



Powering Micro-Businesses: A Theoretical Analysis of Electricity Reliability, Productivity and Capital Investment in Maharashtra

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ABSTRACT

This paper examines how electricity reliability may affect the operating hours and capital investment decisions of micro-businesses in Maharashtra, India. While access to electricity has expanded substantially, having a grid connection does not necessarily guarantee a reliable or predictable supply. For micro-businesses operating with limited financial resources, frequent power interruptions and poor power quality can reduce productive operating time, leave electricity-dependent equipment underutilised, increase operating costs and create uncertainty around future investment. Maharashtra is the setting motivating the research question; the broader Indian and international literature provides the evidence from which the theoretical mechanisms are developed.

The study adopts a theoretical secondary research approach, drawing on existing literature on electricity reliability, firm productivity, capacity utilisation, infrastructure and investment under uncertainty. Rather than estimating a direct causal relationship using original business-level data, the paper synthesises these strands of literature to develop a conceptual framework for understanding how electricity reliability can influence micro-business decisions. The analysis focuses on two main channels: the effect of electricity reliability on productive operating time and capacity utilisation, and its potential effect on the expected returns and risks associated with capital investment.

The paper argues that the economic value of electricity cannot be fully captured by measuring access alone. For micro-businesses, the reliability and predictability of supply may influence how effectively existing productive resources are used and the conditions under which further investment becomes worthwhile. The study concludes by considering the implications for electricity and MSME policy in Maharashtra and identifying areas for future empirical research.

Keywords: Electricity Development, Reliability Capital, Cost of Production, Opportunity Cost

1. INTRODUCTION

1.1 Background

A reliable electricity supply is critical to the everyday operation and expansion of micro-businesses in developing economies. Unlike larger corporations, which may have greater financial capacity to purchase backup generators or absorb periods of downtime, small enterprises often operate with limited capital and tight margins. Grocery shops, pharmacies, restaurants, repair businesses and other local enterprises can depend on electricity for refrigeration, lighting, digital payments, computers, machinery and other basic activities. When power is interrupted or voltage becomes unstable, businesses may lose productive time, experience equipment disruption, spoil perishable goods or be unable to serve customers. The effects of unreliable electricity can extend beyond the immediate period of an outage. A business owner considering the purchase of refrigeration, machinery or other electricity-dependent equipment must consider whether the equipment can be used sufficiently and consistently to generate an acceptable return. If electricity supply is unpredictable, the expected usefulness of such capital may become less certain. Electricity reliability can therefore affect both the utilisation of existing capital and incentives surrounding future investment.

India provides a useful setting in which to examine the distinction between electricity access and electricity reliability. The country has made substantial progress in expanding electricity connections, but access does not necessarily imply continuous or high-quality

supply. Existing research has examined electricity and development through economic growth, household welfare, rural development and manufacturing productivity. Less attention has been given to the mechanisms through which electricity reliability may influence the everyday decisions of micro-businesses. Maharashtra provides a relevant setting because the state contains major urban centres alongside smaller towns and rural areas with different economic and infrastructure conditions. Electricity reliability can also be considered using operational indicators rather than treating electricity as a simple connection-or-no-connection variable. MSEDCL reports measures relating to interruptions, supply hours and reliability, providing an institutional basis for considering reliability as a measurable characteristic of the business environment.

This paper therefore examines how electricity reliability may affect the operating hours and capital investment decisions of micro-businesses in Maharashtra. It uses a theoretical secondary research approach. Evidence from Maharashtra is considered where available, while India-wide and international literature is used to establish broader economic mechanisms. Maharashtra is consequently the geographical setting of the research question rather than a population for which this paper claims to estimate a causal effect.

1.2 Problem Statement

Electricity is a fundamental productive input for many modern businesses, but having a grid connection does not ensure a dependable supply. Small enterprises may continue to experience scheduled load shedding, unexpected interruptions and voltage fluctuations. These disruptions can be particularly difficult for micro-businesses because they often have fewer financial resources with which to purchase backup systems or absorb lost operating time. Across Maharashtra, differences in electricity reliability can create different operating environments for small firms. An inconsistent supply may cause a business to reduce productive operating time, leave machinery idle, turn away customers or incur additional costs. It may also affect investment decisions if business owners are uncertain about whether electricity-dependent equipment can be used consistently. Existing literature contains important evidence on electricity shortages and firm behaviour, but much of it concerns manufacturing, households or broader development outcomes. This creates an opportunity to examine how the mechanisms identified in the literature may apply to micro-businesses, particularly through the relationship between reliability, productive operating time and investment under uncertainty.

