incorporate greater sustainability and disaster preparedness.

This framework allows for a systemic evaluation of the ways in which the principles of creative destruction and resilience manifest following a disaster. By investigating how firms adapt and innovate in response to disruptions, the paper aims to uncover not only the challenges faced but also the potential for positive transformations that enhance long-term sustainability and growth.

This conceptual framework yields hypothesis that are listed in the following subsection.

Resulting Hypothesis

Hypothesis 1:

An exogenous shock, such as an earthquake, destroys capital and hence lowers output, sales and profit. There are three related reasons: Firstly, the destruction of capital directly lowers output. Secondly, the destruction of infrastructure lowers sales and hence profits. Thirdly, the shock changes market demand and hence changes the product mix demanded.

This hypothesis serves as a foundational premise for the analysis, setting the stage for understanding the immediate economic consequences of the earthquake on affected firms. By examining whether the earthquake acted primarily as a supply shock (through capital destruction) or a demand shock (through changes in market demand and product mix), the paper seeks to delineate the mechanisms through which firms' output, sales, and profits were impacted. This analysis is crucial for identifying the nature of the shock and its subsequent effects on the economy, thus forming the basis for subsequent hypotheses that explore industry-specific responses and long-term adaptations.

Hypothesis 2:

Hypothesis 1 only holds for capital intensive industries that deploy more capital making them less resilient to shock. For shock resilient and less capital intensive industries, reduction in sales and profits is likely to be minimal.

We are assuming capital intensive industries are also less resilient to shocks for simplifying our analysis.

This hypothesis builds on the first by introducing the concept of industry het-

erogeneity in response to shocks. By distinguishing between capital-intensive and less capital-intensive industries, the paper explores how the structural characteristics of different sectors influence their vulnerability to exogenous shocks. This distinction is critical for understanding the differential impacts across industries, which in turn, informs the broader analysis of economic resilience. It also sets the stage for investigating the specific mechanisms that allow certain industries to withstand shocks better than others, leading to more targeted policy recommendations.

Hypothesis 3:

Rebuilding stimulates market demand, further changing the product mix demanded. Hence, industry specific results reveal how this mix changes and the overall impact on productivity is likely to be ambiguous.

This hypothesis introduces the dynamic nature of post-shock recovery, where the process of rebuilding itself becomes a significant economic force. By stimulating market demand, rebuilding efforts can alter the product mix demanded across industries, potentially leading to shifts in productivity. The paper examines these industry-specific changes to understand how the initial shock and subsequent recovery efforts interact to influence overall productivity. This hypothesis is key to understanding the long-term economic consequences of the earthquake and the potential for recovery efforts to either enhance or complicate productivity outcomes.

Hypothesis 4:

Short Term Adaptation and Reconstruction activity changes the economic fiber leading to more resilience and enhanced economic activity thereby increasing A in the Cobb Douglas production function.

This hypothesis extends the analysis to the broader implications of short-term adaptations and reconstruction efforts on economic resilience and growth. By positing that these activities can enhance the total factor productivity (A) in the Cobb-Douglas production function, the paper links microeconomic firm-level responses to macroeconomic outcomes. This connection is crucial for understanding how localized adaptation strategies can contribute to systemic resilience and economic recovery. The analysis under this hypothesis will help demonstrate whether the observed adaptations lead to sustained improvements in productivity and resilience, thus contributing to the overall narrative of recovery and growth.

Hypothesis 5:

The heterogeneous adaptation response can be explained by different Capital-Labour ratios and how the shock differentially impacts capital across industries.

This hypothesis seeks to explain the variability in firm responses to the earthquake

by examining differences in Capital-Labor ratios across industries. By analyzing how these ratios influence the impact of the shock on capital and subsequent adaptation strategies, the paper provides a nuanced understanding of why certain industries may have been more resilient than others. This analysis is integral to the overall discussion of economic resilience, as it highlights the importance of industry-specific characteristics in shaping the effectiveness of adaptation strategies. The findings from this hypothesis will contribute to the development of more targeted and effective policy interventions aimed at enhancing resilience.

Hypothesis 6:

Firms take strategic action diversifying markets that build long term resilience by further increasing A.

This hypothesis addresses the strategic responses of firms in the aftermath of the earthquake, specifically through market diversification. By linking market diversification to long-term resilience and increases in total factor productivity (A), the paper explores how proactive strategies can mitigate the impacts of future shocks. This hypothesis is crucial for understanding the forward-looking actions that firms can take to enhance their resilience, beyond immediate recovery efforts. The analysis will demonstrate whether such strategies contribute to sustained improvements in productivity and economic stability, thereby reinforcing the broader theme of resilience and recovery throughout the paper.

4 Context and Data

On 8th October, 2005, a 7.6 magnitude earthquake struck South Asia with its epicenter 19 km[1] (12 mi) northeast of Muzaffarabad, Azad Jammu and Kashmir, Pakistan and 100 km north of its capital in Islamabad. It proved to be the deadliest earthquake since 1935 surpassing the 1935 Quetta earthquake in fatalities and destruction. 780,000 buildings were either completely destroyed or sustained significant damage, 86,000 lives[2] were lost and 3.5 million people were rendered homeless. Overall it lead to economic losses equivalent to 2.6 percent of Pakistan's GDP.

The government setup the Earthquake Reconstruction and Rehabilitation Agency (ERRA) to distribute household grants and loans and rebuild public infrastructure. However, the allocation overlooked grants and loans to firms that were impacted, providing further rationale for evaluating the full impact and ascertaining the optimal government intervention for firms.

This paper, is using a panel survey of 390 firms, to evaluate the impact of this

[1] ReliefWeb (2005)
[2] ReliefWeb (2005)

natural exogenous shock on firm output, productivity and adaptation strategies. The paper is using data from World Bank Enterprise Surveys from years 2002-2007. World Bank Enterprise Surveys are nationally representative firm level surveys conducted across 170 countries by surveying the owner/top manager of the firm collecting quantitative and qualitative data across various firm level dimensions. This paper uses two waves of the data collected in Pakistan in 2002 and 2007 i.e. two years before and approximately two years after the earthquake across 14 cities.

Using the data, this paper constructs a discrete variable of treatment intensity using distance measures of Latitude/Longitude of the firm location from the epicentre. Using this measure we draw causal inferences about the impact of natural disasters on key firm outcomes, such as sales, capital stock, and employment, and to explore how firms adapt and build resilience in the aftermath of such shocks.

5 Methodology

This paper is using difference-in-difference estimation to evaluate the impact of the 2005 earthquake on the immediate firm responses, short term firm adaptation and what forward looking actions does the firm take to build resilience. This paper will also presents some salient heterogeneous responses by firm characteristics.

In this paper, I employ a panel dataset, the World Bank Enterprise Survey Panel Dataset from 2002 to 2007 to analyse firm outcomes before and after disaster exposure. The sample comprises 390 firms in Pakistan. The methodological approach i.e. Difference-in-Differences analysis allows us to control for unobserved heterogeneity by comparing changes in outcomes over time between firms that were exposed to natural disasters and those that were not. This strategy helps isolate the causal impact of disasters from other concurrent economic fluctuations.To ensure robustness, I control for firm level variables such as firm size, exporter status, number of employees, extent of automation and new products introduced along with industry fixed effects which are included in the regression models to draw causal estimates about the impact of natural disasters.

Furthermore, I am clustering the standard errors at the city level, which accounts for spatial correlations in disaster exposure and impact. This setup allows us to draw causal inferences about the impact of natural disasters on key firm outcomes, such as sales, capital stock, and employment, and to explore how firms adapt and build resilience in the aftermath of such shocks. The paper's findings aim to contribute valuable insights into disaster management strategies for businesses in highly vulnerable regions.

In this paper, the following regression specification will be estimated:

$$Y_{it} = B_0 + B_1(Exposure_i * \mathbf{1}(Year = 2007)) + \lambda_i + \mu_t + \epsilon_{it}$$

where Y_{it} are firm level outcomes. Exposure is defined as a discrete variable which takes on the value 1 for cities within 400 km of the epicentre. λ_i and μ_t are firm level controls including industry fixed effects and time fixed effects respectively. Standard errors are robust and clustered at the city level.

To establish the exogeneity of the shock, it is important to highlight that first and foremost it cannot be forecasted. Inspite of seismically active regions, the epicenter is completely randomly located and uncorrelated with local infrastructure. This is also established in the earlier seminal work, for instance Andrabi, Daniels, and Das (2023) and Frankenberg et al. (2011).

Following the difference in difference analysis, I run a policy simulation exercise to ascertain the optimal government response to such an exogenous shock. I test three potential fiscal interventions that may aid recovery: Tax Rebate, Direct Government Spending and Direct Transfer to the firms. I do this using a simple Cobb Douglas production function and then model each one of these interventions post earthquake shock. One policy intervention clearly outperforms the other two and the Section 9 discusses this in detail.

6 Descriptive Analysis and Summary Statistics

Table 3 shows there is considerable variation in sales and labour costs and the firms in the sample are fairly heterogeneous. 35 percent of the firms export, no. of employees ranges from 0 to 2,000, with an average of 39 employees, hours of operations range from 0 to 189 hours, with an average of 31.3 hours per week and firms store an inventory of upto 32 days of the primary input.

Table 4 shows the summary statistics by exposure to the earthquake. Statistically significant differences, especially, in the exporter status and extent of automation justify the use of Difference-in-Difference methodology to evaluate the impact of the earthquake on firm level outcomes.

There is heterogeneity by firm size and industry, as expected, in the firm level outcomes, as visualised by Figure 5 and 6. Leather industry is an outlier and the result section that follows will attempt to explain this heterogeneity empirically.

7 Empirical Results

Impact on Capital Stock and Sales

The results show that the Kashmir earthquake significantly altered the economic landscape for Pakistani firms. The results shows considerable declines in sales and capital

stock alongside shifts in employment patterns and operational strategies, which were indicative of the broader economic impact of the earthquake and the adaptive responses by firms.

Post-earthquake, capital stock declined at 45 percent, significant at 10 percent level indicating tangible asset damage and sales subsequently registered a substantial decline statistically significant at the 1 percent.

The impact on capital stock by industry, however, is heterogeneous. This in turn drives the heterogeneous impact on sales by industry. For instance, Leather industry registers an uptick, but this uptick is also likely driven by increase in market demand as leather products are in greater demand as reconstruction and rebuilding activities pick up post the earthquake. As a result, when all industries adapt by increasing the operational hours, the increase is the greatest for Leather industry.

