From Disruption to Resilience: How Firms in Pakistan Weather Natural Disasters.

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Abstract

How do firms react, respond, and adapt in the aftermath of a natural disaster? This paper provides evidence of the impact of the 2005 Pakistan earthquake on firm-level outcomes along three dimensions: the immediate response of firms to disasters, short-term adaptation strategies, and forward-looking actions that firms undertake to enhance resilience. Using a difference-in-differences methodology with a panel dataset of 390 firms, the paper evaluates the impact of an earthquake which saw capital stock destroyed, supply chains disrupted, and national supporting infrastructure devastated. This destruction led to a notable decline in sales among affected firms, which, in turn, prompted strategic adaptations to facilitate recovery and build resilience. These adaptations included extended production cycles, diversified utilisation of facilities, and increased reliance on private credit markets. Firms also sought to build forward-looking resilience by diversifying across markets. However, there was no evidence of innovation to build adaptability and little to no government support. Consequently, we conducted a policy simulation exercise to determine the optimal policy response, concluding that increased direct government spending would be the most effective approach to achieving a return to pre-disaster outcomes.

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

Using the Neo-Classical Growth Theory, it is clear that in the aftermath of a natural disaster that decreases the functionality of capital, production is disrupted. On the other hand, Schumpeter 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.

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 simulates optimal government response while Section 10 concludes.

2 Related Literature

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

3 Conceptual Framework

The theoretical framework of this research borrows from Neo-Classical Growth Theory and Joseph Schumpeter's 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 also yields the following 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.

We will use the panel data to determine whether this holds true in its entirety. The logical question this hypothesis generates is whether the earthquake is predominantly a

demand shock or a supply shock.

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.

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.

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.

Hypothesis 5:

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

Hypothesis 6:

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

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

[1]ReliefWeb (2005)

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 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

[2]ReliefWeb (2005)

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 shifts in employment. There is a reduction in non-production labor employed as the firms cut corners in face of declining sales and reduced productive capacity. There is a strategic shift towards making employment of skilled workforce a priority in the face of new operational challenges.

This decline driven by Textiles Industry followed by Machinery and Chemicals which in turn is likely a result of these industries being more labour intensive relative to others.

There is no differential impact by gender on labour outcomes.

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.

Strategic Adaptation

Strategic adaptation strategy is evident as firms adapt to infrastructure damage by building infrastructure resilience. There is significant uptick in the use of generators, ensuring operational continuity despite frequent power outages and infrastructure loss. This is both a strategic adaptation enhances overall productivity in face of the exogenous shock.

Building Resilience

Market diversification efforts were also evident, with a positive coefficient indicating that affected firms sought to expand their market presence from 1 to 5 or from 5 to 20 to mitigate risks associated with limited local market presence. However, innovative activities saw no notable increase post-disaster, suggesting that firms were not innovating to adapt their business models in response to the changed economic environment. This reveals a potential area for government intervention if it is to build greater resilience 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 suggests that an exogenous shock, such as the 2005 earthquake, drives out the firms that have low productivity, however, in this panel dataset, we do not see any evidence of exit either directly recorded or through sales that were driven down to a null value. So therefore the market concentration does not change.

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 Simulating Optimal Government Response

This section of the paper discusses how various policy interventions can aid in recovery.

We consider a firm that operates using a Cobb-Douglas production function defined as:

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

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:

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

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:

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	$\frac{\partial Y'}{\partial D} = \alpha A'(K')^{\alpha-1} L^{\beta}$	$\frac{\partial \pi'}{\partial D} = \alpha(1-\tau)A'(K')^{\alpha-1} L^{\beta} - r$

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 economic 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	Based on economic literature
β (Labor's output elasticity)	0.70	Based on economic literature
δ (Fraction of capital destroyed)	0.15	Assumed for simulation purposes
γ (Reduction in TFP)	0.10	Assumed for simulation purposes
τ (Initial tax rate)	0.25	Assumed for simulation purposes
τ' (Reduced tax rate)	0.18	Assumed for simulation purposes
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 for simulation purposes
r (Rental rate of capital)	0.05	Assumed for simulation purposes
w (Wage rate)	50	Assumed for simulation purposes

The results from this simulation exercise indicate that while all fiscal interventions are beneficial, increase in the direct government spending increases the recovery in output and profit by the largest absolute amount. The increase from the other two fiscal interventions is lower but equal to each other making a case for direct government spending in wake of a natural disaster. These simulations underscore the importance of well planned and well targeted government interventions in wake of a natural disaster, such an earthquake, required to initiate and accelerate firm recovery.

10 Conclusion

The findings underscore a critical narrative: while natural disasters pose severe threats to firm stability and economic performance, they also serve as catalysts for entrepreneurial innovation and strategic reorientation. In the immediate aftermath, disasters evidently disrupt firm operations—impacting sales, capital stock, and workforce stability. However, the adaptability and resilience demonstrated by firms in response to these challenges are noteworthy. Firms that had implemented disaster preparedness measures prior to such events not only mitigated the adverse impacts more effectively but also capitalized on new opportunities that arose during the recovery phase. This aligns with Schumpeter's theory of creative destruction, where disruption fosters an environment ripe for innovation and

economic dynamism.

From an operational perspective, firms exhibited significant resilience through diversification of supply chains and adaptation of production processes. Financial resilience was also evident as firms navigated through liquidity challenges by accessing emergency funding, loans, and grants. Strategic resilience emerged as firms reevaluated and adjusted their business models to align with the shifting market demands and the new economic realities post-disaster.