This research therefore addresses the following question: *How does reliable electricity affect the operating hours and capital investment of micro-businesses in Maharashtra?*

The study treats electricity reliability as the primary explanatory variable. The principal outcomes are productive operating time and capital investment. However, electricity is not assumed to determine either outcome on its own. Demand, labour availability, access to finance, technology, market conditions and business characteristics may all influence the strength of the relationship.

1.3 Research Objectives

The primary objective is to develop a theoretical explanation of how electricity reliability may influence the operating and investment decisions of micro-businesses in Maharashtra.

The secondary objectives are to:

- examine how electricity interruptions may affect productive operating time and capacity utilisation;
- investigate how unreliable electricity may influence the expected return to electricity-dependent capital;
- examine the role of adaptation and input substitution in reducing or changing the effects of electricity shortages;
- assess why the relationship may differ across types of micro-businesses and locations; and
- consider the implications for electricity and MSME policy in Maharashtra.

1.4 Scope of the Study

The study is geographically focused on Maharashtra. This focus provides a specific institutional and economic setting for the theoretical analysis rather than assuming that the state is homogeneous. Maharashtra contains major urban centres, smaller towns and rural areas, and businesses operating in different sectors. The study focuses on micro-businesses because larger businesses may have greater capacity to respond to unreliable electricity through generators, alternative technologies or organisational adjustments. Micro-businesses may face tighter financial constraints and therefore have fewer options for adaptation. The analysis considers businesses such as retail shops, restaurants and food outlets, pharmacies and service-oriented enterprises. These businesses differ in their electricity dependence, which is itself an important part of the theoretical framework. The study examines three broad outcomes: productive operating time, capital investment and potential business expansion. However, the main research question focuses specifically on operating hours and capital investment. Business expansion is considered as a possible longer-term consequence rather than as an independently estimated outcome.

1.5 Significance of the Study

The significance of this research lies in connecting electricity infrastructure with firm-level economic decision-making. Electricity is often discussed in terms of access, household welfare or broad economic development. This study instead focuses on the conditions under which small firms can use productive resources and evaluate investment. The paper also brings together several strands of economic literature. Research on electricity shortages demonstrates that firms can experience production losses while adapting through generators, inventories and changes in production. Research on capacity utilisation explains how unreliable electricity can reduce the effective use of existing capital. Investment-under-uncertainty theory provides a mechanism through which unpredictable electricity availability may influence the timing of capital expenditure. Because the research is theoretical and based on secondary literature, the paper does not claim to establish a causal Maharashtra-specific effect. Its purpose is to develop a framework that can guide future empirical research.

2. LITERATURE REVIEW

2.1 Electricity and Economic Growth

Electricity infrastructure has long been associated with economic development. Electricity allows firms to use machinery, refrigeration, lighting, computers and other technologies that can increase the productivity of labour and capital. In developing economies, electricity can therefore form part of the infrastructure required for structural transformation. The relationship between electricity consumption and economic growth is nevertheless more complex than electricity automatically producing growth. Its economic role depends on how it is used, the structure of the economy and the availability of complementary inputs. Research on infrastructure similarly shows that infrastructure can support productivity, employment and income while producing different effects across locations. This literature establishes the broad importance of electricity as an economic input. However, it does not by itself answer the more specific question examined here: what happens when electricity is available but unreliable?

2.2 Electricity and Firm-Level Economic Activity

Several studies examine how electricity constraints affect firms directly. Allcott, Collard-Wexler and O'Connell (2016), for example, examine electricity shortages among Indian manufacturing plants. They find that shortages reduced revenues and producer surplus, while measured productivity losses were smaller partly because firms adapted. This finding is important because it shows that firms are not passive when electricity supply is unreliable. They may use generators, inventories and other adjustments to reduce the immediate effect of shortages. However, adaptation itself uses resources and can therefore create additional costs. Abeberese (2017) similarly finds that electricity costs can influence production processes and machine intensity among Indian firms. Fisher-Vanden, Mansur and Wang (2015), studying firms in China, show that electricity constraints can lead firms to adjust production and sourcing decisions. These studies support the theoretical framework, although their populations differ from Maharashtra's micro-businesses. Evidence from manufacturing should therefore not be treated as a direct estimate of the effects on small retail or service businesses.

2.3 Electricity Access vs. Electricity Reliability

In the empirical study of energy economics, it is imperative to draw a strict analytical distinction between electricity access and electricity reliability. Historically, rural electrification metrics focused heavily on binary outcomes, measuring merely whether a household or business was physically connected to a regional power grid. However, a business may be technically "electrified" while still suffering from a deeply unreliable supply, thereby neutralizing the potential economic advantages of the connection.

