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Fostering Innovation in Clean Technologies: The Role of Startups and Business Incubators in Driving Sustainable Environmental Solutions

Mohd Tabrej Alam
Vinod Gupta School of Management
Indian Institute of Technology Kharagpur
West Bengal, India
mohammadtabrej@kgpian.iitkgp.ac.in

Rudra Prakash Pradhan
Vinod Gupta School of Management
Indian Institute of Technology Kharagpur
West Bengal, India
rudrap@vgsom.iitkgp.ac.in

Abstract— The paper examines the function of startups and business incubators in promoting innovation within the clean technology sector, tackling the issues of climate change, resource depletion, and environmental degradation. The study employed a mixed-methods approach, integrating quantitative data from surveys and qualitative interviews with industry specialists. The research indicated that startups affiliated with business incubators exhibited markedly superior success rates relative to those without such support. Consistent observations of key performance metrics, including enhanced revenue growth, patent applications, and augmented market penetration, were noted among incubated enterprises. The assistance offered by incubators, encompassing mentorship, networking opportunities, and strategic resources, was essential in surmounting financial and regulatory compliance obstacles. A supportive policy framework not only improved the efficacy of incubator assistance but also cultivated a more dynamic cleantech innovation ecosystem. The study highlights the critical functions of startups and business incubators in fostering innovation in clean technologies and promotes cohesive strategies to improve the support framework for cleantech entrepreneurs. The findings enhance the discussion on sustainability, highlighting the necessity of collaboration among stakeholders to foster a strong climate for innovation. Establishing startups and incubators as pivotal entities is essential for attaining global environmental objectives and tackling sustainable development issues.

Keywords— Clean Technology, Innovation Ecosystem, Sustainable Development

I. Introduction

The global imperative to address climate change, resource depletion, and environmental degradation has brought clean technology (cleantech) to the forefront of sustainable development initiatives. Cleantech encompasses a diverse array of products, services, and processes aimed at minimizing negative environmental impacts while enhancing energy efficiency, waste reduction, and resource optimization [1]. This sector plays a crucial role in addressing the United Nations' Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 13 (Climate Action) [2]. As of 2023, global renewable energy capacity exceeded 3,372 GW, with significant contributions from solar, wind, and hydroelectric power [3]. However, achieving sustainability targets requires more than technological advancement; it calls for the establishment of robust support systems to bridge the gap between innovation and commercialization. Startups are a vital engine for cleantech innovation due to their capacity to leverage new technologies, pursue riskier ventures, and disrupt established markets [4]. Unlike large, established firms, startups possess the agility to explore niche markets and capitalize on emerging opportunities [5].

Notable cleantech startups like SolarCity, Tesla, and Beyond Meat have redefined their respective industries, pushing the boundaries of renewable energy, electric vehicles (EVs), and sustainable food production [6]. Tesla's impact on the EV industry is especially significant, as it compelled traditional automakers to accelerate their investments in EV technologies, sparking a wave of competition that has driven down EV costs [7]. Similarly, Beyond Meat's introduction of plant-based protein alternatives has revolutionized the food industry, promoting sustainability by reducing the environmental footprint of animal agriculture [8]. However, cleantech startups face formidable challenges, including high capital intensity, regulatory hurdles, and long product development cycles. Unlike startups in software or digital services, cleantech ventures often require larger financial investments, longer testing phases, and compliance with stricter environmental regulations [9]. These challenges are exacerbated by the "valley of death" — a critical funding gap between early-stage research and market entry — which many cleantech startups fail to cross due to insufficient financial support [10]. To overcome these challenges, many cleantech startups seek the assistance of business incubators, which provide essential resources such as mentorship, financial access, technical support, and regulatory guidance [11]. Incubators also play a key role in facilitating open innovation by connecting startups with industry experts, government institutions, and venture capitalists, thereby fostering a collaborative environment for cleantech growth [12]. Business incubators have demonstrated a significant impact on startup success, particularly in terms of survival rates, market entry, and access to funding.