For policymakers, the paper highlights the importance of fostering an environment that supports firm-level disaster preparedness and resilience. This can be achieved through incentives for disaster risk reduction investments, enhanced access to emergency financial services, and robust infrastructure development that considers disaster risk. Furthermore, the role of public-private partnerships is crucial in bolstering economic resilience, suggesting that government collaboration with the private sector can lead to more robust disaster response frameworks.

In conclusion, while the adverse effects of natural disasters on firms are undeniable, the ability of businesses to adapt and innovate in the face of such challenges offers a silver lining. This paper not only contributes to the academic discourse on economic resilience but also provides practical insights that can help businesses and governments design better strategies for disaster management and recovery. Looking forward, continued research is essential to further understand the specific mechanisms and strategies that best contribute to building durable economic resilience in the face of increasing disaster risks. This will aid Pakistan's Industries Department and Small and Medium Enterprise Development Authority's (SMEDA) policy formulation for medium to long run and allow the state to determine the apt response in wake of natural shocks to the manufacturing sector.

11 Appendix

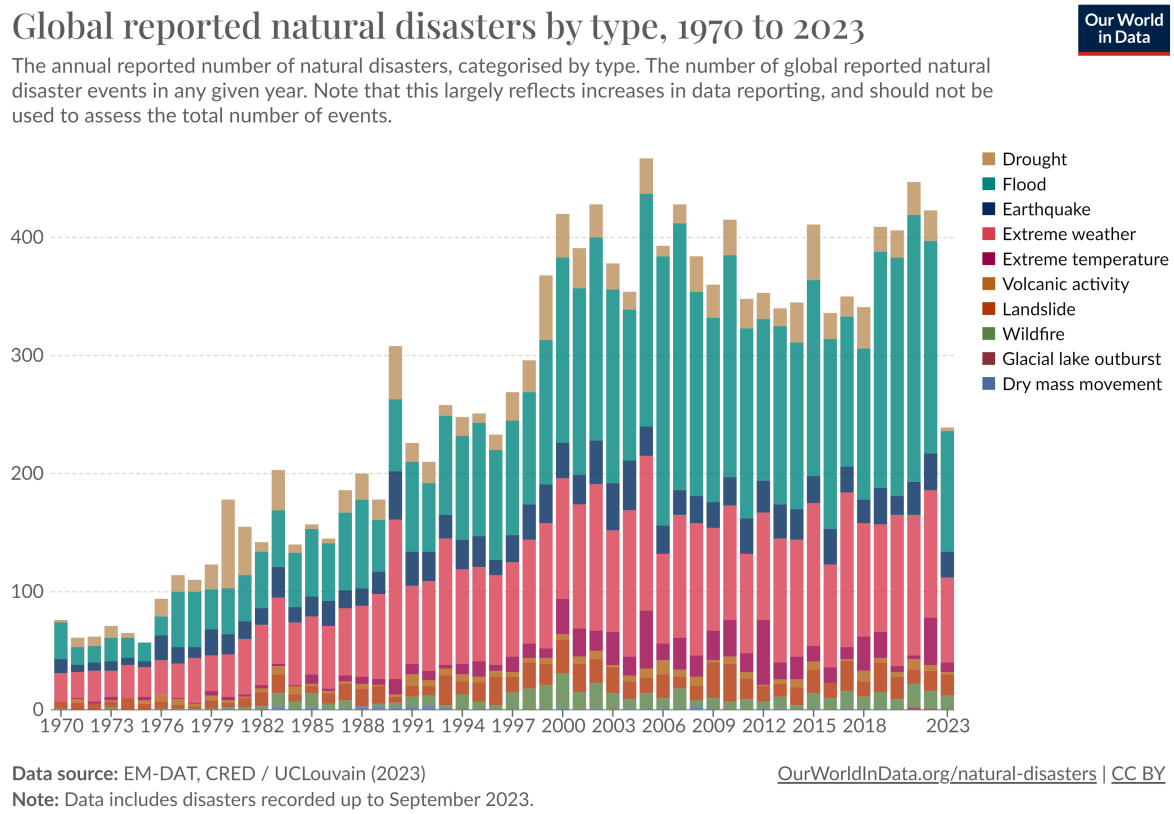


Figure 1: Increase in Frequency of Natural Disasters globally. Source: Our World in Data 2024