2.3.1 The Shift from Binary Access to Reliability

Electricity access simply denotes grid connectivity, whereas electricity reliability refers to the continuity, quality, and stability of that supply. According to the World Bank's Energy Sector Management Assistance Program (ESMAP) in its seminal report *Beyond Connections: Energy Access Redefined*, evaluating energy access through binary metrics (connected versus not connected) is insufficient for understanding socio-economic development. Consequently, institutions have pivoted toward a Multi-Tier Framework (MTF) that measures access based on capacity, availability (duration), reliability (outage frequency), and voltage quality. Measuring only whether a micro-business has an electricity connection fails to capture the actual economic drag caused by structural grid problems. Fan Zhang's research for the World Bank (*Benefits of Electrification and the Role of Reliability: Evidence from India*) reinforces this, demonstrating that the full economic dividends of electrification such as increased non-farm business creation and higher operational productivity are only realized when power is supplied consistently without abrupt disruptions.

2.3.2 Core Metrics of Reliability

When defining the quality of supply, state utilities like the Maharashtra State Electricity Distribution Co. Ltd. (MSEDCL) continuously monitor and report specific grid performance metrics to evaluate reliability. These indices include:

- **System Average Interruption Frequency Index (SAIFI):** The average number of power outages (frequency) a consumer experiences over a specific period.
- **System Average Interruption Duration Index (SAIDI):** The total duration (in minutes or hours) of outages a consumer experiences.
- **Voltage Fluctuations and Unexpected Interruptions:** Unscheduled load shedding or severe voltage dips that can damage sensitive commercial equipment like refrigerators or computers.

2.3.3 Ground-Level Impact: The Gap Between Access and Reliability

The divergence between access and reliability leads to severe operational disparities on the ground. For example, evidence from Indian government primary health-care facilities which operate similarly to essential service-oriented micro-businesses like pharmacies reveals wide intra-state variations. While a state may boast high overall electrification rates, actual availability of regular, 24/7 power varies drastically. Facilities with highly reliable electricity are substantially more capable of optimizing their essential equipment (such as cold-storage chains or radiant warmers) and delivering round-the-clock services compared to those crippled by intermittent outages.

Table -1: Electricity Access versus Electricity Reliability

Aspect	Electricity Access	Electricity Reliability
Meaning	Availability of a physical electricity connection	Continuity, stability, and quality of electricity supply
Main question	Does the business have electricity?	How consistently is electricity available?
Measurement	Binary metric: Connection/No connection	Multi-Tier Framework: SAIFI, SAIDI, voltage quality
Business effect	Allows the installation of electricity-dependent equipment	Determines how smoothly and profitably activities can continue
Relevance to study	Basic condition	Main independent variable of the study

The distinction is central to this study. Electricity access may be necessary for productive activity, but reliability determines how consistently that access can be converted into productive use.

2.4 Rural Electrification

Rural electrification has historically been a major development objective in India and other developing economies. Electricity can enable rural businesses to operate machinery, refrigeration and lighting and create opportunities for non-agricultural activity. However, a physical connection does not necessarily guarantee reliable electricity. Rural areas may continue to experience interruptions, voltage fluctuations and limited supply quality. Consequently, the economic benefits of electrification may depend not only on whether electricity is available but also on whether it is sufficiently reliable for productive use. Chakravorty, Pelli and Ural Marchand examine electricity access and quality in rural India and find that electricity quality can have important economic effects beyond connection alone. Their findings support the idea that the productive value of electricity depends partly on quality. Burlig and Preonas (2024) provide another important qualification. Their analysis of rural electrification in India finds that electrification substantially expanded access but produced limited economic effects overall after several years, with stronger effects in larger villages. This suggests that electricity infrastructure can create opportunities without automatically producing economic transformation.

Table -2: Rural Electrification vs. Reliable Electricity

Rural Electrification	Reliable Electricity
Focuses on providing electricity access	Focuses on continuity and quality
Establishes basic electricity connection	Reduces disruptions and voltage drops
Enables businesses to install electrical equipment	Allows equipment to be used consistently
Can support economic activity	Can improve productivity and investment
Necessary first step	Important for achieving full economic benefits

Table -3: Maharashtra Context Table

Type of Area	Expected Electricity Situation	Expected Business Implication
Major urban centres	Generally more reliable	Longer and more predictable operating hours
Smaller towns	Moderate variation	Some disruption to business activity
Rural/remote areas	Potentially greater reliability challenges	Greater risk of interrupted operations and damaged equipment

These categories should not be interpreted as proof that every urban area is reliable or every rural area is unreliable. They provide a framework for considering how local conditions may differ.

2.5 Electricity Reliability and Economic Development

The broader infrastructure literature demonstrates that access to electricity can influence employment, non-agricultural activity and household welfare. However, several studies show that complementary inputs such as finance, technology, appliances and market access influence the magnitude of these effects.