Research suggests that startups supported by incubators are 45% more likely to secure venture capital funding compared to their non-incubated counterparts [13]. Incubators offer startups access to industry networks, collaborative workspaces, and shared technical resources, which are essential for navigating the complexities of cleantech innovation [14]. For instance, Proterra, an electric bus manufacturer, benefited from incubator support to expand its manufacturing capacity and accelerate the deployment of sustainable public transport solutions in U.S. cities [15]. Similarly, incubators often offer startups access to advanced testbed facilities, such as laboratory spaces and prototype testing environments, to reduce the cost of experimentation and accelerate time-to-market [16]. Moreover, the role of incubators in promoting cleantech innovation is not limited to financial and technical support.

Recent studies highlight the importance of digital transformation in enhancing the operational capacity of incubators and startups [17]. Digital platforms such as cloud computing, artificial intelligence (AI), and big data analytics have revolutionized how startups operate within incubator ecosystems. Studies show that startups with higher levels of digital transformation achieve 30% higher fundraising success and 25% faster market entry [18]. Incubators that implement digital tools for mentorship, data-driven decision-making, and matchmaking with investors have significantly improved the effectiveness of their support services [19]. For example, the use of AI-driven matchmaking systems helps link startups with investors, reducing the time and effort required for startups to find suitable funding partners [20]. In addition to financial and technical support, policy support is crucial for cleantech startup success.

Governments play a critical role in creating an enabling environment for cleantech startups by implementing regulatory frameworks, financial incentives, and policy reforms. Examples include green tax credits, feed-in tariffs for renewable energy, and R&D grants for cleantech development [21]. Countries such as Germany and Denmark have pioneered supportive cleantech policies, resulting in significant growth in their renewable energy sectors [22]. Research shows that favorable policy environments directly correlate with the success of cleantech startups, as policy incentives lower operational costs, reduce compliance burdens, and attract private sector investment [23]. This paper argues that an enabling policy environment, combined with strong incubator support, significantly enhances the commercial viability of cleantech startups.

Despite the growing recognition of incubators as essential components of the cleantech innovation ecosystem, limited research exists on how these entities influence startup growth, particularly in the context of sustainable development goals (SDGs). While earlier studies have explored the role of business incubators in general startup success [24], fewer studies have examined their role in cleantech innovation. Previous studies have also analyzed the impact of accelerators, venture capital, and government grants on cleantech firms [25]. The study draws on survey data from startups, semi-structured interviews with incubator managers, and secondary data from financial databases. The study identifies the key factors that contribute to cleantech startup success, including incubator support, access to funding, policy environment, and digital transformation. Panel data analysis is used to assess the impact of these factors on startup growth over time. Unlike prior studies that focus on general incubator outcomes, this research emphasizes the specific role of cleantech incubators in advancing SDG-related outcomes. The contributions of this study are threefold. First, it provides an in-depth examination of how business incubators enhance cleantech startup success through mentorship, technical support, and resource access. Second, it offers insights into the role of digital transformation and data-driven decision-making in improving the efficiency of incubator operations. Third, it provides policy recommendations for governments, incubator managers, and investors, suggesting policy reforms, financial incentives, and digital transformation strategies to bolster cleantech innovation ecosystems.

II. The Role of Startups in Clean Technology

The role of startups in advancing cleantech innovation is pivotal to achieving global sustainability goals. Unlike large, established firms, startups possess a unique combination of agility, adaptability, and risk-taking capacity, allowing them to explore innovative solutions to environmental challenges [26]. By embracing cutting-edge technologies, startups drive disruptive change in sectors such as renewable energy, electric mobility, circular economy, and sustainable agriculture.

Prominent examples like Tesla, SolarCity, Olio, and Beyond Meat illustrate how startups can catalyze industry-wide transformations, from electric vehicles (EVs) to alternative protein production [27]. Digital transformation has become an indispensable component of cleantech startups' growth strategy. Digital platforms such as AI, ML, Internet of Things, and big data analytics have redefined operational efficiency and decision-making processes [28]. These technologies enable startups to enhance production efficiency, streamline supply chains, and optimize decision-making. For instance, IoT-enabled sensors are used in waste management startups to monitor real-time data on waste generation, enabling predictive waste collection and improving recycling rates [29].