Next, I look at the impact on capital stock and sales by firm size. While there is no differential impact on stock, the impact on sales is the largest for smallest firms. This is critical and we will revisit this finding as we look at grant receipt.

Impact on Labour

The results illustrate nuanced and significant shifts in employment patterns as firms adapted to the challenges posed by declining sales and reduced productive capacity. In response to these pressures, firms strategically opted to reduce their non-production labor force. This decision to cut back on non-essential roles was likely driven by the need to streamline operations and minimize costs during a period of economic strain. By focusing on core production activities, firms aimed to maintain operational efficiency while grappling with the constraints imposed by the economic downturn.

At the same time, there was a noticeable strategic shift toward prioritizing the employment of a skilled workforce. As firms encountered new and complex operational challenges, particularly in maintaining production levels and navigating disrupted supply chains, the value of a highly skilled labor force became increasingly apparent. Skilled workers, with their ability to adapt to changing circumstances and manage more sophisticated tasks, were seen as essential to sustaining business continuity and driving recovery efforts. This emphasis on skilled labor reflects a broader strategy to not only survive the immediate crisis but also to build a more resilient and adaptable workforce capable of supporting long-term growth.

The decline in non-production labor was most pronounced in the Textiles industry, followed by the Machinery and Chemicals sectors. These industries, being more labor-intensive compared to others, were particularly vulnerable to the economic pressures of the time. The significant reduction in non-production labor within these sectors high-

lights the difficult choices firms had to make in order to preserve their core production capabilities. The labor-intensive nature of these industries likely exacerbated the impact, as firms in these sectors faced greater challenges in balancing cost-cutting measures with the need to maintain operational capacity.

Moreover, the analysis indicates that these employment shifts did not differentially impact labor outcomes based on gender. Despite the reductions in non-production roles and the strategic emphasis on skilled labor, the data suggest that male and female workers were affected similarly. This finding is significant as it suggests that, at least in terms of employment outcomes, gender did not play a defining role in how labor adjustments were made during this period. The uniformity of impact across gender lines may reflect broader industry-wide trends rather than gender-specific vulnerabilities, indicating that the challenges faced were more universally felt across the workforce.

Firms reduced non-production labor to cut costs and maintain operational efficiency, while simultaneously prioritizing skilled labor to address new challenges. The differential impact across industries, particularly in labor-intensive sectors, underscores the varying degrees of vulnerability faced by different types of firms. However, the absence of a differential gender impact suggests a uniform approach to labor adjustments during this period of economic restructuring.

Operational Adaptation

Operational strategies also demonstrate significant adaptations. Notably, there was an observed increase in operational hours, with a coefficient of 62.8 indicating that firms extended their weekly working hours significantly to compensate for production time lost due to the earthquake. This was a direct attempt to sustain business continuity amidst ongoing disruptions. Moreover, facilities utilization saw a marked increase, reflecting a strategic shift in resource allocation—firms likely repurposed their facilities to streamline operations and reduce dependencies on disrupted supply chains. This short term adaptation and reconstruction activity changes the economic fiber leading to more resilience and enhanced economic activity thereby increasing A in the Cobb Douglas production function and lending empirical evidence to Hypothesis 4.

Financial Adaptation

These operational adaptive measures were accompanied by a greater likelihood amongst the firms to borrow from a private bank indicative of the firms' readiness to expedite recovery and build resilience. This increased likelihood of borrowing suggests that firms were not only focused on short-term survival but were also strategically positioning themselves to rebuild and enhance resilience against future shocks.

Strategic Adaptation

Strategic adaptation was particularly evident in how firms responded to infrastructure damage. The need to ensure continuity despite frequent power outages and other infrastructure losses led to a notable increase in the adoption of backup power solutions, particularly generators. This shift towards infrastructure resilience is a clear strategic response, ensuring that operational disruptions were minimized even in the face of ongoing external shocks.

The increased use of generators and other resilience-building measures not only allowed firms to maintain productivity but also enhanced their overall capacity to withstand similar challenges in the future. This strategic adaptation goes beyond immediate recovery; it contributes to long-term productivity gains and underscores the importance of infrastructure resilience in sustaining economic activities during and after crises.

Building Resilience

Market diversification efforts became increasingly apparent in the aftermath of the disaster, as evidenced by a positive coefficient that highlights the strategic decisions made by affected firms to broaden their market reach. These firms, recognizing the risks inherent in relying on a limited local market, actively sought to expand their presence. This expansion was not incremental but rather substantial, with some firms moving from operating in just one market to as many as five, or from five markets to twenty. Such diversification was a deliberate strategy to mitigate the vulnerabilities associated with a concentrated market presence, allowing firms to spread risk across a broader geographic or customer base. By entering new markets, these firms aimed to stabilize their revenue streams and reduce the impact of any future disruptions in their local markets.

Despite these proactive steps towards market diversification, it is noteworthy that there was no significant increase in innovative activities among the affected firms following the disaster. The data suggests that while firms were keen on reducing their market risk through expansion, they did not similarly prioritize innovation as a means of adapting their business models to the new economic realities. This lack of innovation could indicate a reliance on traditional business practices and a reluctance or inability to explore new ways of operating in the changed environment. The absence of a notable rise in innovation efforts points to a potential weakness in the firms' overall adaptive strategies, as innovation is often crucial for long-term resilience and competitiveness.

The failure to increase innovative activities in response to the disaster also reveals a critical gap that could be addressed through targeted government intervention. If the goal is to build greater resilience to future shocks, it may be necessary for the government to encourage and support innovation within these firms. This could involve offering incen-

tives for research and development, providing grants or subsidies for innovation projects, or creating an environment that fosters creative problem-solving and the adoption of new technologies. By stepping in to promote innovation, the government could help firms develop more robust and flexible business models, better equipping them to withstand and adapt to future economic disruptions.

In summary, while market diversification was a clear and strategic response to the disaster, the lack of corresponding innovation efforts highlights a potential area of vulnerability. Firms may have successfully mitigated some risks by expanding their market reach, but their overall resilience could be compromised without a concurrent focus on innovation. This presents an opportunity for government action to bolster innovation and, in turn, enhance the long-term resilience of these firms to future shocks.

Grants

While there is no differential impact on stock by size, the impact on sales is the largest for smallest firms. This means it is critical for grants to be well-allocated to small and medium enterprises. However, grants analysis reveals contrary results with no significant grants disbursed by Small and Medium Enterprise Development Authority.

The overall effectiveness of financial aid and grants was mixed, with some sources like Export Promotion Bureau and Board of Investment showing almost no grant delivery underscoring the under deliverance in external support effectiveness.

In sum, the empirical findings demonstrate the heterogeneous impact on firms in light of varying capital and labour intensiveness and varying capital-labour ratios. This also drives the heterogeneity in varying adaptive responses that build overall productivity of the economy via enhancing firm level A. Increases in operational hours, strategic borrowing, and market diversification were among the key strategies employed to cope with and recover from the disaster's impacts. These strategies not only facilitated recovery but also potentially contributed to a foundation for longer-term business resilience in a region prone to natural disasters. The results provide critical insights into the adaptive capacities and strategic resilience of firms in disaster-affected regions, offering valuable lessons for economic policy in disaster management and resilience planning.

Heterogeneous Impact on Sales and Capital

In order to underscore and highlight the heterogeneity in the response and adaptation, this section also separately discusses the heterogeneity results.

The impact on sales by industry, as discussed above, is heterogeneous. Leather industry registers an uptick. The impact on capital stock is also non-negative. The positive impact on sales may also be a result of greater demand as reconstruction and

rebuilding activities pick up post the earthquake.

The decrease in the non-production workers is primarily driven by Textiles Industry followed by Machinery and Chemicals. The hours of operations increase for all industries, but unsurprisingly most for Leather industry as demand for leather products increases with the reconstruction activities picking up in Pakistan's fierce winter weather in area of impact.

Next I look at the impact on capital stock and sales by firm size. While there is no differential impact on stock, the impact on sales is the largest for smallest firms. This is critical for policy planning and grant delivery.

There is no differential impact by exporter status both for direct exports and indirect exports. There is also no differential impact by the gender and experience of the owner and/or senior manager. The same also holds true for ownership structure.

Does the overall market concentration change?

Economic theory traditionally suggests that an exogenous shock, such as the 2005 earthquake, would lead to the exit of firms with lower productivity. The rationale behind this is that less productive firms, already operating on thinner margins, are less likely to withstand the financial and operational pressures imposed by such a disruptive event. The shock would typically exacerbate their vulnerabilities, driving them out of the market as they fail to compete with more resilient, higher-productivity firms. This process would, in theory, result in a market characterized by fewer, more productive firms, thereby increasing overall market concentration.

However, in the analysis of this panel dataset, there is no evidence to support this theoretical outcome. The data does not indicate any significant exit of firms in the aftermath of the earthquake. There are no direct records of firm closures, and importantly, no observations where sales figures drop to a null value, which would typically signify that a firm has ceased operations. This lack of observed exits suggests that firms, regardless of their productivity levels, managed to survive the immediate effects of the earthquake.

As a result, the expected shift in market dynamics—wherein lower-productivity firms exit the market and concentration increases—did not materialize. The market concentration, therefore, remains stable, with no significant changes in the composition of firms. This outcome may suggest that other factors, such as government support, access to credit, or pre-existing resilience strategies, played a role in helping even less productive firms maintain their operations during this period of crisis. Alternatively, it could indicate that the shock, while significant, did not reach the threshold necessary to trigger widespread exits within this particular market.

This finding challenges the conventional expectations derived from economic theory

and highlights the complexity of market responses to exogenous shocks. It suggests that in certain contexts, firms may have the capacity to absorb and survive shocks without leading to the anticipated market restructuring.

8 Robustness Checks

To establish the robustness of the results, we run the following tests:

8.1 Continuous Treatment

I now define the exposure as continuous distance variable measuring the distance of the firms from the epicentre. I do this using the Longitude and Latitude of the epicenter and each of the firms in the sample. The results are displayed in Table 12. The closer the firm to the epicenter, the larger is the increase in reduction in capital stock and hence sales.This new definition yields similar results establishing beyond doubt that the exposure variable is robust to any changes in definitions. I also use alternate definitions of discrete Treatment Variables and the results are robust beyond 400 km. Additionally, I used propensity score matching to compare affected firms to similar but unaffected firms to strengthen the robustness of the results. These alternate definition establish the robustness of our results beyond doubt.