Lee, Miguel and Wolfram (2020), for example, find limited economic returns from subsidised electricity connections in rural Kenya. Blimpo and Cosgrove-Davies emphasise demand-side constraints and complementary inputs, while Khandker, Barnes and Samad (2013) show that electricity effects can differ according to access to complementary assets. The relevance to micro-businesses is straightforward. Reliable electricity may create an opportunity to use productive capital, but a business still requires demand, finance, labour and technology to convert that opportunity into investment or growth.

2.6 Micro-Enterprises and Electricity

Micro-enterprises are particularly relevant because they often operate under financial and organisational constraints. Grimm, Hartwig and Lay (2013) show that the effects of electricity access on micro-enterprises can vary by sector and business

characteristics. The effect of reliability is therefore unlikely to be uniform. A business dependent on refrigeration or electrically powered machinery may experience a much larger economic effect from an outage than a business that can continue using manual methods. This heterogeneity provides an important foundation for the present research.

2.7 Electricity Reliability and Investment

Investment represents a longer-term decision than daily production. A business owner considering a new machine must consider its purchase cost, expected demand, operating costs and expected future utilisation. Unreliable electricity can affect this calculation in two ways. First, it may reduce the number of hours for which the machine can be used. Second, it may increase uncertainty about future utilisation. The investment-under-uncertainty literature provides a theoretical explanation for the second mechanism. Pindyck (1991) argues that when investment is irreversible and future conditions are uncertain, firms may have an option value of waiting. Bloom, Bond and Van Reenen (2007) similarly demonstrate a relationship between uncertainty and investment dynamics. Applied to electricity, the mechanism is not that unreliable electricity automatically stops investment. Rather, uncertainty about future electricity availability may increase the attractiveness of delaying investment when the investment is costly to reverse and heavily dependent on electricity.

2.8 Literature Gap

The literature provides several important pieces of the argument. Electricity shortages can reduce firm revenues and producer surplus. Firms can adapt through generators and changes in production. Electricity quality can matter beyond basic access. Electrification effects depend on complementary conditions. Finally, uncertainty can influence investment when capital is partly irreversible. However, these strands are rarely brought together around the specific question of how electricity reliability may influence both productive operating time and capital investment among micro-businesses in Maharashtra. This paper addresses that gap through theoretical synthesis rather than new econometric estimation. Its contribution is to connect the short-run operating effects of unreliable electricity with the longer-run investment decision.

3. THEORETICAL FRAMEWORK

3.1 Electricity as a Productive Input

Firms combine capital, labour and other inputs to produce output. A simplified production function can be represented as:

$$Y = AF(K, L, E)$$

where Y represents output, A represents productivity or technology, K represents capital, L represents labour and E represents electricity. The important implication is that electricity can be complementary to capital and labour. A machine may be available, but its productive value is limited if electricity is unavailable when the firm needs to operate it. Electricity reliability therefore affects the effective quantity of electricity available for production. A firm experiencing interruptions may possess the same physical capital as a reliable-power firm while producing less because its capital cannot be used continuously.

3.2 Electricity Reliability and Capacity Utilisation

Capacity utilisation refers to the extent to which a firm's productive capacity is actually used. If a business owns machinery capable of operating for ten hours per day but electricity interruptions prevent it from operating for several of those hours, effective capacity utilisation falls. This provides a direct theoretical link between electricity reliability and productivity. Reliability does not necessarily change the physical amount of capital owned by a firm; instead, it changes the conditions under which that capital can be used. The relationship remains conditional. Operating hours are also determined by demand, labour availability, competition and business decisions. Electricity reliability is therefore one potential constraint rather than the sole determinant.

3.3 Opportunity Cost of Power Interruptions

The economic cost of an electricity interruption depends on what the business could otherwise have produced or sold during that period. An outage can result in lost sales, idle machinery, unused labour, spoiled inventory, delayed orders and disruption to customer transactions. Its opportunity cost may also depend on timing. An outage during high demand may have a greater economic cost than one during a quiet period. Consequently, the same number of outage hours can have different effects across businesses.

3.4 Transaction Costs and Adaptation

Firms can adapt to unreliable electricity through generators, batteries, inverters, production rescheduling, inventory management, outsourcing and changes in production methods. Adaptation means that the observed effect of an outage may be smaller than the initial disruption. However, adaptation is not costless. Firms may incur expenditure on fuel, backup equipment, maintenance, additional labour and reorganising production. The effective economic cost of electricity can therefore exceed the price paid to the electricity supplier. This is particularly relevant for micro-businesses because limited financial resources may make adaptation difficult.