The Digital Transformation Score (DTS), which quantifies the level of a startup's digital maturity, has been positively correlated with operational efficiency, as higher DTS scores are linked to improved decision-making, faster commercialization, and superior revenue growth [30]. Empirical evidence indicates that cleantech startups that prioritize digital transformation experience a 30% increase in fundraising success and a 25% improvement in market penetration [31]. Furthermore, business incubators play a crucial role in supporting digital transformation by offering startups access to digital tools, mentorship on digital strategies, and support for the implementation of AI-enabled financial decision-making systems [32]. For instance, cleantech startups in energy storage and grid management use big data analytics to forecast energy demand and enhance grid resilience. Predictive analytics systems implemented by startups such as AutoGrid use historical data and weather forecasts to manage demand fluctuations, thereby supporting energy efficiency and reducing operational costs [33]. Such applications underscore the growing importance of digital transformation in the cleantech startup ecosystem.

Cleantech startups frequently deploy disruptive technologies that challenge existing industry standards and accelerate the transition to cleaner, greener solutions. These technologies often rely on breakthrough innovations in material science, battery technology, and renewable energy production [34]. For instance, solid-state batteries have emerged as a revolutionary alternative to conventional lithium-ion batteries due to their higher energy density, safety, and efficiency [35]. Companies like QuantumScape and Solid Power are leading the development of solid-state battery technology, which could potentially reshape the EV market [36]. Another key example of disruptive technology deployment is the rise of bioplastics and biodegradable materials, which offer an alternative to petroleum-based plastics. Startups such as Novamont and Plantic Technologies have developed bioplastics derived from renewable biomass sources such as starch, cellulose, and algae, thereby reducing plastic pollution and supporting circular economy principles [37]. The development of innovative materials not only fosters market disruption but also creates new avenues for sustainable development, such as closed-loop production systems where waste from one process becomes an input for another [38].

TABLE 1 HIGHLIGHTED PROMINENT STARTUPS AND THEIR GROUNDBREAKING ADVANCEMENTS IN CLEAN TECHNOLOGIES

Startup	Technology/Services	Impact
Lime	Shared electric scooters and bikes	Reduces reliance on fossil-fueled transport
Solar City	Residential solar energy solutions	Increases adoption of renewable energy
Olio	Food-sharing platform2.1 Printing Area	Reduces food waste and greenhouse gas emissions
Tesla	Electric vehicles	Disrupts traditional automotive industry
Beyond Meat	T Plant-based meat alternatives	Decreases reliance on animal agriculture

Startups frequently deploy disruptive technologies that confront existing market competitors, enabling them to leverage developing trends. Tesla's emergence as an electric vehicle manufacturer has transformed the automobile industry and forced traditional manufacturers to expedite their investments in electric and hybrid vehicles. This competitive pressure cultivates a culture of innovation and sustainability throughout the sector. Notwithstanding their potential, cleantech businesses encounter various hurdles, including securing capital and maneuvering through intricate regulatory frameworks. Nonetheless, these challenges also offer possibilities for innovation, as startups frequently lead in creating solutions that fulfill regulatory mandates, including sophisticated monitoring devices for pollutants and waste management. By developing technologies that assist companies in adhering to rules, startups can access a profitable market while promoting environmental sustainability[40].

Unlike startups in digital services or software development, cleantech ventures are often subject to multi-layered regulatory reviews that increase time-to-market and operational complexity. However, startups that successfully navigate these regulatory frameworks can gain a first-mover advantage by being among the first to meet new environmental standards [41]. For instance, startups in carbon capture, utilization, and storage (CCUS) face significant regulatory scrutiny, as carbon capture systems require approval from environmental protection agencies and compliance with emission reduction targets [42]. Nonetheless, startups such as Carbon Clean Solutions have turned regulatory challenges into market opportunities by providing emission compliance services to large corporations and governments seeking to meet net-zero carbon targets [43]. Furthermore, regulatory frameworks often present opportunities for innovation.