8.2 Alternate Controls

The main specification is controlling for exporting status of the firms. I split this into direct and indirect exports and the results are robust to the changing definition. I am also controlling for introduction of new products. Addition or replacement of this by introduction of new processes does not alter the definition. Addition of more controls such as various definitions of the labour employed, extent of automation and other firm level heterogeneous characteristics does not alter the results or change its statistical significance.

9 Expectation-Based Model of Firm Adaptation, Minimal Expected Government Aid, and Misallocation.

This model explores the behavior of firms that anticipate minimal future government aid in the face of natural disasters and, as a result, increase their adaptation efforts. However, these adaptation efforts lead to a form of adaptive misallocation, where firms

over-invest in self-protection at the expense of productive investment. The production function incorporates expected government aid and the inefficiencies caused by misallocation. Additionally, firms use both short-term adaptation (STA) and long-term adaptation (LTA) strategies in response to disaster risks. I provide detailed explanations of the model setup, including step-by-step derivations of the firm's optimization problem, the government response, and the breakdown of the social contract due to these misaligned incentives.

Post Disaster, thefirm's production function depends on several factors: expected future government aid $E_t[G_{t+1}]$, firm adaptation A_t, post-earthquake capital K_t, and labor L_t. In this model, the production function incorporates a misallocation term τ_A, representing the inefficiencies arising from firms diverting too many resources into adaptation.

$$Y_t = A_0 \cdot (1 + \theta A_t^{\gamma}) \cdot (1 - \lambda E_t[G_{t+1}]^{\delta}) K_t^{\alpha} L_t^{\beta} \cdot (1 - \tau_A)$$

Where:

- A_t is the firm's adaptation effort at time t,
- $E_t[G_{t+1}]$ is the **expected future government aid** at time $t + 1$,
- τ_A represents the distortion caused by **adaptive misallocation** due to over-allocation to adaptation,
- $\theta, \lambda, \gamma, \delta, \alpha, \beta$ are output elasticities of adaptation, expected aid, capital, and labor,
- A_0 is post disaster productivity.

In this framework, firms anticipate minimal future government aid $E_t[G_{t+1}]$, which drives them to invest more heavily in adaptation A_t. However, over-investment in adaptation causes a distortion τ_A, which reduces overall productivity. This is the resulting misallocation, where resources are diverted inefficiently.

We introduce the distortion τ_A to represent inefficiencies that arise due to excessive adaptation. This term captures how the over-reliance on private adaptation, in response to expected minimal government aid, leads to a reduction in total factor productivity (TFP).

Firms maximize their expected discounted profits over an infinite time horizon, accounting for minimal expected government aid and the distortion caused by adaptive misallocation. The firm's objective is to choose the optimal adaptation effort A_t that maximizes the present value of its expected profits:

$$\max_{A_t} E_t \left[\sum_{t=0}^{\infty} \beta^t \Pi_t \right]$$

Where:

- β is the discount factor, capturing the firm's time preference for future profits,
- Π_t is the firm's profit at time t,
- E_t is the expectation operator, representing the firm's expectation of future government aid based on information at time t.

The firm's profit Π_t is given by:

$$\Pi_t = A_0 \cdot (1 + \theta A_t^{\gamma}) \cdot (1 - \lambda E_t[G_{t+1}]^{\delta}) K_t^{\alpha} L_t^{\beta} \cdot (1 - \tau_A) - c(A_t)$$

Where the non-linear cost of adaptation $c(A_t)$ is modeled as:

$$c(A_t) = \psi A_t^{\zeta}$$

This non-linear cost function reflects the idea that as firms increase their adaptation efforts, the marginal cost of adaptation rises. The parameter ζ determines the degree of non-linearity in the adaptation cost.

The firm faces a trade-off: adaptation increases its productivity, but it also incurs higher costs. Moreover, the expected minimal government aid $E_t[G_{t+1}]$ affects the firm's decision-making. As firms expect less aid from the government in the future, they compensate by increasing their adaptation efforts, but this leads to inefficiencies captured by τ_A.

The government provides aid G_{t+1} in response to firm adaptation efforts, but this aid is both non-linear and subject to **stochastic shocks** ε_t, representing uncertainty in disaster severity and the government's response. The government aid function is:

$$G_{t+1} = \frac{G_0}{1 + \kappa A_t^{\eta}} + \varepsilon_t$$

Where:

- G_0 is baseline government aid,
- κ and η capture the non-linear response of government aid to firm adaptation efforts,
- $\varepsilon_t \sim N(0, \sigma^2)$ represents stochastic disaster shocks.

As firms adapt more, government aid decreases non-linearly because the government expects firms to bear a larger share of the disaster response. However, there is a stochastic element ε_t representing the inherent uncertainty in government aid due to the unpredictable nature of disasters.

Firms' adaptation efforts A_t are divided into short-term adaptation (STA) and long-term adaptation (LTA) components:

$$A_t = STA_t + LTA_t$$

Where:

- STA_t represents immediate, short-term measures taken by firms to mitigate disaster risks,
- LTA_t represents long-term strategic investments aimed at improving overall resilience to future disasters.

Short-term adaptation (STA) is focused on operational flexibility and immediate responses to disasters, whereas long-term adaptation (LTA) reflects more strategic, investment-based actions that enhance resilience over time. Both are crucial in shaping the firm's adaptation strategy, and both contribute to the overall A_t term in the production function.

To derive the firm's optimal adaptation decision, we differentiate the firm's expected profit function with respect to adaptation A_t. The firm's first-order condition (FOC) is obtained by solving:

$$\frac{\partial E_t \left[\sum_{t=0}^{\infty} \beta^t \Pi_t\right]}{\partial A_t} = 0$$

Substituting the profit function Π_t:

$$\frac{\partial}{\partial A_t} \left[A_0(1 + \theta A_t^{\gamma}) \cdot (1 - \lambda E_t[G_{t+1}]^{\delta}) K_t^{\alpha} L_t^{\beta} \cdot (1 - \tau_A) - \psi A_t^{\zeta}\right] = 0$$

$$\frac{\partial}{\partial A_t} \left[A_0(1 + \theta A_t^{\gamma})\right] = A_0 \theta \gamma A_t^{\gamma - 1}$$

This captures the direct effect of adaptation on the firm's production.

We now differentiate the term involving expected government aid $E_t[G_{t+1}]$, using the government aid response function:

$$\frac{\partial}{\partial A_t} \left[(1 - \lambda E_t[G_{t+1}]^{\delta})\right] = \lambda \delta E_t[G_{t+1}]^{\delta - 1} \frac{\partial E_t[G_{t+1}]}{\partial A_t}$$

Since:

$$E_t[G_{t+1}] = \frac{G_0}{1 + \kappa A_t^{\eta}}$$

We differentiate $E_t[G_{t+1}]$ with respect to A_t:

$$\frac{\partial E_t[G_{t+1}]}{\partial A_t} = -\frac{G_0 \kappa \eta A_t^{\eta-1}}{(1 + \kappa A_t^{\eta})^2}$$

Thus, the full differentiation of the second term is:

$$\lambda \delta E_t[G_{t+1}]^{\delta-1} \left(-\frac{G_0 \kappa \eta A_t^{\eta-1}}{(1 + \kappa A_t^{\eta})^2} \right)$$

The cost of adaptation is non-linear, so the derivative of the cost function is:

$$\frac{\partial}{\partial A_t} \left[-\psi A_t^{\zeta} \right] = -\psi \zeta A_t^{\zeta-1}$$

Combining all these terms, the firm's first-order condition for optimal adaptation is:

$$A_0 \theta \gamma A_t^{\gamma-1} (1 - \lambda E_t[G_{t+1}]^{\delta}) K_t^{\alpha} L_t^{\beta} (1 - \tau_A) - \lambda \delta E_t[G_{t+1}]^{\delta-1} \frac{G_0 \kappa \eta A_t^{\eta-1}}{(1 + \kappa A_t^{\eta})^2} K_t^{\alpha} L_t^{\beta} (1 - \tau_A) - \psi \zeta A_t^{\zeta-1} = 0$$

This condition describes the optimal level of firm adaptation A_t, balancing the benefits from increased adaptation, the expected minimal government aid, the distortions from misallocation, and the rising marginal costs of adaptation.

At steady state, firm adaptation and expected government aid stabilize. The steady-state adaptation A^* and expected government aid G^* are determined by solving:

$$A^* = \left(\frac{A_0 \theta \gamma (1 - \lambda E[G^*]^{\delta}) K^{\alpha} L^{\beta} (1 - \tau_A)}{\psi \zeta} \right)^{\frac{1}{\zeta - \gamma}}$$

$$E[G^*] = \frac{G_0}{1 + \kappa (A^*)^{\eta}}$$

These equations describe the long-run equilibrium where firm adaptation and expected government aid stabilize. The distortions caused by misallocation τ_A affect the firm's ability to achieve optimal productivity in the steady state.

The social contract between the government and firms breaks down when the combined efforts of firm adaptation A^* and expected government aid $E[G^*]$ fall short of the required threshold C:

$$A^* + E[G^*] < C$$

In steady state, the total adaptation and expected aid must meet or exceed the threshold:

$$A^* + E[G^*] = \left(\frac{A_0 \theta \gamma (1 - \lambda E[G^*]^\delta) K^\alpha L^\beta (1 - \tau_A)}{\psi \zeta} \right)^{\frac{1}{\zeta - \gamma}} + \frac{G_0}{1 + \kappa (A^*)^\eta}$$

If this condition is violated, the social contract erodes, leading to inefficient cooperation between firms and the government.

This model captures the behavior of firms that adapt their efforts based on the expectation of minimal future government aid. The inclusion of a misallocation term τ_A highlights how over-allocation of resources to adaptation can reduce productivity. Firms must balance short-term adaptation (STA) and long-term adaptation (LTA) strategies to mitigate risks, but excessive adaptation results in inefficiencies.

The breakdown of the social contract can be understood as a failure of a Nash bargain between firms and the government. Misaligned incentives, where firms expect minimal government support, lead them to over-adapt while the government reduces its own efforts, resulting in a failure to achieve optimal disaster preparedness. Policy coordination between firms and governments is necessary to restore the social contract and prevent inefficiencies caused by adaptive misallocation.