3.5 Electricity Reliability and Input Substitution

Unreliable electricity may lead firms to substitute towards other inputs, including diesel-generated electricity, labour-intensive production, manual processes, outsourcing or alternative technologies. An electricity shortage therefore does not necessarily translate directly into an equivalent reduction in output. Instead, the business may change the combination of inputs used to produce output. This mechanism is consistent with Allcott et al. (2016) and Abeberese (2017), who show that firms respond to electricity constraints through changes in production and input use.

3.6 Electricity Reliability and Capital Investment

Capital investment concerns future conditions. A business considering an electrically powered machine must evaluate whether it will generate sufficient returns. Expected utilisation is part of this calculation. Reliable electricity may increase expected utilisation

by reducing interruptions, thereby increasing the expected return to electricity-dependent capital. Unreliable electricity may have the opposite effect. This creates the relationship: Reliability → Expected utilisation → Expected return → Investment incentive. Reliability does not guarantee investment. Finance, demand, profitability and other factors remain important.

3.7 Uncertainty, Irreversibility and Investment

The investment decision becomes particularly important when electricity reliability is uncertain. Investment in machinery is often partly irreversible. Once capital has been purchased, the business may not recover its full cost by selling the asset. At the same time, the business can delay investment and obtain more information about future conditions. This creates an option value of waiting. Pindyck (1991) explains that uncertainty can make waiting more attractive when investment is irreversible. Bloom, Bond and Van Reenen (2007) similarly demonstrate the relationship between uncertainty and investment dynamics. Applied to electricity, unpredictable future availability may increase uncertainty about the utilisation and profitability of electricity-dependent capital. The precise proposition is therefore that uncertainty may increase the threshold at which investment becomes attractive or encourage postponement when investment is costly to reverse.

3.8 Complementary Constraints and Heterogeneity

Electricity reliability cannot guarantee investment. Investment also depends on access to credit, expected demand, profitability, skilled labour, machinery availability, input prices, market access, land and technology. The effects should therefore vary across businesses. A pharmacy or food retailer requiring refrigeration may be highly exposed to interruptions, while a business relying mainly on manual labour may be less affected. Other sources of heterogeneity include business size, access to finance, location, availability of generators, alternative production methods and the reversibility of investment. A state-wide relationship could therefore conceal substantial differences between individual businesses.

3.9 Integrated Theoretical Framework

The mechanisms can be brought together into one framework.

The short-run mechanism is: Electricity reliability → productive operating time → capacity utilisation → productivity

The investment mechanism is: Electricity reliability → expected utilisation → expected returns → capital investment

Adaptation operates alongside both: Unreliable electricity → backup and input substitution → higher adaptation costs

The uncertainty mechanism is: Uncertain electricity availability → uncertain future utilisation → greater value of waiting → possible investment postponement

Together: Electricity reliability → productive operating time → capacity utilisation → expected returns → capital investment → potential business expansion

The reverse pathway is: Unreliable electricity → interruptions and uncertainty → lost productive time → under-utilised capital and adaptation costs → lower or more uncertain expected returns → possible investment postponement

The word possible is important. This study does not estimate these relationships for Maharashtra; it combines evidence for individual mechanisms into a theoretical framework.

3.10 Theoretical Predictions and Hypotheses

H1: Higher electricity reliability is expected to be associated with longer productive operating hours among micro-businesses, particularly where electricity is a binding input into production.

H2: Higher electricity reliability is expected to be associated with greater capital investment, conditional on access to finance, expected demand and other complementary inputs.

H3: The relationship between electricity reliability and operating hours is expected to be stronger for more electricity-intensive businesses.

H4: The relationship between electricity reliability and capital investment is expected to be stronger where planned investment is highly dependent on reliable electricity.

H5: The effect of electricity reliability on investment is expected to be weaker where businesses face binding financial, demand or technological constraints.

These are theoretical predictions rather than claims that the existing evidence has established causal relationships for Maharashtra.

3.11 Limitations of the Framework

Several limitations must be recognised. Electricity reliability is unlikely to be randomly distributed across businesses or locations. Areas with better electricity may also have better roads, stronger markets, higher incomes or greater access to finance, creating potential omitted-variable problems. Demand can affect both operating hours and investment. Firms can also adapt through generators, batteries, inventories and production scheduling, reducing the observable effect of outages. Finally, investment is influenced by interest rates, credit access, expected demand, profitability, business age and investment costs. Opening hours should not automatically be interpreted as productive hours, and business listings should not be treated as direct evidence of capital stock or investment. These limitations define what can reasonably be concluded from secondary evidence. The purpose of the framework is to identify plausible mechanisms rather than establish a causal Maharashtra-specific effect.