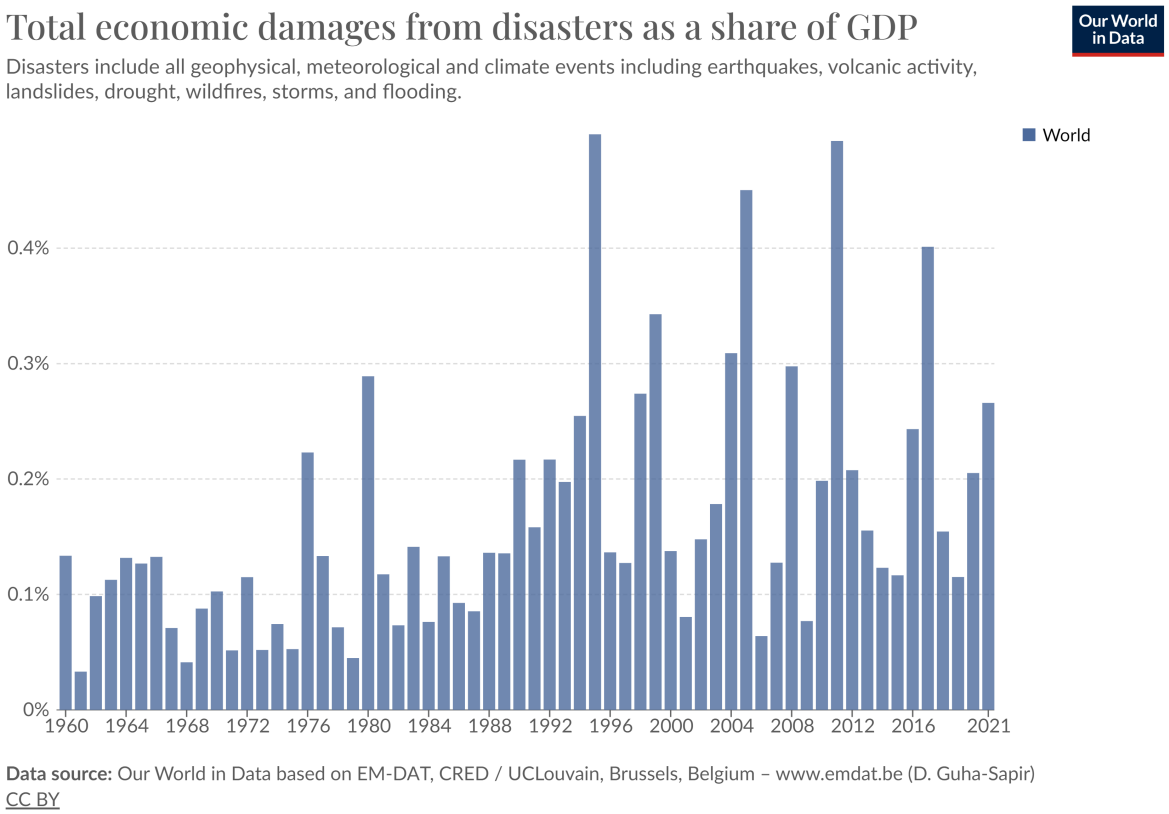


Figure 2: How the economic damages from natural disasters as a percentage of GDP are increasing globally. Source: Our World in Data 2024



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.