The more firms engage in adaptive behavior, the lower the government's perceived need to provide aid or infrastructure, thereby reinforcing a feedback loop of declining public intervention and increasing private adaptation. These countervailing incentives result in a breakdown of the social compact, where firms bear a disproportionate share of the disaster risk mitigation efforts, while the government retreats from its role in providing public goods, leading to inefficiencies in disaster resilience and an erosion of cooperative behavior between the public and private sectors.

10 Policy Simulation: Optimal Government Response

After a theoretical discussion of the level of government support, this section will explore the optimal form for this intervention.

To understand the potential recovery paths, we simulate three types of government

interventions: tax rebates, increased government spending, and direct financial transfers. The goal is to evaluate how each intervention affects the recovery of output and profit, thereby influencing firm resilience.

1. **Tax Rebates**: Reducing the tax rate (τ) can provide immediate financial relief to firms, allowing them to retain more earnings for reinvestment. The profit function under this scenario becomes:

$$\pi = (1 - \tau)Y - wL - rK \tag{1}$$

2. **Government Spending**: Increased government spending can enhance Total Factor Productivity (A) by improving infrastructure, public services, or direct support for innovation. This intervention aims to restore and potentially increase A, thereby boosting output.

3. **Direct Financial Transfers**: Direct financial aid to firms can compensate for the loss of capital. This scenario assumes an increase in capital by D units due to the transfer, modeled as:

$$K'' = K' + D \tag{2}$$

We derive the partial derivatives of output and profit with respect to the policy parameters to understand their impacts.

This section presents the detailed calculations of partial derivatives of output and profit with respect to key parameters in each policy intervention scenario. These derivatives quantify the sensitivity of economic variables to changes in policy settings.

The post earthquake output and profit for which we will take the partial derivatives are as under:

$$Y' = (1 - \gamma)A\left((1 - \delta)K\right)^{\alpha} L^{\beta}$$

$$\pi' = (1 - \tau)Y' - wL - rK'$$

The partial derivatives of output and profit with respect to tax rates (τ), productivity (A), and capital (K) under each scenario are detailed below:

These derivatives illustrate how output and profit respond to incremental changes in policy-related variables across various scenarios, providing insights into the effectiveness of each intervention in promoting economic recovery after a disaster.

The parameters used in the model are defined based on empirical studies and eco-

Table 1: Partial Derivatives of Output and Profit for Post-Disaster Interventions

Intervention	**Output Partial Derivative**	**Profit Partial Derivative**
Tax Rebate	$\frac{\partial Y'}{\partial \tau} = 0$	$\frac{\partial \pi'}{\partial \tau} = -Y'$
Govt Spending	$\frac{\partial Y'}{\partial A'} = (K')^{\alpha} L^{\beta}$	$\frac{\partial \pi'}{\partial A'} = (1-\tau)(K')^{\alpha} L^{\beta}$
Direct Transfers	$\frac{\partial Y'}{\partial D} = \alpha A'(K')^{\alpha-1} L^{\beta}$	$\frac{\partial \pi'}{\partial D} = \alpha(1-\tau)A'(K')^{\alpha-1} L^{\beta} - r$

nomic theory. The following table outlines each parameter along with its source.

Table 2: Model Parameters and Sources

Parameter	Value	Source
α (Capital's output elasticity)	0.30	Hsieh and Klenow 2009
β (Labor's output elasticity)	0.70	Hsieh and Klenow 2009
δ (Fraction of capital destroyed)	0.15	Noy 2009
γ (Reduction in TFP)	0.10	Cavallo and Noy 2011a
τ (Initial tax rate)	0.25	Fuest, Peichl, and Schaefer 2008
τ' (Reduced tax rate)	0.18	Fuest, Peichl, and Schaefer 2008
A (Initial productivity)	1	Standard normalization
A' (Post-earthquake productivity)	0.90	$(1-\gamma)A$
A'' (Productivity with increased spending)	0.95	Assumed
D (Direct financial transfers)	5 units	Assumed
r (Rental rate of capital)	0.05	Caselli and Feyrer 2007
w (Wage rate)	50	Assumed

Our simulations show that increased government spending has the most significant positive impact on recovery, as it directly addresses both the destruction of capital and the reduction in TFP. By reducing the need for firms to over-adapt, this intervention minimizes the inefficiencies caused by misallocation, restoring productivity to pre-disaster levels.

Tax rebates, while providing some immediate relief, do not fully mitigate the adaptive misallocation. Similarly, direct financial transfers help replace lost capital but fail to fully address the broader issue of reduced productivity due to misallocation.

11 Conclusion

This paper explores the dynamic relationship between firm adaptation and government aid expectations following the 2005 Pakistan earthquake. The findings demonstrate that when firms anticipate minimal future government support, they engage in significant private adaptation. However, this behavior leads to adaptive misallocation, as firms divert resources away from productive investments and toward defensive strategies to mitigate disaster risks. This misallocation results in reduced productivity and slows economic recovery.

The breakdown of the social contract can be understood as a failure of a Nash bargain between firms and the government. Misaligned incentives, where firms expect minimal government support, lead them to over-adapt while the government reduces its own efforts, resulting in a failure to achieve optimal disaster preparedness. Policy coordination between firms and governments is necessary to restore the social contract and prevent inefficiencies caused by adaptive misallocation.

The more firms engage in adaptive behavior, the lower the government's perceived need to provide aid or infrastructure, thereby reinforcing a feedback loop of declining public intervention and increasing private adaptation. These countervailing incentives result in a breakdown of the social compact, where firms bear a disproportionate share of the disaster risk mitigation efforts, while the government retreats from its role in providing public goods, leading to inefficiencies in disaster resilience and an erosion of cooperative behavior between the public and private sectors.

The policy simulations presented in this paper highlight the importance of strategic government intervention to address the inefficiencies caused by adaptive misallocation. When the government provides consistent and adequate aid, firms can reduce their reliance on excessive adaptation, leading to a more efficient allocation of resources. This approach not only accelerates recovery but also restores productivity to pre-disaster levels by breaking the feedback loop that drives misallocation.

These findings underscore the critical need for public-private cooperation in disaster resilience. While firms can play an important role in mitigating the impacts of natural disasters, government intervention is essential to ensure that these efforts do not result in inefficient outcomes. The failure of Nash bargaining illustrates the need for coordinated strategies between the private and public sectors to achieve optimal recovery after natural disasters.

Moving forward, this analysis suggests that disaster resilience policies should include mechanisms for pre-committing government aid to prevent over-adaptation by firms. Such policies would help ensure a balanced and effective recovery process, reducing the long-term negative effects of adaptive misallocation. Further research into the design of such

policies, as well as the broader implications of misallocation in disaster recovery, could provide valuable insights for both governments and firms operating in disaster-prone regions.

12 Appendix

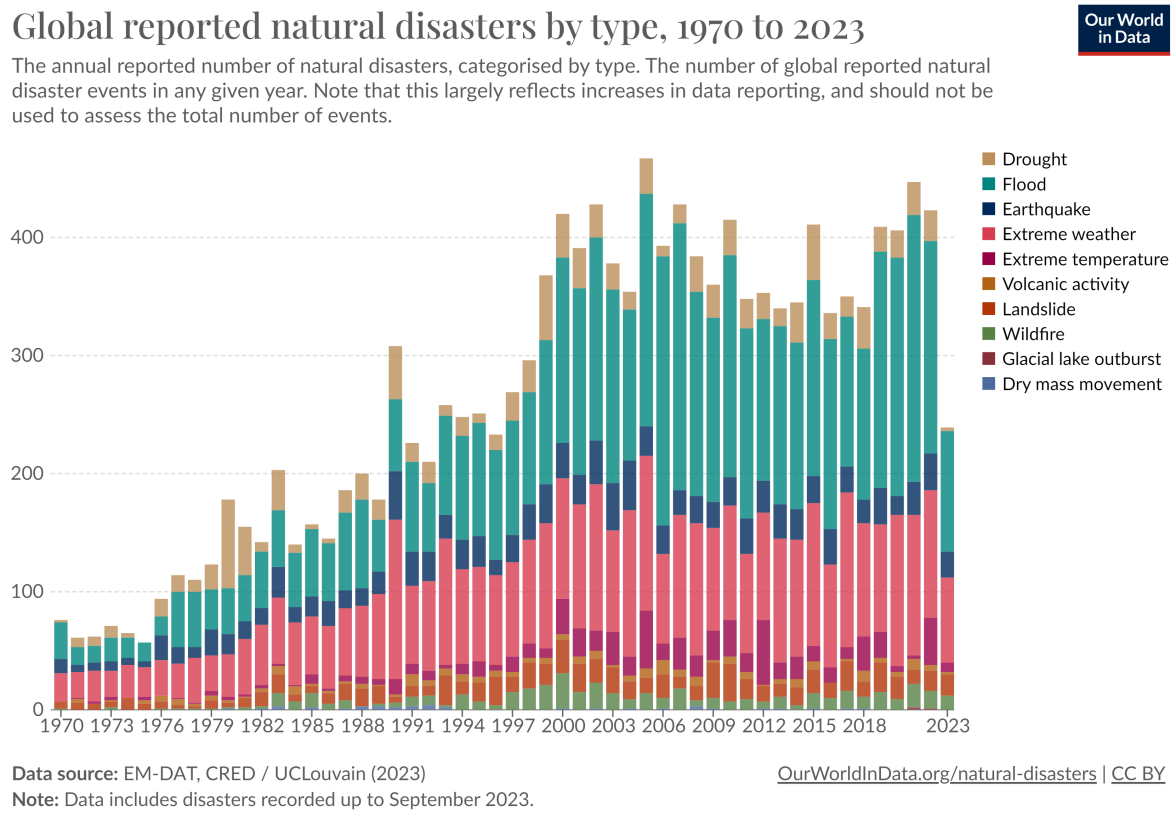


Figure 1: Increase in Frequency of Natural Disasters globally. Source: Our World in Data 2024