4. THEORETICAL ANALYSIS

4.1 Electricity Reliability and Operating Hours

Electricity reliability can affect the amount of time for which a micro-business can operate productively. This is particularly important where electricity is directly required for production or service delivery. A business may have grid access but still experience interruptions that prevent machinery from operating, disrupt refrigeration, interrupt digital transactions or require workers to wait until electricity is restored. However, the effect on operating hours should not be overstated. Businesses also choose opening hours according to customer demand, labour availability, competition and owner preferences. Reliable electricity therefore removes one possible constraint on productive operating time rather than determining opening hours by itself.

4.2 Electricity Reliability and Productivity

The productivity effect can occur through capacity utilisation. If a business owns machinery but cannot operate it consistently because of electricity interruptions, its physical capital stock may remain unchanged while effective productive capacity falls. For example, a repair shop may own electrically powered tools but be unable to complete jobs during an outage. A restaurant may remain open while being unable to use refrigeration or certain cooking equipment. A pharmacy may remain open while facing risks to temperature-sensitive inventory. The economic effect therefore depends on electricity intensity and the importance of electrical equipment to the firm's production process.

4.3 Electricity Reliability and Capital Investment

The investment mechanism is longer term. A business may continue operating despite unreliable electricity by using a generator or changing its production schedule while simultaneously deciding not to purchase additional electricity-dependent machinery. The reason is that investment depends on expected future utilisation rather than only current production. If the owner is uncertain about how often a machine will be usable, its expected return may be lower or more uncertain than its technical productivity suggests. This creates a distinction between capital utilisation and capital accumulation. Reliable electricity may first allow firms to use existing equipment more effectively. If this raises expected returns, it may subsequently make additional investment more attractive. However, investment also depends on finance, demand and profitability. Electricity reliability should therefore not be treated as a sufficient condition for investment.

4.4 Electricity Reliability and Business Uncertainty

Electricity reliability can affect businesses through uncertainty as well as direct production losses. Business owners make decisions about production, staffing, inventory and investment based on expectations about future conditions. If electricity availability is unpredictable, forecasting becomes more difficult. The same uncertainty can influence investment. An owner considering new machinery must estimate future utilisation and revenue. If electricity availability is uncertain, expected returns become less predictable. The theoretical proposition is therefore not that power cuts automatically cause businesses to stop investing, but that uncertainty may increase the attractiveness of postponing investment when capital is costly to reverse and highly dependent on reliable electricity.

4.5 Backup Power as a Coping Mechanism

Businesses may respond to interruptions through generators, batteries, inverters or solar systems. These technologies can reduce the immediate effect of an outage but create costs. A generator requires fuel and maintenance, while batteries and other systems require upfront capital. For a micro-business, expenditure on backup power can compete with investment in productive equipment, inventory or expansion. Adaptation can therefore protect current output while affecting future investment: Unreliable electricity → adaptation expenditure → higher effective operating costs → fewer resources for other uses

The strength of this mechanism depends on financial capacity and the cost of alternative power.

4.6 Urban-Rural Differences and Business Heterogeneity

Maharashtra contains diverse economic environments. Businesses in major cities, smaller towns and rural areas may differ in market size, access to finance, transport infrastructure, technology and electricity dependence. The theoretical effect of reliability may therefore vary across locations. A small manufacturing or repair business that depends heavily on electrically powered machinery may experience a significant effect from interruptions, while a business using electricity mainly for lighting may be less affected. Similarly, businesses with sufficient capital may purchase generators or batteries and reduce the visible effects of outages. Financially constrained businesses may have fewer adaptation options. The relationship is therefore shaped by the interaction between infrastructure and firm-level resources.

4.7 Limitations of the Analysis

Much of the empirical evidence on electricity shortages concerns manufacturing firms rather than micro-businesses. Allcott et al. (2016), for example, provide important evidence from Indian manufacturing, but their estimates should not be transferred directly to Maharashtra's micro-businesses. Evidence from international rural electrification studies provides mechanisms and comparisons but cannot be treated as direct evidence for Maharashtra. Electricity reliability data also do not establish causality because areas with better electricity may differ in income, market size, transport, finance and other factors. Adaptation creates another challenge. A firm may experience frequent outages but maintain production through backup generation. Conversely, a firm with reliable electricity may still operate for relatively few hours because demand is weak. These limitations define the boundaries of the conclusions rather than undermining the theoretical framework.