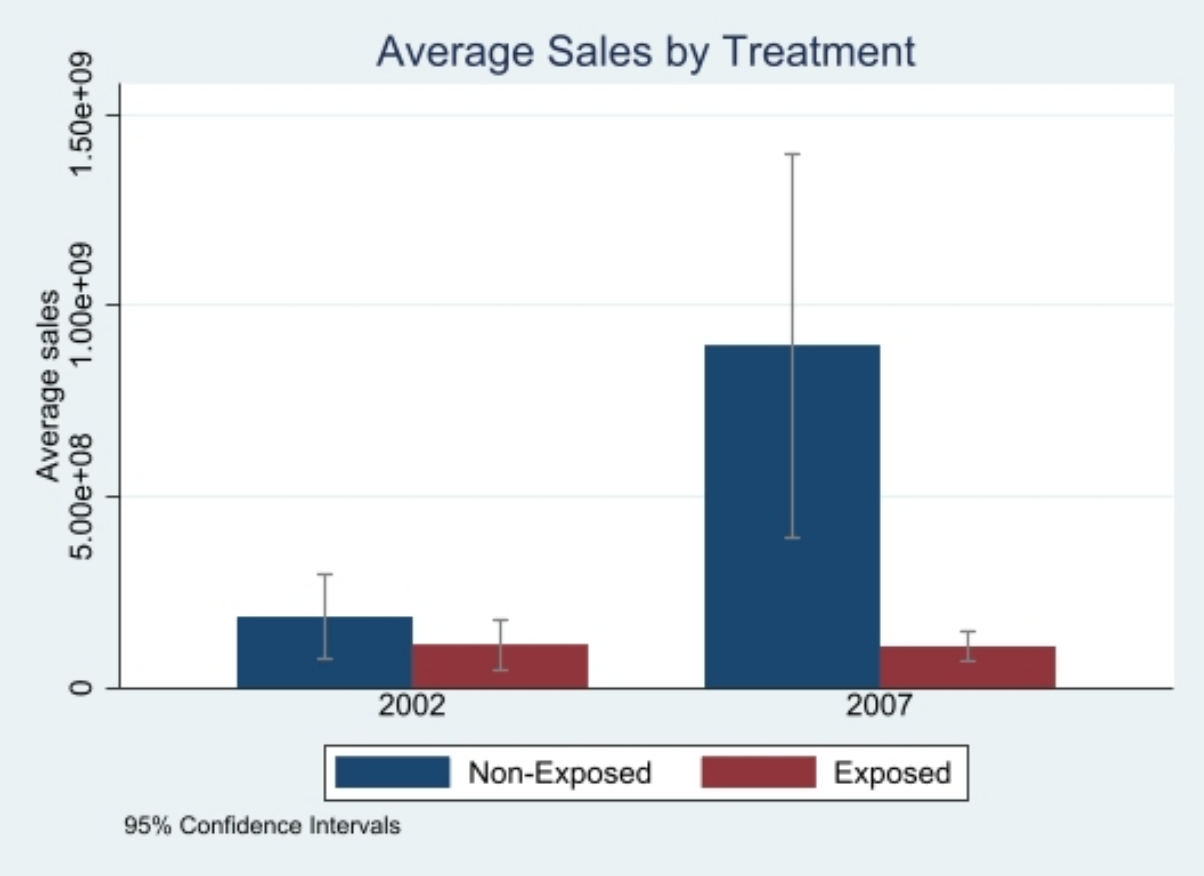


Figure 4: Sales by Exposure



Figure 5: Average Sales by Firm Size

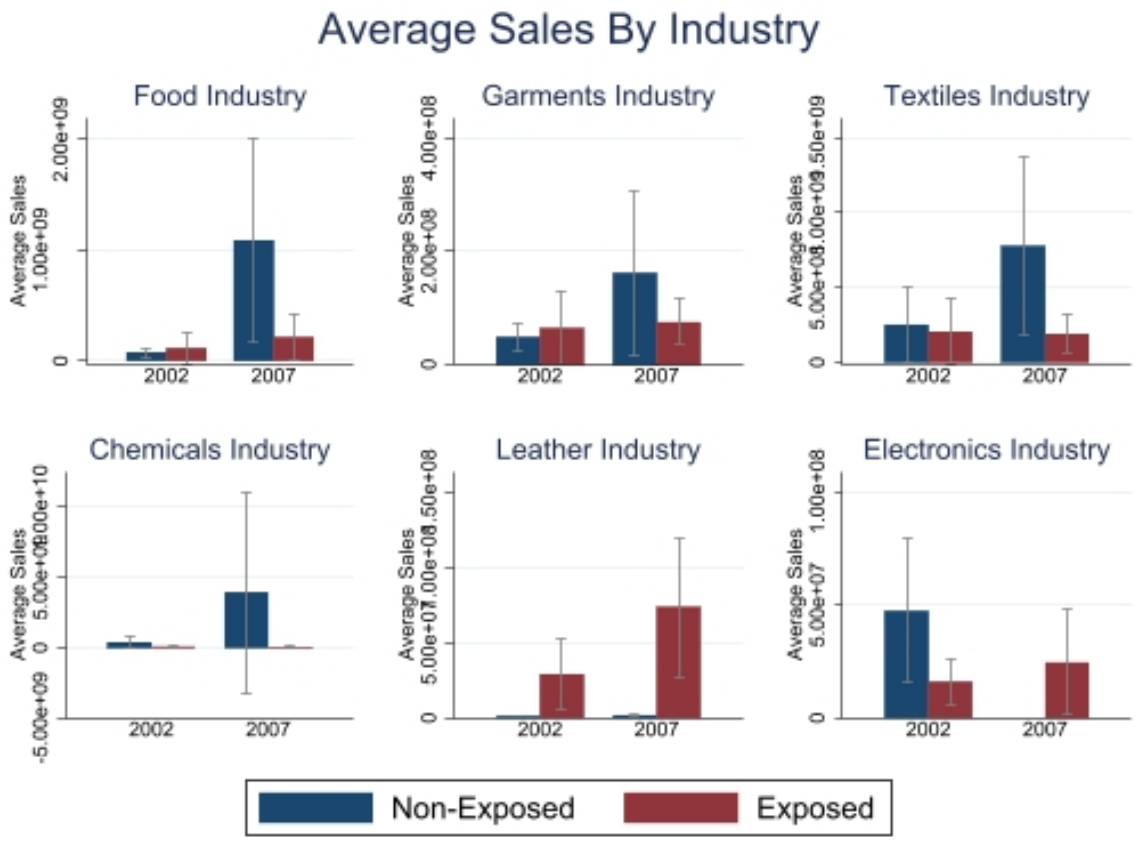


Figure 6: Average Sales by Industry

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.