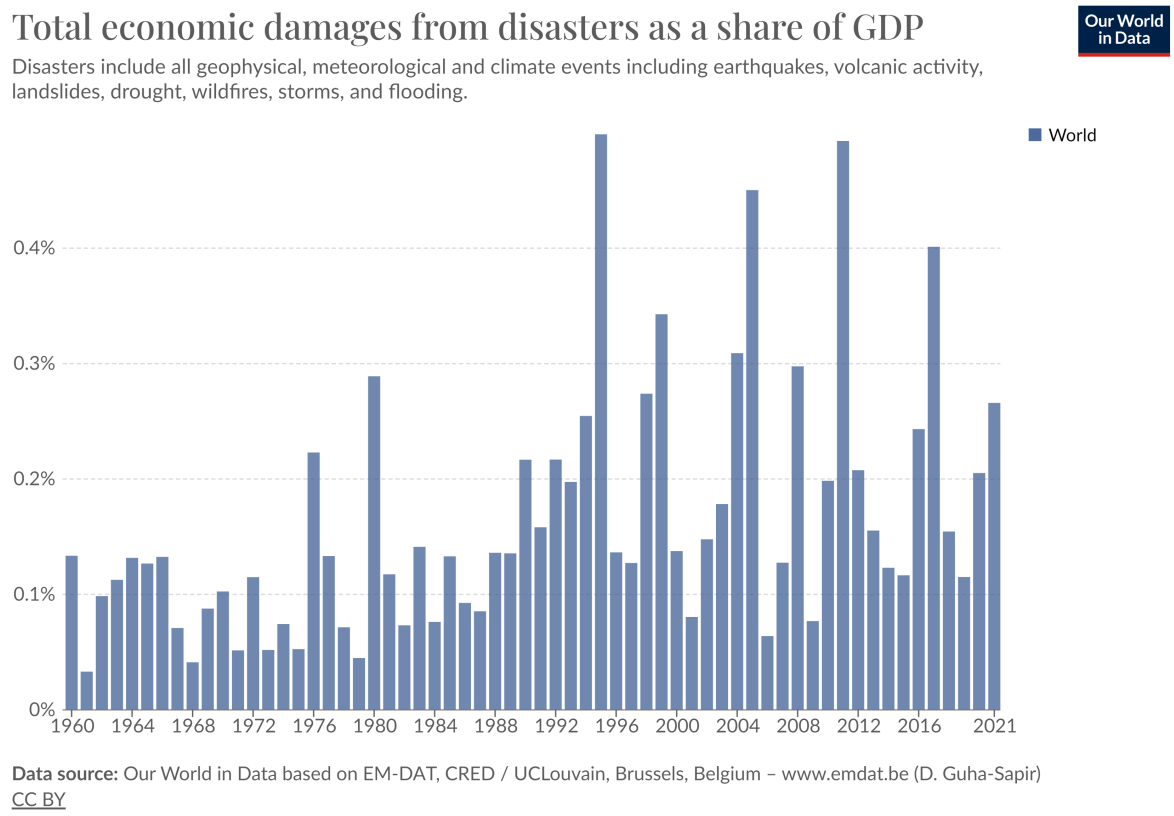


Figure 2: How the economic damages from natural disasters as a percentage of GDP are increasing globally. Source: Our World in Data 2024



Figure 3: Epicenter of the 2005 Earthquake, Source: ReliefWeb (2005)

Table 3: Summary Statistics

Variables	Count	Mean	Std. Dev	Min	Max
Annual Sales	780	2.06e+08	9.86e+08	0.00	1.83e+10
Exporter	780	0.35	0.48	0.00	1.00
Computerisation	780	8.27	18.02	0.00	100.00
No. of Employees	780	39.15	102.11	0.00	2000.00
Days of Inventory	780	32.32	43.38	0.00	365.00
New Product Introd.	780	3.52	16.30	0.00	100.00
Hours of Operations	780	31.29	39.98	0.00	189.00
Labour Costs	780	1.11e+07	4.90e+07	0.00	7.20e+08

Note: This table summarises the key variables in the dataset. Annual Sales and Labour Costs record large variations, exporter is a categorical variable that takes on the value 1 for an exporting firm, computerisation is also a categorical variable that takes on the value 1 if a firm uses computers, days of inventory is the number of days for which a primary input's stock is kept in the store, new product introduced is a categorical variable that takes on the value 1 if the firm introduced a new product in the last fiscal year.

Table 4: Summary Statistics By Treatment

Variables	Control	Treatment	P-Value	Std. Diff
Annual Sales	1.5e+08	1.1e+08	0.500	-0.278
	(5.2e+08)	(5.4e+08)		
Exporter	0.138	0.301	0.000	-0.318
	(0.347)	(0.460)		
Computerisation	12.943	3.878	0.000	-0.932
	(20.511)	(8.274)		
No. of Employees	33.301	28.563	0.464	-0.558
	(55.906)	(61.335)		
Days of Inventory	24.667	25.538	0.764	-0.923
	(27.474)	(26.428)		
Labour Costs	7.8e+06	3.8e+06	0.102	-0.339
	(3.0e+07)	(1.9e+07)		

Note: This table summarises the key variables in the dataset. Annual Sales and Labour Costs record large variations, exporter is a categorical variable that takes on the value 1 for an exporting firm, computerisation is also a categorical variable that takes on the value 1 if a firm uses computers, days of inventory is the number of days for which a primary input's stock is kept in the store, new product introduced is a categorical variable that takes on the value 1 if the firm introduced a new product in the last fiscal year.