5. CONCEPTUAL MODEL

The central relationship developed in this paper is:

Electricity Reliability → Operating Time → Capacity Utilisation → Productivity → Expected Returns → Capital Investment → Potential Business Expansion

When electricity is reliable, businesses are less likely to experience unexpected interruptions. This can increase productive operating time and allow existing capital to be used more intensively. The productivity relationship is not necessarily direct. Businesses may adapt through production schedules, inventories, alternative technologies and backup electricity. Consequently, the observed productivity effect may be smaller than the initial disruption. The next stage concerns expected returns. If machinery can be used more consistently, its expected productive value may increase, making additional investment more attractive. Reliability may also influence investment through uncertainty. When electricity availability is unpredictable, future utilisation and revenue become harder to forecast. Where investment is costly or difficult to reverse, the value of waiting may increase. The reverse pathway is: Unreliable Electricity → Interruptions and Uncertainty → Lost Operating Time → Under-utilised Capital → Higher Costs → Lower or More Uncertain Expected Returns → Possible Investment Postponement

The model should not be interpreted as a guaranteed causal chain. Finance, demand, technology, electricity intensity and other constraints can influence every stage. The main conceptual contribution is therefore to connect the short-run use of productive resources with the longer-run decision to acquire additional capital.

6. DISCUSSION

The analysis suggests that the economic importance of electricity cannot be understood simply through access to the grid. What matters for productive activity is whether electricity is sufficiently reliable and predictable to allow businesses to use their resources effectively. Evidence from rural India supports this distinction, while research on Indian manufacturing shows that firms can adapt to shortages through generators, inventories and changes in production. Thus, unreliable electricity does not necessarily translate into an equivalent reduction in output, although adaptation can create additional costs. For micro-businesses, this adaptation may involve generators, batteries, production rescheduling or changes in technology. These responses can protect current operations while diverting resources from other uses. The effect of reliability is therefore likely to depend on the electricity intensity of the business and its access to finance and alternative technologies.

The longer-term investment mechanism is more subtle. Reliable electricity may increase the expected utilisation of electricity-dependent capital, making its future returns easier to predict. Conversely, unreliable supply can increase uncertainty about whether new equipment will be used sufficiently. Where investment is costly or difficult to reverse, this uncertainty may increase the value of waiting. However, electricity reliability remains only one determinant of investment alongside demand, profitability, finance, technology and market access. The wider electrification literature reinforces this conditional interpretation. Burlig and Preonas (2024), for example, find that rural electrification substantially expanded access in India but produced limited economic effects overall, with stronger effects in larger villages. Infrastructure can therefore create opportunities without automatically producing economic transformation.

The theoretical contribution of this paper is to bring these mechanisms together. Electricity reliability may affect not only whether a business can operate productively today, but also the conditions under which it evaluates investment for tomorrow. The paper does not establish a causal Maharashtra-specific effect; instead, it identifies mechanisms and conditions that future empirical research could test using business-level data on operating hours, capacity utilisation, electricity dependence, backup expenditure and capital investment.

7. POLICY IMPLICATIONS

The theoretical analysis has implications for electricity and MSME policy in Maharashtra. The central policy issue is not simply whether businesses are connected to electricity, but whether they receive a sufficiently reliable and predictable supply to use electricity productively.

7.1 Improving Distribution-System Reliability

Continued investment in electricity distribution infrastructure can focus on reducing the frequency and duration of interruptions. The Revamped Distribution Sector Scheme (RDSS) provides a relevant national policy framework because it aims to improve the quality, reliability and operational efficiency of electricity distribution. For Maharashtra, this provides a policy context for considering reliability as an infrastructure objective rather than treating connection as the final stage of electricity provision.

7.2 Strengthening Reliability Monitoring and Standards

If reliability is an economic input, policymakers need measures that capture its performance. Maharashtra's regulatory framework includes indicators such as SAIFI, SAIDI and CAIDI. These provide information on interruption frequency and duration that connection rates alone cannot capture. Continued monitoring and transparent reporting can therefore help identify differences in electricity performance and provide information for distribution planning.

7.3 Considering Power Quality

Policy should also consider power quality alongside complete interruptions. Voltage fluctuations and unstable electricity can affect businesses using sensitive equipment even when a complete power cut does not occur. Equipment damage, maintenance and process disruption can create additional costs. A comprehensive approach should therefore consider continuity, duration and quality of electricity supply.

7.4 Supporting Business Adaptation

Infrastructure improvements may take time, meaning that businesses will continue to face some disruptions. Policies supporting micro and small enterprises can therefore consider their ability to adapt. Access to credit, technology upgrading and appropriate business support can influence whether a firm is able to purchase efficient equipment or backup systems. However, such support

should not substitute for improving electricity distribution. Requiring small businesses to compensate entirely for unreliable infrastructure through private investment may shift costs onto firms least able to absorb them.

7.5 Backup Power and Decentralised Energy

Generators, batteries, inverters and solar systems can provide businesses with additional resilience where technically and financially suitable. However, backup systems should be treated as complementary measures rather than replacements for reliable grid electricity. A micro-business may benefit from a battery or solar system, but the upfront cost may itself represent a significant investment constraint.