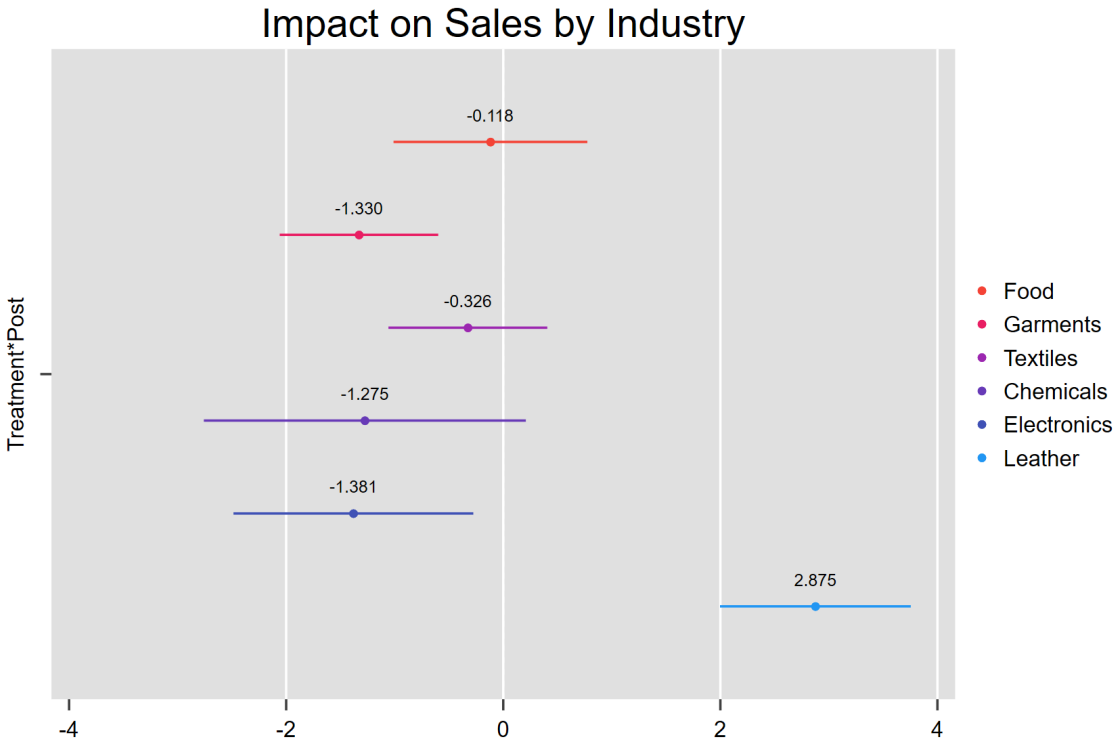


Figure 7: Heterogeneous Impact on Sales by Industry

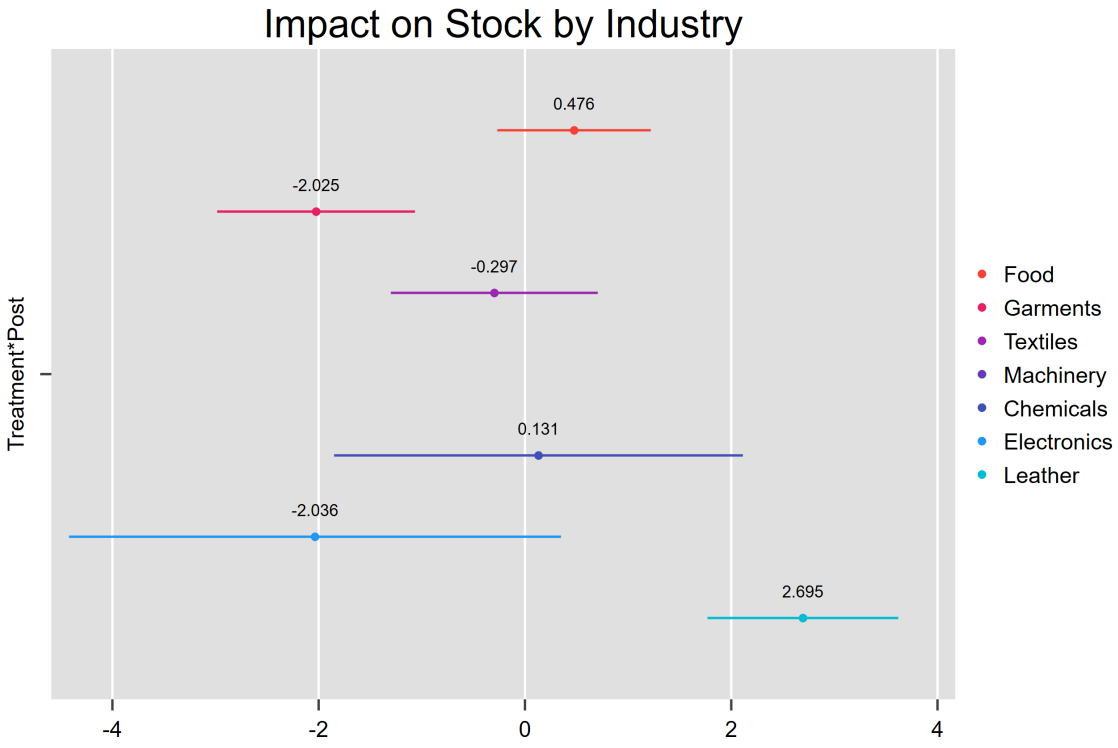


Figure 8: Heterogeneous Impact on Capital Stock by Industry

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.

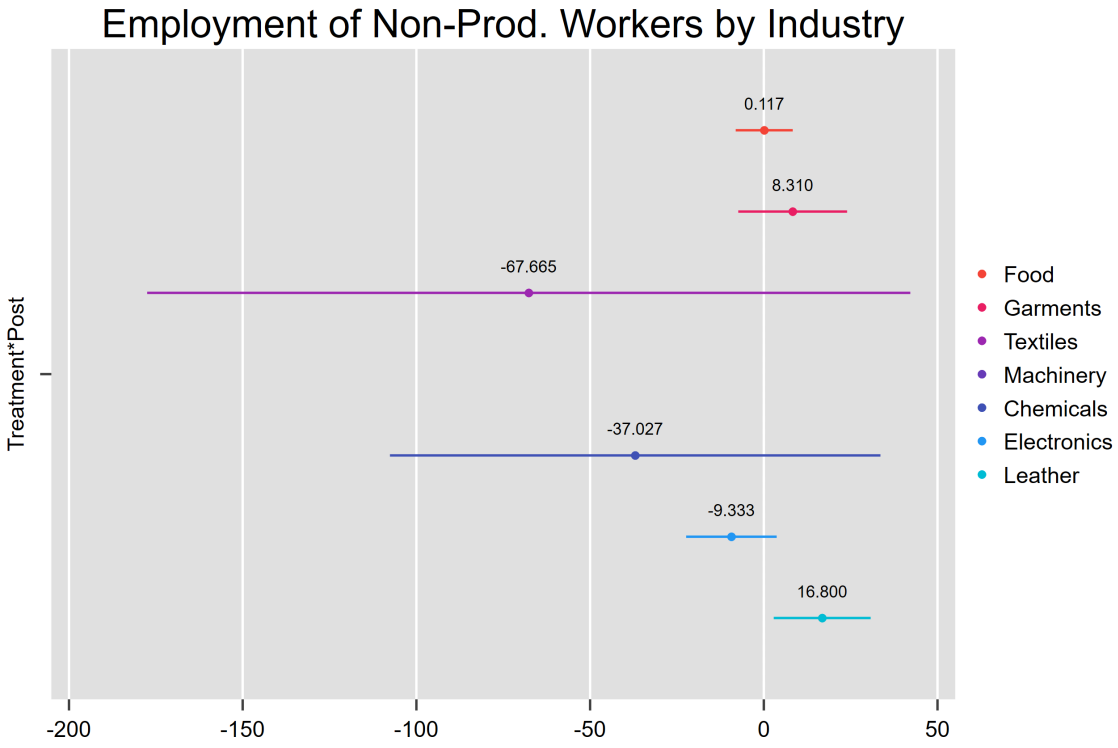


Figure 9: Impact on Employment of Non-Production Workers by Industry

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.