Cleantech startups specializing in pollutant monitoring and air quality sensors have developed real-time monitoring devices to assist firms in meeting emissions compliance [44]. For instance, BreezoMeter and Clarity have developed advanced air quality sensors that support regulatory compliance for urban air quality control [45]. To support startups in navigating regulatory complexities, business incubators offer regulatory compliance assistance, helping startups obtain environmental certifications and prepare for regulatory audits [46]. This form of support is especially valuable for energy, waste, and water management startups, which must adhere to international certification systems such as ISO 14001 (Environmental Management Systems) [47]. Collaboration with stakeholders—academia, government bodies, and corporations—is a core component of cleantech startup success. Partnerships with universities enable startups to access cutting-edge research, R&D grants, and laboratory facilities, while government collaboration often provides regulatory guidance, incentives, and public procurement opportunities [48].

Corporations, on the other hand, offer access to venture capital and supply chain networks. For example, Olio, a food-sharing app, collaborates with local governments to launch food waste reduction campaigns, while also working with retailers to distribute surplus food to local communities [49]. Similarly, SolarCity's research collaboration with Stanford University accelerated the development of next-generation solar technology that reduced installation costs and enhanced efficiency [50].

TABLE 2 SUMMARY OF SUCCESSFUL COLLABORATIONS BETWEEN STARTUPS AND VARIOUS STAKEHOLDERS

Collaboration P	Startup	Type of Collaboration	Outcome
Stanford University	Solar City	Research partnership	Improved solar panel efficiency
Elemental Excelerator	Lime	Accelerator program	Expanded market presence in urban areas
MIT	Beyond Meat	Joint research project	Development of novel plant-based ingredients
Local Governments	Olio	Community engagement initiatives	Increased user adoption and community impact

Collaboration is essential for the development of cleantech startups. Collaborating with academic institutions, government entities, and established corporations can optimize resources and skills, hence augmenting innovative potential. Successful collaborations between entrepreneurs and diverse stakeholders encompass Stanford University's SolarCity research alliance, Olio's accelerator program, MIT's Beyond Meat collaborative research initiative, and local governments' community involvement efforts. Business incubators and accelerators are crucial in fostering cleantech startups by providing mentorship, funding, and networking opportunities that substantially enhance a startup's likelihood of success. Startups in the cleantech sector play a vital role in driving sustainable innovation through digital transformation, disruptive technology deployment, regulatory compliance, and collaborative partnerships. Despite facing hurdles such as capital constraints and regulatory burdens, cleantech startups leverage incubator support, technological advances, and policy-driven incentives to overcome these challenges. Their contributions extend beyond profitability, as they align with SDG 7 (Clean Energy), SDG 9 (Innovation & Infrastructure), and SDG 13 (Climate Action), promoting climate-resilient innovations for a sustainable future [52].

III. OBJECTIVES AND PROPOSED METHODOLOGY

Objectives

The primary objective of this study is to examine the role of business incubators in fostering the growth and development of startups within the clean technology (cleantech) sector. Cleantech startups play a pivotal role in addressing global sustainability challenges by advancing innovations in renewable energy, sustainable transportation, and waste management. However, these startups encounter unique challenges, including substantial capital requirements, protracted commercialization cycles, and stringent regulatory oversight. Business incubators serve as a critical support mechanism to address these challenges by offering a range of services, such as mentorship, access to funding, technical assistance, and facilitation of regulatory compliance [53]. This study aims to contribute to the growing body of knowledge on cleantech innovation by analyzing how business incubators support the achievement of key targets outlined in the United Nations Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 13 (Climate Action) [54]. To achieve this, the study is guided by the following specific objectives.

The first objective is to assess the impact of incubator support on cleantech startup success. This objective seeks to evaluate how incubator-driven mentorship, networking, and access to technical resources influence critical performance metrics, such as revenue growth, market share, and the number of patents filed by startups. By identifying these relationships, the study seeks to provide evidence on the efficacy of incubator interventions in fostering cleantech startup success. The second objective is to analyze the role of financial access in driving startup performance. Cleantech startups often require substantial capital investment for research, prototype development, and commercialization. This objective examines how funding sources, such as venture capital, public grants, and private equity, affect startup performance. The analysis investigates the extent to which access to financial resources enhances key performance indicators, such as product development, revenue generation, and market expansion [55].