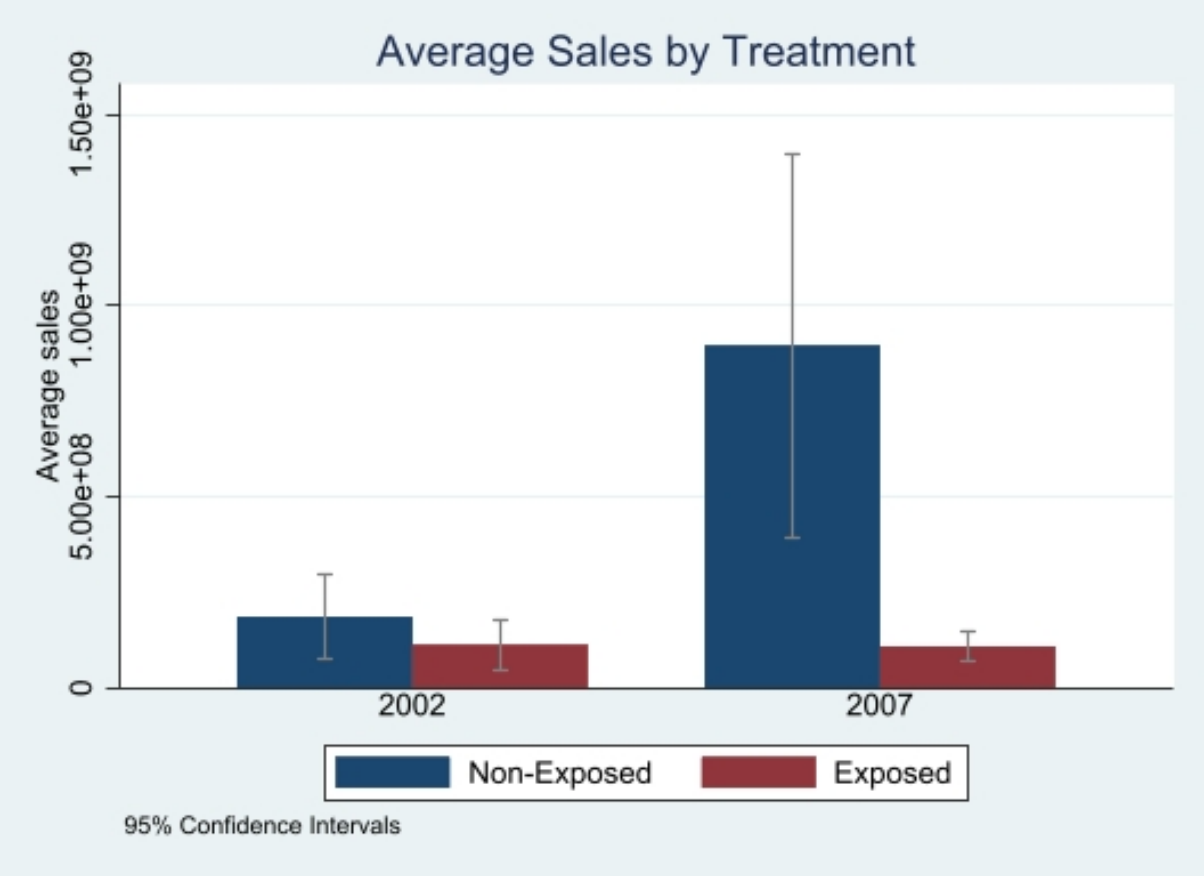


Figure 4: Sales by Exposure



Figure 5: Average Sales by Firm Size

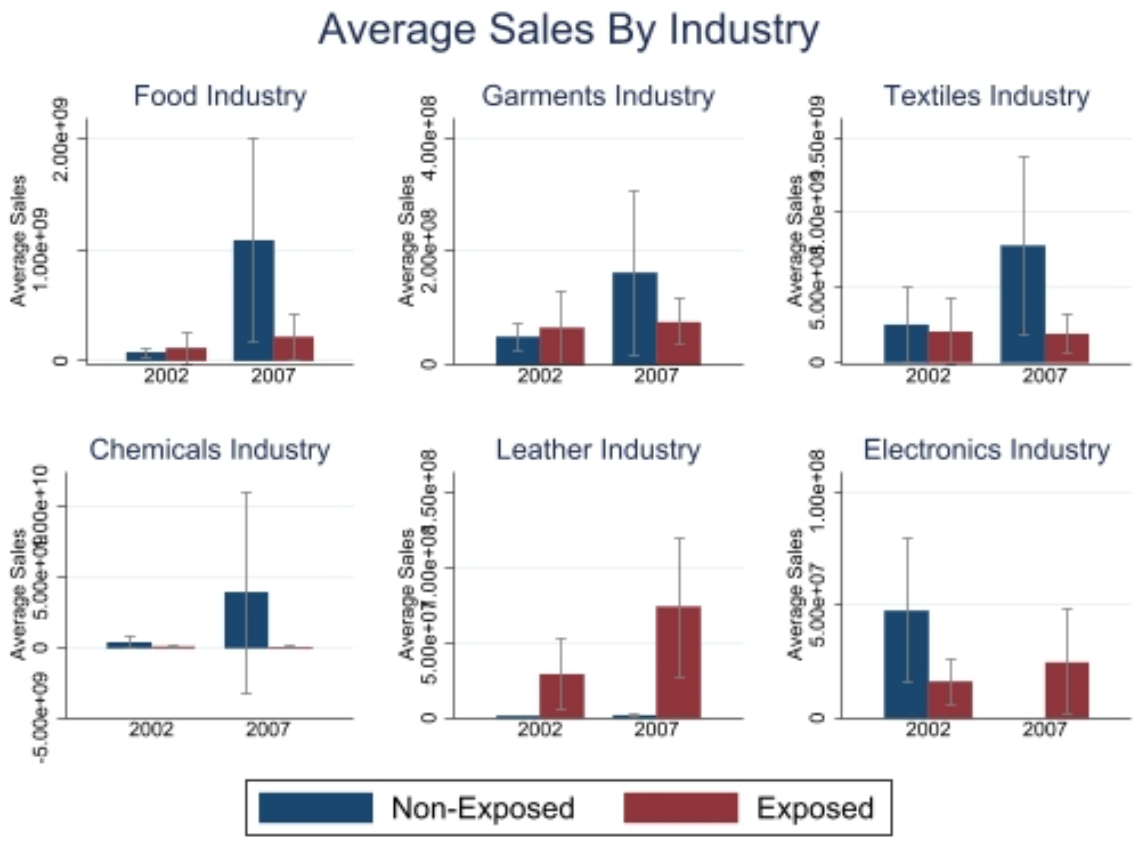


Figure 6: Average Sales by Industry

Table 5: Impact on Sales and Capital Stock

	(1)	(2)
	Log Sales	Log Stock
Treatment=1 × Post=1	-.769***	-.374*
	(.202)	(.227)
Exporter	1.233***	.921***
	(.139)	(.158)
Observations	780	780
Firm Level Controls	Yes	Yes
Industry FE	Yes	Yes

Note: This table reports the impact of the earthquake on Log Sales and Log Capital Stock. The treatment dummy is interacted with the post dummy. Firms within 400 km of the epicenter are exposed and ones outside are not. The regression is controlling for firm level variables and industry fixed effects. Standard errors in parentheses:*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. The dataset used is the World Bank Enterprise Survey.

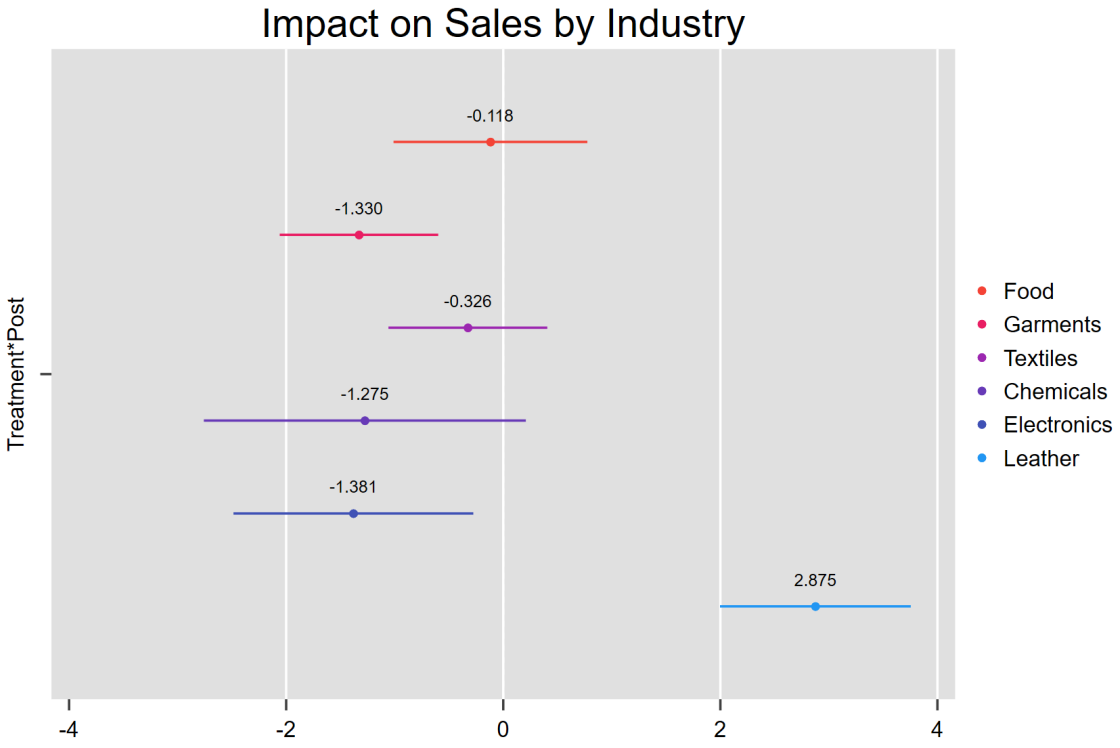


Figure 7: Heterogeneous Impact on Sales by Industry

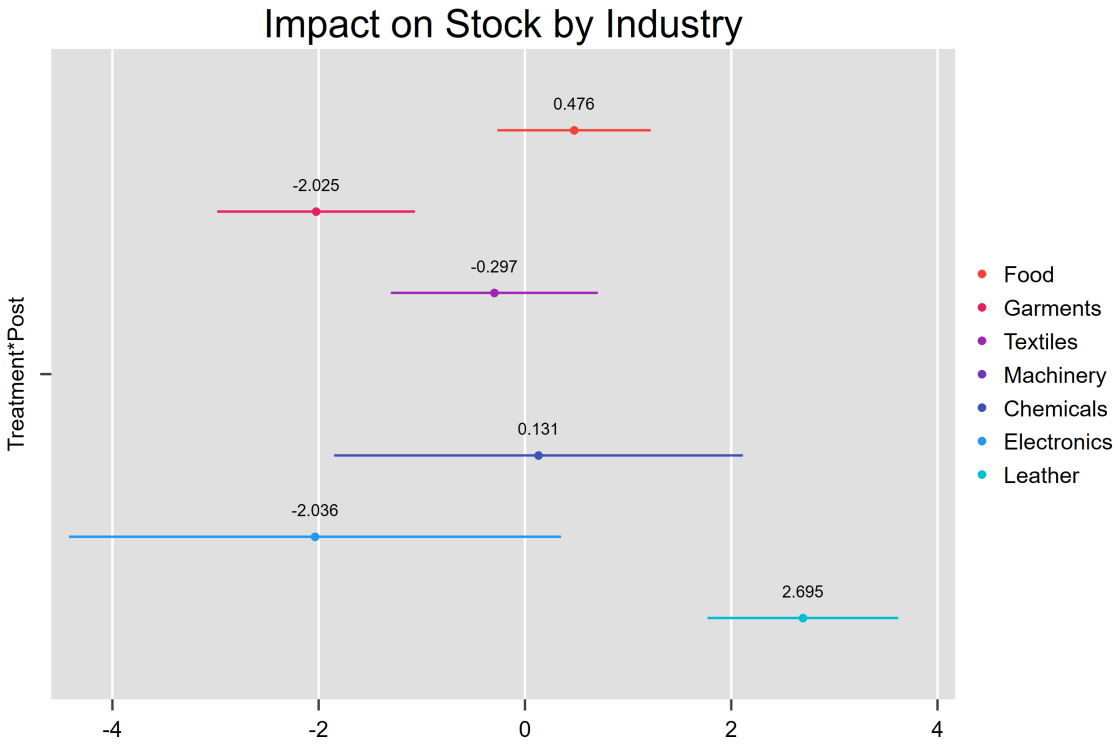


Figure 8: Heterogeneous Impact on Capital Stock by Industry

Table 6: Impact on Labour Employed

	(1) Production	(2) Non-production	(3) Skilled	(4) Unskilled
Treatment×Post	8.58	-27.99**	13.48	-4.60
	(28.39)	(11.83)	(23.31)	(9.42)
Exporter	84.28***	25.98***	54.40***	30.47***
	(18.98)	(7.93)	(15.58)	(6.34)
Observations	780	780	780	780
Firm Level Controls	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes

Note: This table reports the impact of the earthquake on Labour Employed. The Treatment dummy is interacted with the Post dummy. Firms within 400 km of the epicenter are exposed and ones outside are not. The regression is controlling for firm level variables and industry fixed effects. Standard errors in parentheses:*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. The dataset used is the World Bank Enterprise Survey.

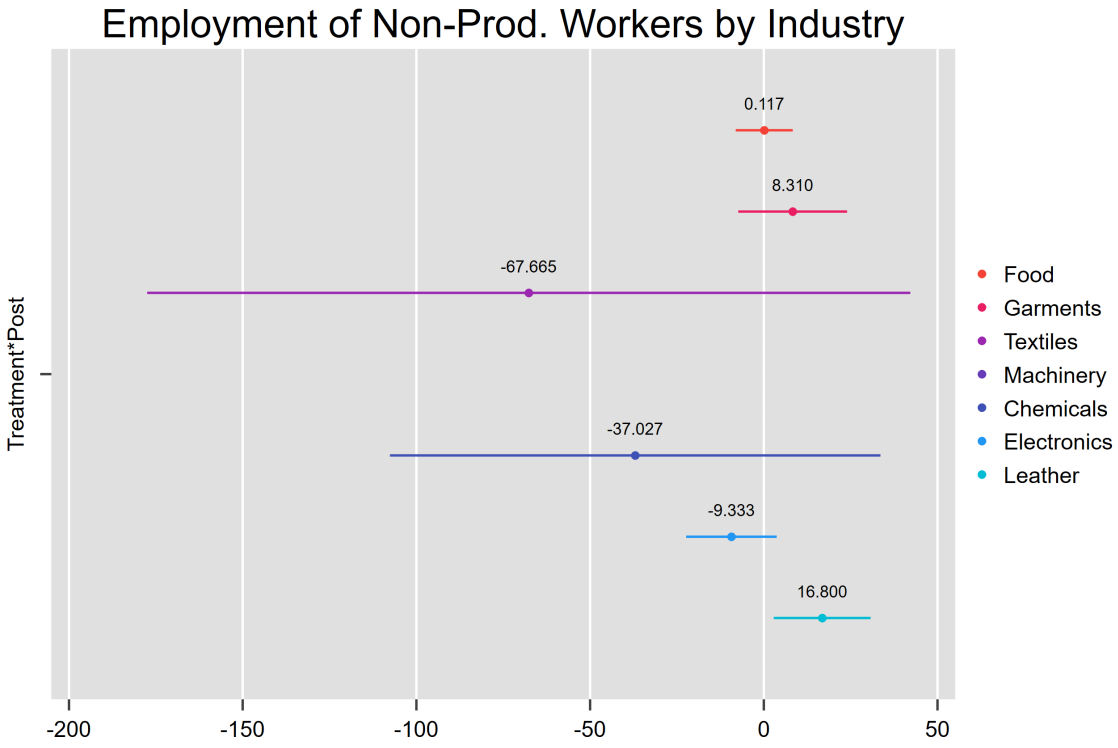


Figure 9: Impact on Employment of Non-Production Workers by Industry

Table 7: Firm Level Adaptation

	(1) Hrs of Ops	(2) Facilities Utilisation	(3) Borrowed:Pvt banks
Treatment×Post	62.793***	61.668***	1304.787***
	(3.051)	(2.660)	(152.472)
Exporter	3.383*	-1.593	
	(2.013)	(1.755)	
Observations	780	780	780
Firm Controls	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes

Note: This table reports the impact of the earthquake on Firm Level Adaptation. The Treatment dummy is interacted with the Post dummy. Firms within 400 km of the epicenter are exposed and ones outside are not. The regression is controlling for firm level variables and industry fixed effects. Standard errors in parentheses:*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. The data used is from the World Bank Enterprise Survey.