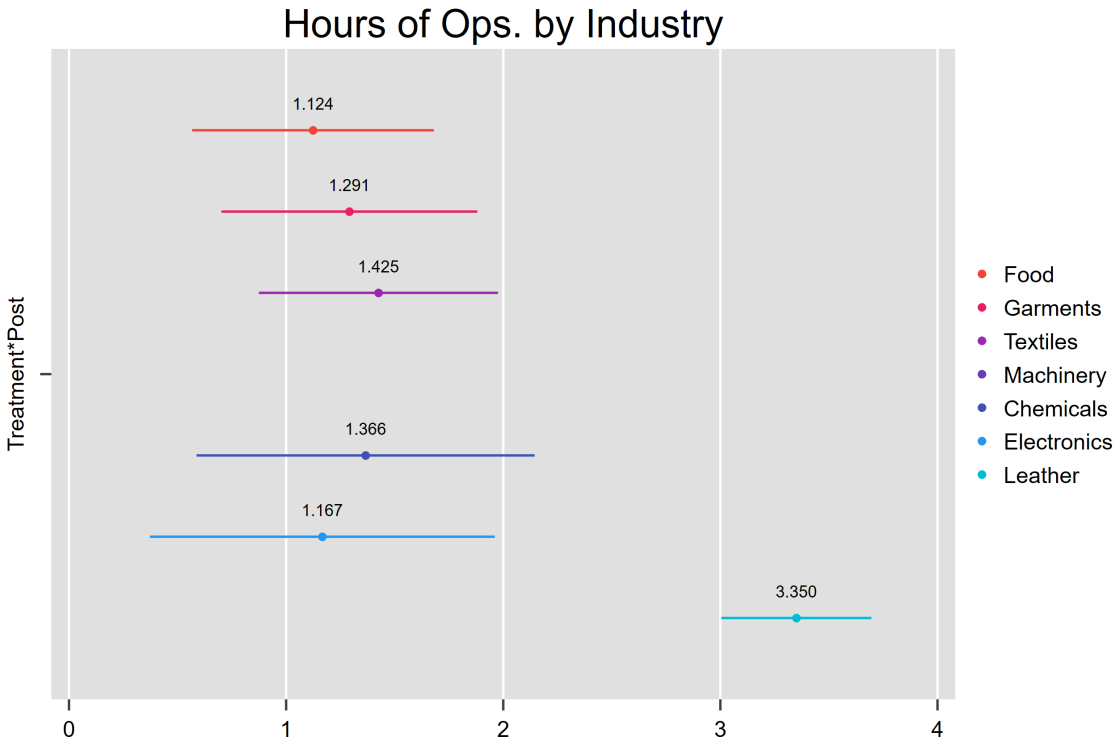


Figure 10: Impact on Hours Of Operations by Industry

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.