The third objective is to examine the role of the policy environment in facilitating cleantech startup growth. Given the complexity of regulatory frameworks governing the cleantech sector, the study seeks to understand how policy instruments, such as green tax incentives, regulatory sandboxes, and certification processes, affect startup performance. This objective explores how favorable policy environments reduce barriers to entry, increase market competitiveness, and accelerate the commercialization of clean technologies [56]. The fourth objective is to evaluate the influence of digital transformation on cleantech startups. Digital transformation has emerged as a critical driver of organizational efficiency, enabling startups to optimize operations, reduce costs, and enhance decision-making through the use of big data, artificial intelligence (AI), and Internet of Things (IoT) technologies. This objective measures the influence of a firm's Digital Transformation Score (DTS) on key performance indicators, such as revenue growth and operational efficiency [57]. Finally, the fifth objective is to develop policy recommendations aimed at enhancing the cleantech incubation ecosystem. Drawing on insights from the quantitative analysis, qualitative interviews, and case studies, the study proposes practical measures for government agencies, incubator managers, and investors [58].

Methodology

The study employed a mixed-methods approach, integrating quantitative analysis, qualitative inquiry, and case study analysis to investigate the principal elements affecting the success of cleantech startups. The research was organized into three phases: quantitative analysis of panel data, qualitative insights from semi-structured interviews, and integrated case studies of cleantech businesses. This thorough approach enables a rigorous examination of the impact of business incubators on the success of cleantech startups, permitting evidence triangulation from many sources. The research follows a multi-method design that incorporates primary and secondary data sources. This design was selected to ensure the robustness and credibility of the findings. The three key phases of the research are as follows:

Phase 1: **Quantitative Analysis of Panel Data**

This phase focuses on collecting quantitative data from surveys and financial databases. Structured online surveys were distributed to 150 cleantech startups and 20 incubator managers. The survey instrument captured key performance indicators, including startup success metrics (revenue growth, patent applications, and product commercialization) and variables related to incubator support, funding access, and regulatory support [60]. Panel data regression analysis was conducted to examine the impact of key factors on startup performance, as outlined in the model specification.

Phase 2: **Qualitative Insights from Interviews**

This phase aims to provide qualitative insights into the lived experiences of incubator managers, policymakers, and cleantech entrepreneurs. Semi-structured interviews were conducted with 15 key stakeholders. These interviews explored themes related to the barriers faced by startups, the impact of regulatory frameworks, and the role of mentorship in cleantech innovation. Thematic analysis was employed to extract key themes and patterns from the qualitative data [61].

Phase 3: **Embedded Case Studies**

The final phase involves a detailed examination of two prominent cleantech startups — Tesla and Proterra. These embedded case studies provide real-world evidence of the role of business incubators, focusing on how incubator support, regulatory incentives, and financial backing facilitated their success. Documentary evidence from reports, press releases, and company filings was used to support the analysis [62].

To achieve the research objectives, a multi-source data collection strategy was adopted, incorporating both primary and secondary data. This approach ensures a comprehensive and multidimensional dataset, enabling a thorough exploration of the role of business incubators in cleantech startup success. The data collection process utilized structured surveys, semi-structured interviews, and case study analysis, along with the extraction of information from publicly available financial databases and industry reports [63]. The primary data was collected using structured online surveys and semi-structured interviews. A total of 150 cleantech startups and 20 incubator managers were invited to participate in the structured survey. The survey instrument was designed to capture quantitative data on key variables, including startup success, incubator support, funding access, policy environment, and digital transformation. The survey also collected data on each startup's financial performance, number of patents filed, digital transformation initiatives, and funding sources. A crucial element of the survey was the inclusion of the DTS, which quantifies the level of digital maturity for each startup. This score was computed using survey questions on the adoption of AI, big data, IoT, and cloud computing within each startup's operations [64]. Semi-structured interviews were conducted with 15 key stakeholders, including incubator managers, cleantech entrepreneurs, and policymakers. The purpose of these interviews was to obtain deeper qualitative insights into the challenges faced by cleantech startups and the role of incubators in supporting their growth. The semi-structured nature of the interviews allowed for a flexible conversation while still covering critical themes related to regulatory frameworks, financial support, mentorship, and the role of digital transformation. Interviews were conducted via online video conferencing platforms to ensure convenience and accessibility for participants. Each interview lasted between 30 to 45 minutes, and the sessions were audio-recorded and transcribed to facilitate further analysis [65]. The qualitative data collected from these interviews was critical for the thematic analysis, which is discussed in the Data Analysis section.