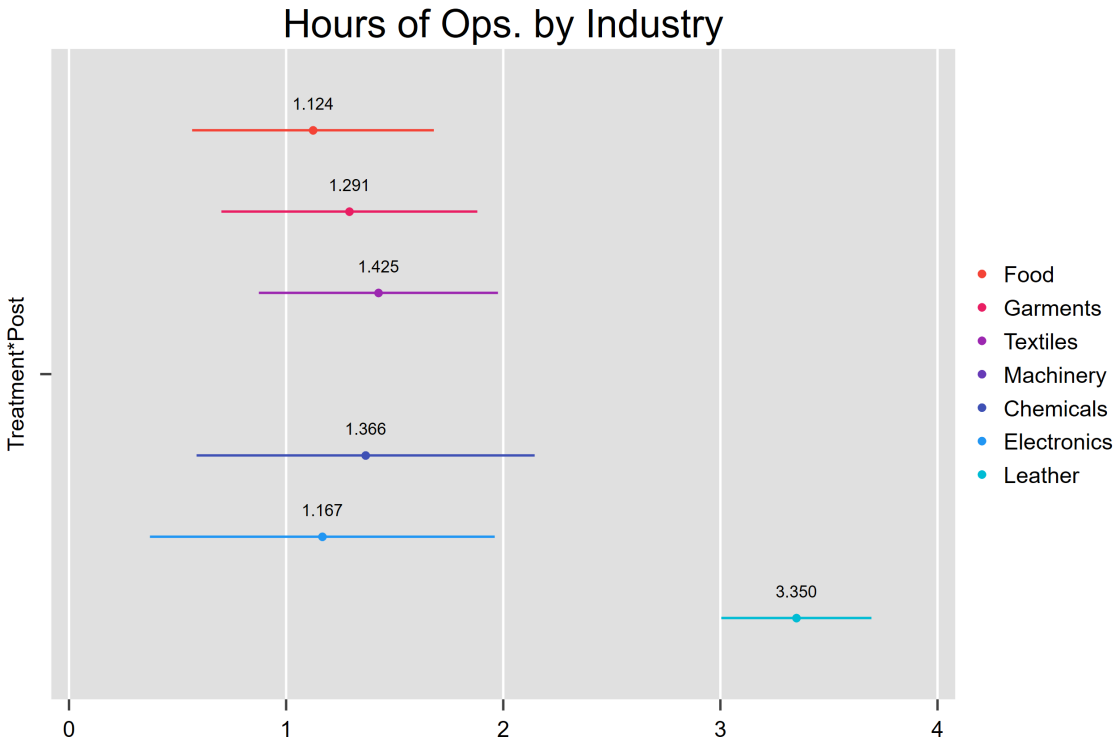


Figure 10: Impact on Hours Of Operations by Industry

Table 8: Infrastructure Impact and Adaptation

	(1) Electricity Obs.	(2) Generator Use
Treatment=1 × Post=1	1.488***	14.064***
	(.155)	(3.839)
Observations	780	780
Industry FE	Yes	Yes

Note: This table reports the impact of the earthquake on Infrastructure Adaptation. The Treatment dummy is interacted with the Post dummy. Firms within 400 km of the epicenter are exposed and ones outside are not. The regression is controlling for firm level variables and industry fixed effects. Standard errors in parentheses:*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. The data used has been sourced from World Bank Enterprise Surveys.

Table 9: Do Firms Diversify Markets?

	Diversify Markets?
Treatment=1 × Post=1	.106*
	(.061)
Observations	780
Industry FE	Yes

Note: This table reports the impact of the earthquake on Firm's Market Diversification. The treatment dummy is interacted with the post dummy. Firms within 400 km of the epicenter are exposed and ones outside are not. The regression is controlling for firm level variables and industry fixed effects. Standard errors in parentheses:*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. The dataset used is the World Bank Enterprise Survey.

Table 10: Do Firms Innovate?

	Innovate
Treatment=1	.209***
	(.060)
Observations	390
Firm Level Controls	Yes
Industry FE	Yes

Note: This table reports the impact of the earthquake on Firm's Innovation. The treatment dummy is interacted with the post dummy. Firms within 400 km of the epicenter are exposed and ones outside are not. The regression is controlling for firm level variables and industry fixed effects. Standard errors in parentheses:*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. The dataset used is the World Bank Enterprise Survey.

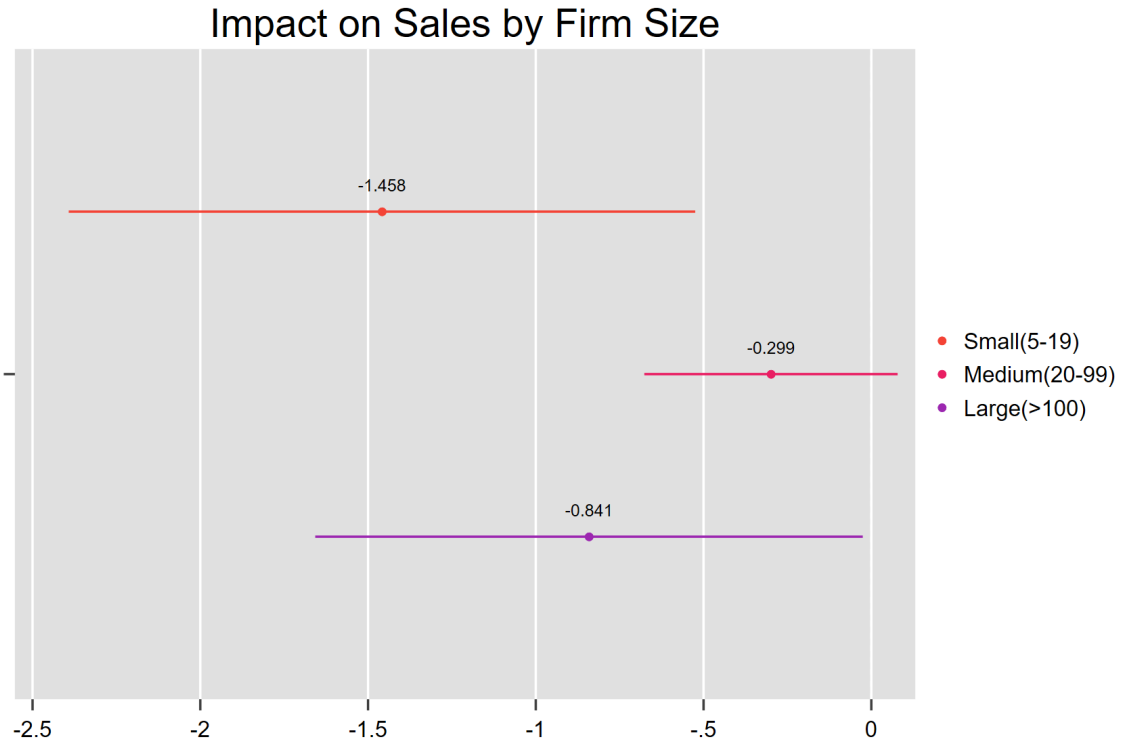


Figure 11: Impact on Sales by Firm Size

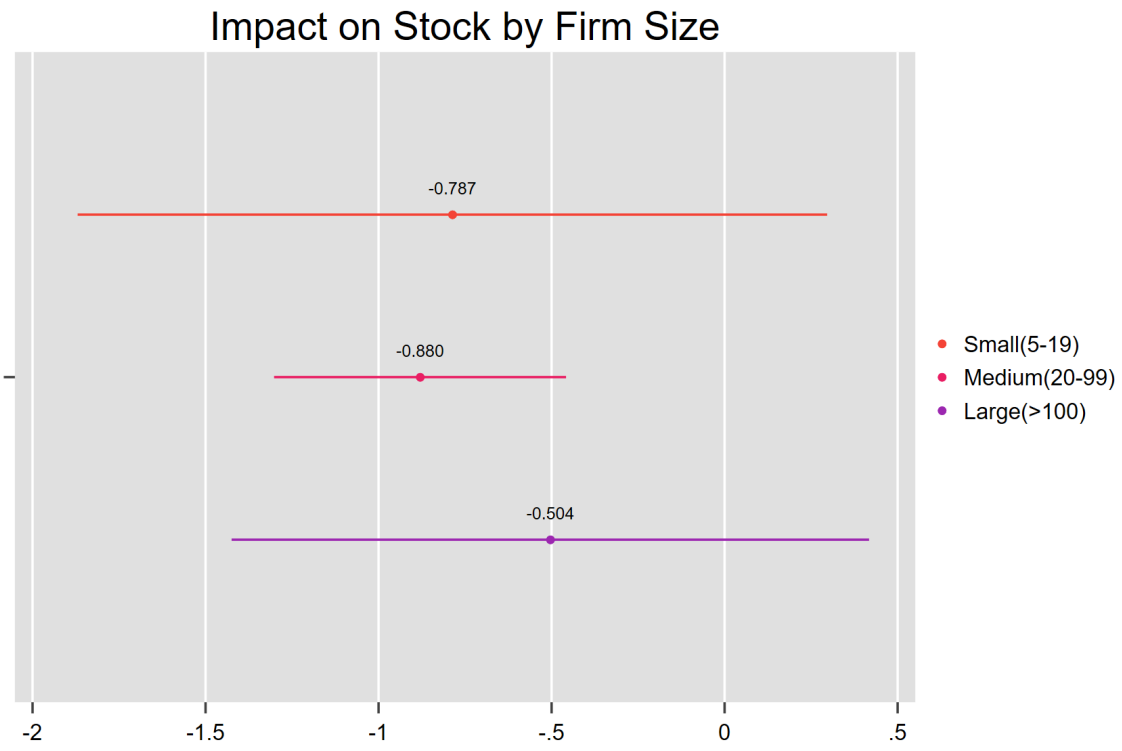


Figure 12: Impact on Stock by Firm Size

Table 11: Grants

	(1) SMEDA	(2) EPB	(3) BOI	(4) Others
Treatment=1	.075	.288***	.164**	-.140***
	(.074)	(.078)	(.066)	(.049)
Observations	390	390	390	390
Industry FE	Yes	Yes	Yes	Yes