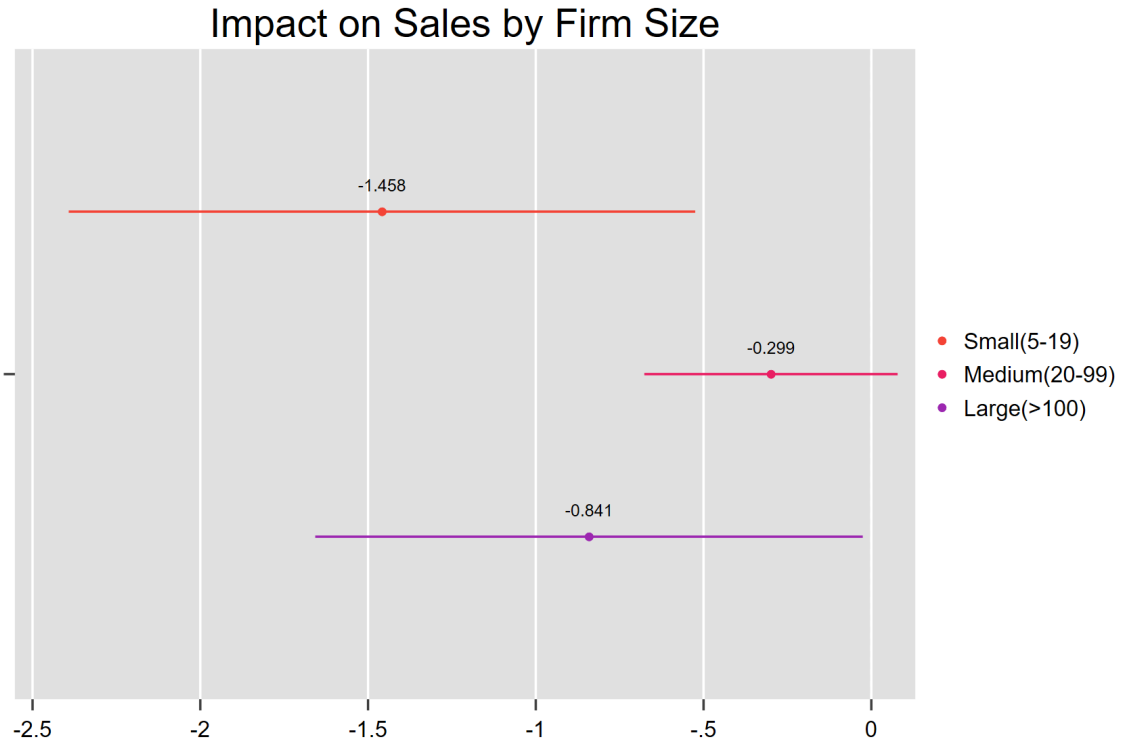


Figure 11: Impact on Sales by Firm Size

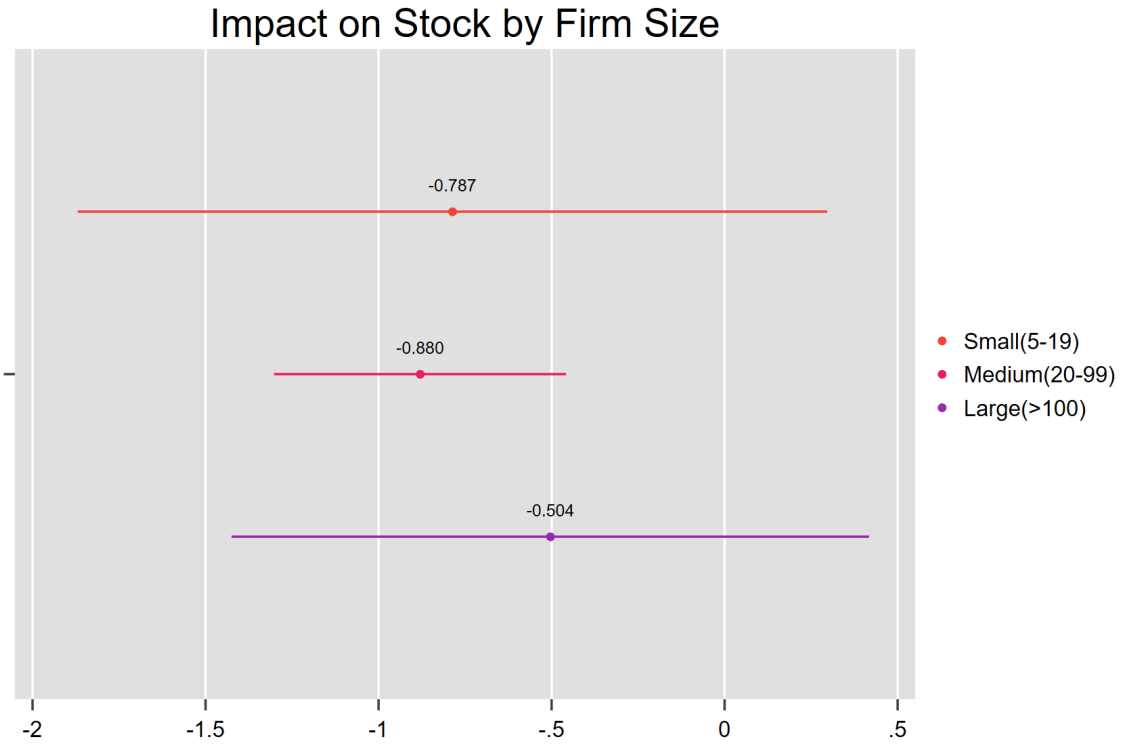


Figure 12: Impact on Stock by Firm Size

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.