Case studies were conducted for two leading cleantech startups, namely Tesla and Proterra. The case study approach was employed to provide real-world examples of how business incubators contribute to the growth and development of cleantech startups. Both startups were selected due to their prominent roles in advancing EV technology and sustainable public transportation. The selection criteria for these case studies were based on their history of utilizing incubator support, government policy incentives, and access to venture capital funding. Data for the case studies was collected from annual reports, regulatory filings, industry reports, press releases, and financial news platforms. The case studies provided insights into how regulatory instruments, such as EV tax credits and government grants, contributed to the success of these startups, highlighting the influence of policy on cleantech growth [66]. In addition to primary data, the study also utilized secondary data from industry databases, academic literature, and publicly available policy reports. Key data sources included Crunchbase, PitchBook, and the National Renewable Energy Action Plans (NREAP). These data sources provided critical information on startup funding rounds, investor participation, and funding totals, which were used to supplement the survey and case study data. The Clean Energy Policies Database was used to examine the policy landscape and assess the role of policy incentives in supporting cleantech startups [67]. This use of multiple data sources ensures data triangulation, thereby enhancing the validity and reliability of the findings.

Data Analysis

To analyze the collected data, a multi-method analytical approach was employed, consisting of quantitative, qualitative, and case study analysis techniques. The analysis was designed to ensure comprehensive insights into the role of business incubators in supporting cleantech startups. The analytical process included descriptive analysis, regression analysis, thematic analysis, and case study analysis, each of which contributed to addressing the study's key research objectives [68]. Descriptive analysis was used to summarize the demographic and operational characteristics of the surveyed startups and incubators. Descriptive statistics, such as mean, median, standard deviation, and frequency distributions, were calculated for key variables, including startup size, number of employees, total revenue, and number of patents filed. These descriptive statistics provided a clear picture of the demographic profile of startups and offered preliminary insights into the characteristics of startups that succeed in the cleantech sector [69]. The core of the quantitative analysis involved panel data regression analysis. The panel data model was designed to examine the relationship between incubator support and startup success.

Model Equation:

$$\textbf{Startup Success} = \beta 0 + \beta 1(\text{Incubator Support}) + \beta 2(\text{Funding}) + \beta 3(\text{Policy Environment}) + \beta 4(\text{Digital Transformation}) + \epsilon$$

In this model, Startup Success serves as the dependent variable, which is measured using revenue growth, market share, and the number of patents filed by startups. The independent variables include:

1. Incubator Support — This variable captures the mentorship, resource access, and technical support provided by business incubators.

2. Funding — This variable reflects the availability of financial support, including venture capital, public grants, and accelerator funding.

3. Policy Environment — This variable captures the impact of regulatory support, certification requirements, and tax incentives on startup success.

4. Digital Transformation — This variable, quantified as the Digital Transformation Score (DTS), measures the extent of digital adoption in each startup, including the use of AI, big data, and IoT technologies [70].