7.6 Coordinating Electricity and MSME Policy

Electricity policy and MSME policy can also be considered together. A financial programme that enables a business to purchase machinery may have different effects depending on whether the local electricity system allows that machinery to be used consistently. Technology-upgrading programmes may similarly need to consider electricity reliability where equipment is highly electricity-dependent. This does not mean that every MSME policy should become an electricity policy. Rather, infrastructure conditions can be treated as part of the business environment in which enterprise support operates.

7.7 Local and Sector-Specific Planning

The economic consequences of electricity interruptions differ across businesses. A refrigeration-dependent business may face greater losses from an outage than a business using electricity mainly for lighting. Similarly, an industrial cluster may have different electricity requirements from a small retail market. Infrastructure planning can therefore consider the characteristics of local economic activity alongside household and industrial demand. This does not imply that businesses should automatically receive priority over other electricity users. Instead, the economic uses of electricity can form part of the information considered when planning distribution improvements.

7.8 Policy Priorities for Maharashtra

The policy implications can be summarised through a broader shift from an access-only approach to an access, reliability, quality and resilience approach.

First, continued investment in distribution infrastructure can focus on reducing interruption frequency and duration. Second, reliability policy can pay greater attention to power quality, including voltage stability where businesses depend on electrical equipment. Third, MSME support can recognise that small businesses may have limited resources for adapting to infrastructure disruptions. Where appropriate, suitable backup and renewable technologies can provide additional resilience. These measures should be considered together rather than as substitutes.

The resulting policy approach can therefore be expressed as: Electricity access + reliability + quality + business resilience rather than electricity access alone.

This should not be interpreted as a claim that these measures will automatically increase investment or business expansion. Their purpose is to reduce infrastructure constraints and create conditions in which micro-businesses can make more effective use of productive resources.

8. CONCLUSION

This study examined how electricity reliability may affect the operating hours and capital investment decisions of micro-businesses in Maharashtra. The analysis suggests that the economic value of electricity cannot be understood through access alone. For businesses that depend on electricity for machinery, refrigeration, digital systems or other productive activities, reliability can influence how effectively existing resources are used and how confidently future investments can be evaluated.

The theoretical framework identifies two main channels. First, reliable electricity can increase productive operating time and capacity utilisation by reducing interruptions to electricity-dependent activities. Second, reliability can affect investment by influencing the expected utilisation and return of electricity-dependent capital. When future electricity availability is uncertain and investment is difficult to reverse, waiting may become more attractive. Businesses can adapt through generators, batteries, inventories and changes in production, but these responses impose additional costs and may themselves compete with productive investment. These effects should not be interpreted as automatic or uniform. Demand, finance, technology, electricity dependence and other local conditions can determine whether reliability represents a binding constraint. The evidence reviewed in this paper therefore supports a conditional theoretical relationship rather than a claim that reliable electricity guarantees investment or business expansion. The main limitation is that the study does not use original business-level data to estimate the magnitude of these relationships in Maharashtra. Future empirical research could combine geographically disaggregated electricity-reliability measures with business-level data on operating hours, capacity utilisation, backup expenditure and capital investment.

The central conclusion is that reliable electricity may matter not only because it allows businesses to operate today, but because it changes the conditions under which investment becomes worthwhile tomorrow. Establishing the size and distribution of this effect among Maharashtra's micro-businesses remains an empirical question.

REFERENCES

- [1] Abeberese, A. B. (2017). Electricity cost and firm performance: Evidence from India. *The Review of Economics and Statistics*, 99(5), 839–852.
- [2] Allcott, H., Collard-Wexler, A., & O'Connell, S. D. (2016). How do electricity shortages affect industry? Evidence from India. *American Economic Review*, 106(3), 587–624.

- [3] Bloom, N. (2009). The impact of uncertainty shocks. *Econometrica*, 77(3), 623–685.
- [4] Bloom, N., Bond, S., & Van Reenen, J. (2007). Uncertainty and investment dynamics. *The Review of Economic Studies*, 74(2), 391–415.
- [5] Burlig, F., & Preonas, L. (2024). Out of the darkness and into the light? Development effects of rural electrification. *Journal of Political Economy*, 132(9).
- [6] Energy Sector Management Assistance Program. (2015). *Beyond connections: Energy access redefined*. World Bank.
- [7] Jha, A., Preonas, L., & Burlig, F. (2021). *Blackouts: The role of India's wholesale electricity market* (NBER Working Paper No. 29610). National Bureau of Economic Research.
- [8] Pindyck, R. S. (1991). Irreversibility, uncertainty, and investment. *Journal of Economic Literature*, 29(3), 1110–1148.
- [9] Samad, H. A., & Zhang, F. (2016). *Benefits of electrification and the role of reliability: Evidence from India* (Policy Research Working Paper No. 7889). World Bank.