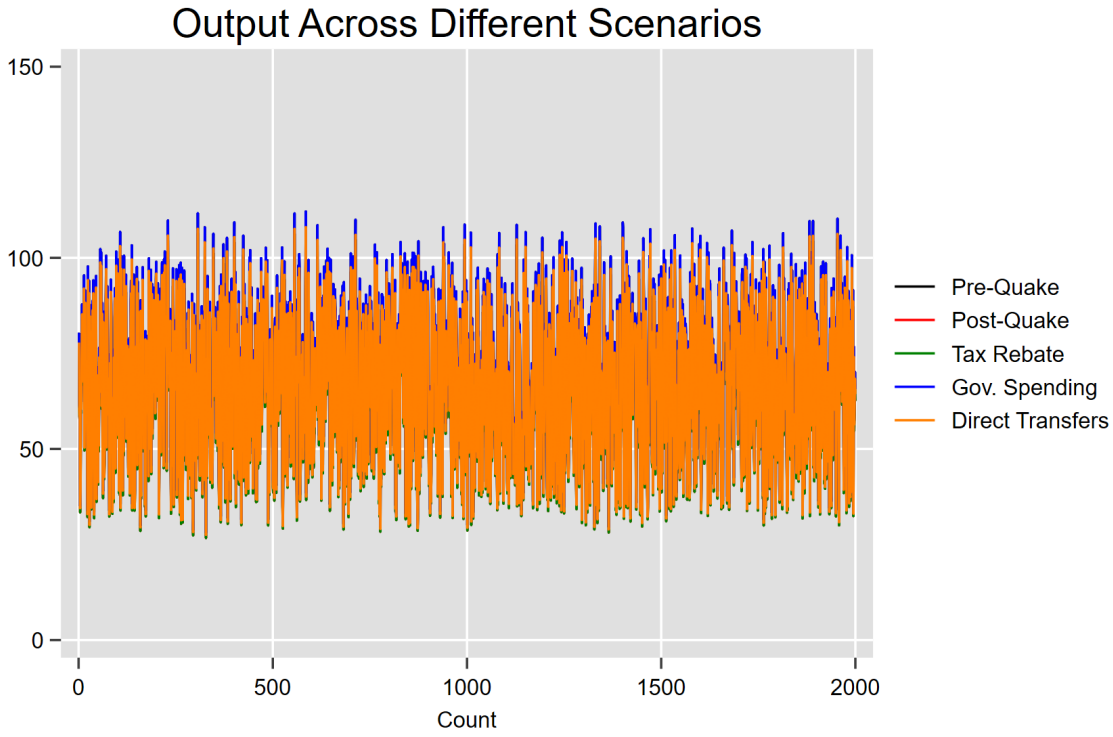


Figure 13: Simulated Output

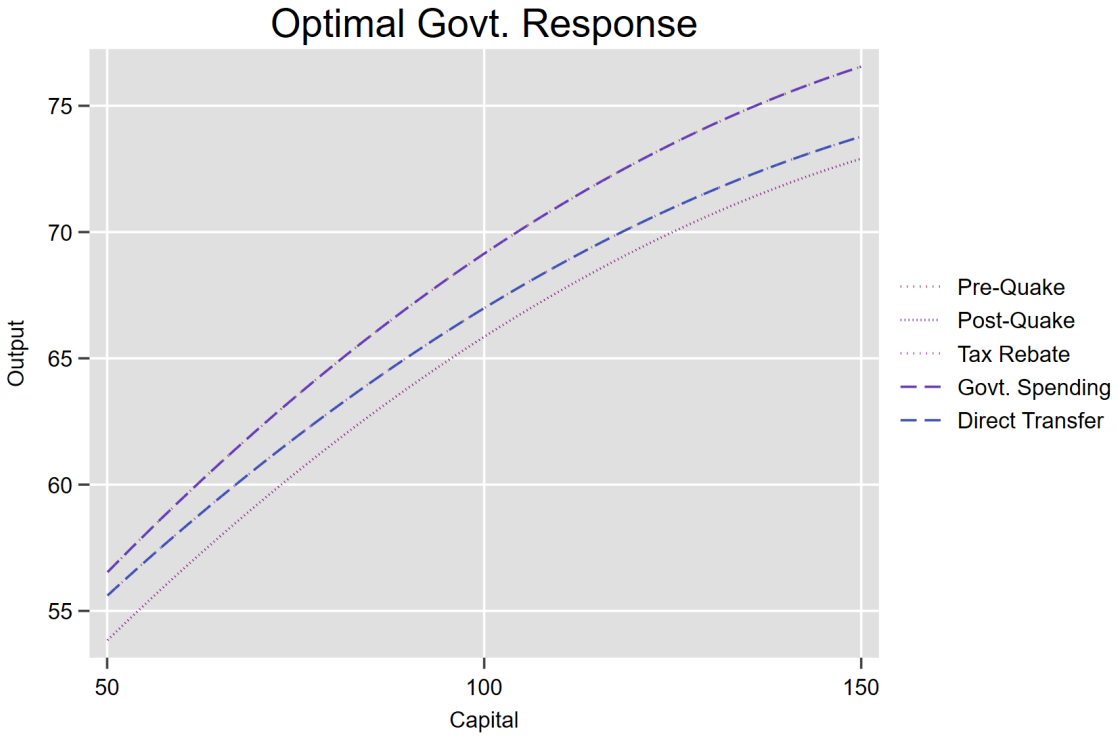


Figure 14: Simulated Output when the Government Intervenes

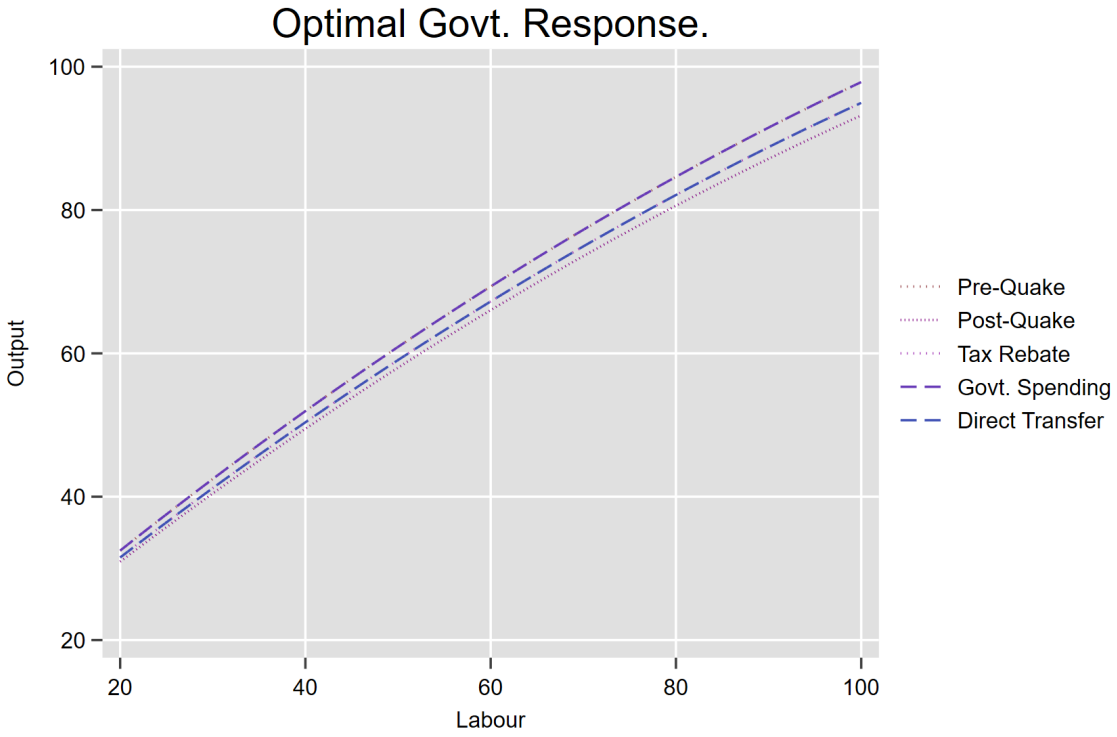


Figure 15: Simulated Output when the Government Intervenes

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