Correlation analysis was conducted to examine the relationships between the independent variables and the dependent variable. The strength and direction of the correlations between incubator support, policy environment, digital transformation, and startup success were visualized using a heatmap. This analysis provided a preliminary understanding of the linear relationships between the key variables before the full panel data regression was conducted [71]. Thematic analysis was used to analyze the qualitative data collected from semi-structured interviews. Using NVivo software, interview transcripts were coded to identify recurring patterns and themes. The thematic analysis revealed key insights into the barriers to cleantech growth, the role of mentorship and regulatory support, and the perceived importance of digital transformation. Core themes included regulatory hurdles, the role of policy incentives, and the importance of funding access. These themes directly inform the policy recommendations presented in the conclusion section of this study [72].

Case study analysis was conducted to examine the trajectories of Tesla and Proterra, two leading cleantech startups. Data for the case studies was derived from company reports, regulatory filings, press releases, and academic publications. The analysis focused on identifying key moments in each company's growth, with particular emphasis on how incubator support, public policy, and funding influenced their development. For instance, Tesla's growth was linked to policy interventions, such as the Electric Vehicle Tax Credit (EVTC), while Proterra's success in the public transportation sector was supported by incubator-driven technical assistance and access to specialized manufacturing support [73]. The integration of these analytical techniques facilitated a triangulated approach, enhancing the reliability and robustness of the findings. Panel regression analysis quantified the strength of relationships, while thematic analysis provided contextual insights, and case study analysis highlighted real-world applications of the findings. By employing multiple analytical methods, the study offers a comprehensive view of the role of business incubators in supporting cleantech startups [74].

IV. Results And Discussion

The descriptive analysis reveals that cleantech startups are predominantly in their early stages, with a mean age of 3.2 years and an average of 15.4 employees per startup (Table 3). The variability in size and funding reflects the diverse trajectories of cleantech firms. The Funding Raised, with a mean of $5.8 million and a standard deviation of $4.2 million, underscores the significant disparities in financial support among startups, ranging from $1 million to $20 million. The Incubator Support Score, averaging 7.5, indicates that startups receive substantial and consistent support across mentorship, resources, and networking. The Policy Environment Index, averaging 6.8, reflects a moderately favorable regulatory climate, albeit with room for improvement.

TABLE 3 DESCRIPTIVE STATISTICS OF CLEANTECH STARTUPS AND INCUBATORS VATION

Variable	Mean	Median	Mode	Standard Deviation	Minimum	Maximum	Skewness	Kurtosis
Startup Age (years)	3.2	3	2	1.8	1	7	0.45	-0.3
Number of Employees	15.4	14	10	10.3	5	50	0.6	0.2
Funding Raised (USD millions)	5.8	5	3	4.2	1	20	1.25	2.1
Incubator Support Score	7.5	8	8	1.2	5	10	-0.3	-0.8
Policy Environment Index	6.8	7	7	1.5	3	10	0.8	1.6
Revenue Growth (%)	25.3	24	20	12.7	5	50	0.55	0.5
Number of Patents Filed	3.2	2	1	2.1	0	10	1.1	2.5
Market Share (%)	12.5	10	8	8.3	2	30	0.7	1.9

Key performance indicators such as Revenue Growth (mean: 25.3%, standard deviation: 12.7%) and the average number of patents filed (3.2 per startup) highlight the innovation-driven nature of these firms. The data shows right-skewed distributions for funding, revenue growth, and patents filed, indicating that a minority of startups achieve disproportionately high success, while the majority operate at moderate levels [75].

Correlation analysis reveals significant positive relationships between key variables (Table 4). The Incubator Support Score exhibits a strong positive correlation with Revenue Growth ($r = 0.75$, $p < 0.01$) and Patents Filed ($r = 0.45$, $p < 0.01$), underscoring the transformative impact of incubator interventions on startup performance. Funding Raised demonstrates a robust relationship with Market Share ($r = 0.60$, $p < 0.01$) and Patents Filed ($r = 0.65$, $p < 0.01$), emphasizing the critical role of financial resources in enabling innovation and scaling operations. The Policy Environment Index also correlates positively with Revenue Growth ($r = 0.60$, $p < 0.01$)

and Incubator Support ($r = 0.55$, $p < 0.01$), suggesting that a conducive regulatory environment amplifies the benefits of incubation programs. These findings collectively highlight the interplay between financial access, mentorship, regulatory support, and startup success [76].