Note: This table reports the impact of the earthquake on grants utilised. The treatment dummy is interacted with the post dummy. Firms within 400 km of the epicenter are exposed and ones outside are not. The regression is controlling for firm level variables and industry fixed effects. Standard errors in parentheses:*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. The dataset used is the World Bank Enterprise Survey.

Table 12: Robustness Check: Impact on Sales and Capital Stock

	(1) Log Sales	(2) Log Stock
Post=1 × distance	.001***	.001**
Observations	780	780
Firm Level Controls	Yes	Yes
Industry FE	Yes	Yes

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: This table reports the impact of the earthquake on sales and capital stock using continuous treatment measure. The treatment dummy is interacted with the post dummy. The regression is controlling for firm level variables and industry fixed effects. Standard errors in parentheses:*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. The dataset used is the World Bank Enterprise Survey.

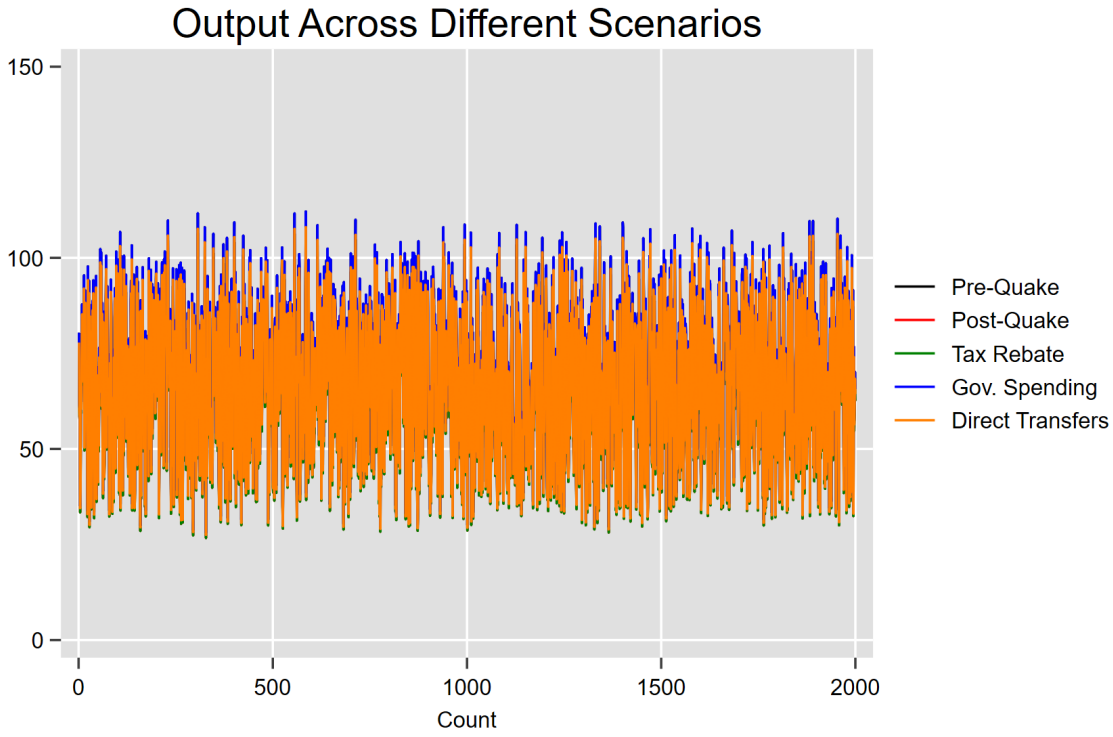


Figure 13: Simulated Output

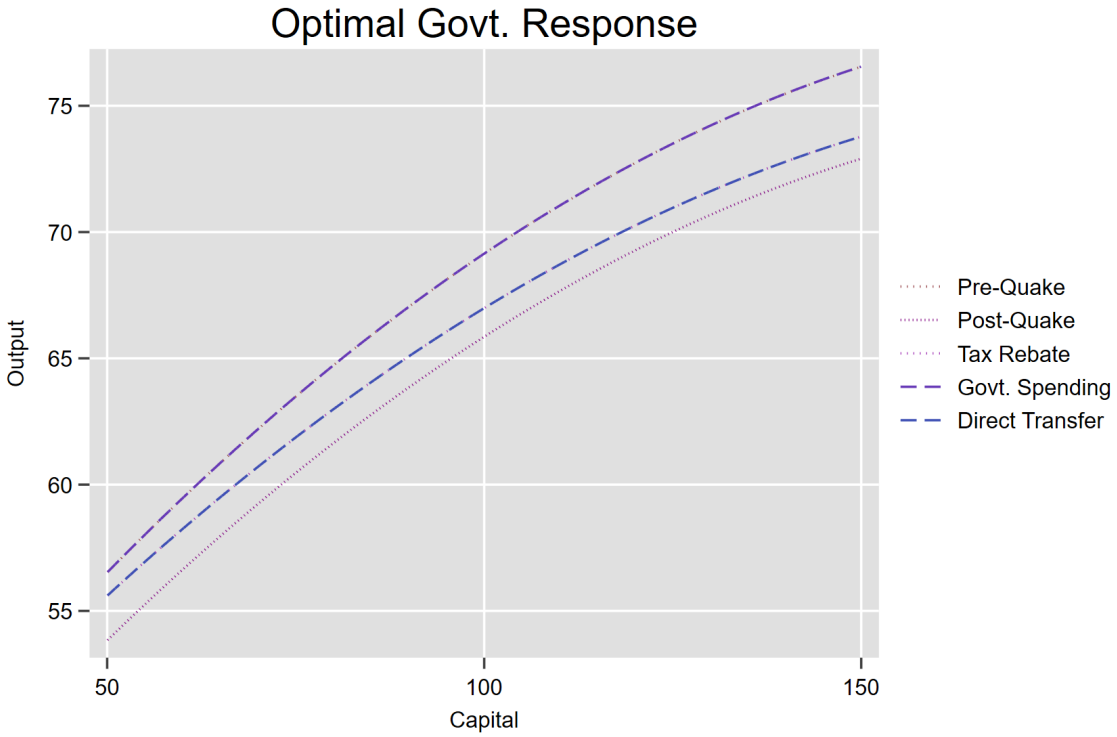


Figure 14: Simulated Output when the Government Intervenes

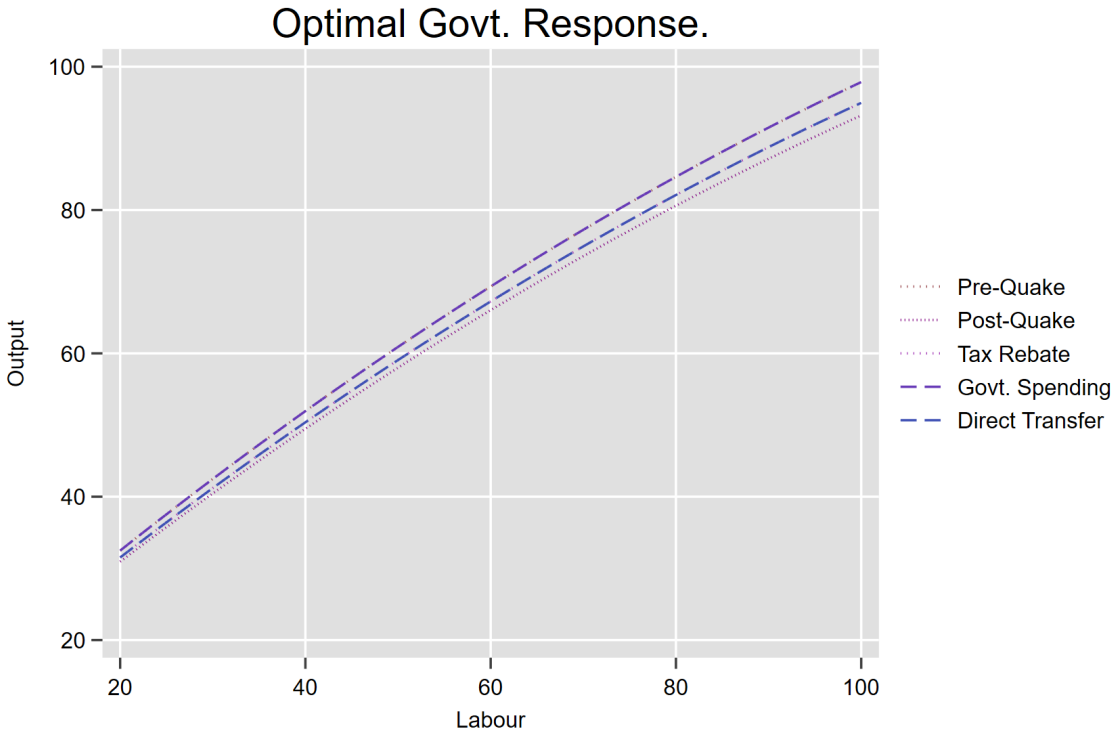


Figure 15: Simulated Output when the Government Intervenes

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