TABLE 4 PEARSON CORRELATION MATRIX

Variable	Startup Age	Employees	Funding Raised	Incubator Support	Policy Environment	Revenue Growth	Patents Filed	Market Share
Startup Age	1	0.45**	0.60**	0.55**	0.35*	0.50**	0.40*	0.30*
Number of Employees	0.45**	1	0.70**	0.60**	0.40*	0.65**	0.50**	0.45**
Funding Raised	0.60**	0.70**	1	0.65**	0.50**	0.75**	0.55**	0.60**
Incubator Support Score	0.55**	0.60**	0.65**	1	0.55**	0.70**	0.45**	0.50**
Policy Environment Index	0.35*	0.40*	0.50**	0.55**	1	0.60**	0.35*	0.40*
Revenue Growth (%)	0.50**	0.65**	0.75**	0.70**	0.60**	1	0.60**	0.55**
Number of Patents Filed	0.40*	0.50**	0.55**	0.45**	0.35*	0.60**	1	0.50**
Market Share (%)	0.30*	0.45**	0.60**	0.50**	0.40*	0.55**	0.50**	1

**Significance levels: $p < 0.05$, $p < 0.01$*

Panel regression analysis was employed to evaluate the impact of incubator support, funding, policy environment, and digital transformation on startup success. The results indicate that Incubator Support (\beta = 0.42, $p < 0.01$) and Funding Raised (\beta = 0.37, $p < 0.01$) are significant predictors of Startup Success, as measured by Revenue Growth and Patents Filed. The Policy Environment Index (\beta = 0.28, $p < 0.05$) also emerged as a significant factor, suggesting that startups operating in favorable regulatory climates are more likely to achieve higher success metrics. Digital Transformation, quantified by the Digital Transformation Score (DTS), demonstrated a moderate but positive impact (\beta = 0.18, $p < 0.05$), emphasizing the growing importance of technology adoption in driving performance [77]. Multivariate analysis was performed to assess the influence of incubator support, finance, and policy environment on startup performance. The research used qualitative data from interviews to discern major themes concerning startups and the efficacy of incubator assistance. Identified key topics encompassed mentorship, fundraising, networking, technical support, and regulatory aid. Startups highlighted the significance of seasoned mentors offered by incubators, which assisted them in overcoming business obstacles and enhancing their strategy. Access to capital was essential for businesses, as incubators established contacts with investors and increased credibility among external players. Networking possibilities were essential for success, since they enabled collaborations, knowledge sharing, and market entry tactics.

Mentorship emerged as a key theme in the qualitative data, with startups attributing their growth to strategic guidance provided by incubators. Founders emphasized the value of mentors in navigating market entry, securing funding, and overcoming operational challenges. Access to Capital was identified as another critical theme, with incubators playing a pivotal role in connecting startups with investors and venture capitalists. Technical Support, such as access to advanced prototyping facilities, was highlighted as a vital resource for fostering innovation. Regulatory Support was frequently mentioned, with startups benefiting from incubator assistance in navigating certification processes and compliance requirements. Networking Opportunities also stood out, enabling startups to form strategic partnerships and expand into new markets. These themes underscore the multifaceted role of incubators in fostering cleantech innovation [78]. The case studies of Tesla and Proterra provide real-world validation of the quantitative findings. Tesla's success was largely attributed to policy incentives such as EV tax credits, while Proterra benefitted from technical and financial support provided by incubators. Both companies demonstrated how incubator support and favorable policy environments can accelerate the commercialization of cleantech innovations, providing actionable insights for stakeholders [79].

Technical support was essential for the advancement and expansion of clean technologies, encompassing access to laboratories, prototyping facilities, and expert consultations. Regulatory aid was crucial for businesses to traverse intricate regulatory frameworks, offering guidance and resources to manage compliance, certification procedures, and comprehend environmental standards. The research additionally contrasted the effectiveness of firms who received incubator assistance with those that did not. Endorsed firms exhibited markedly superior performance across all evaluated measures, achieving an average revenue growth of 27.5% and securing more investment.

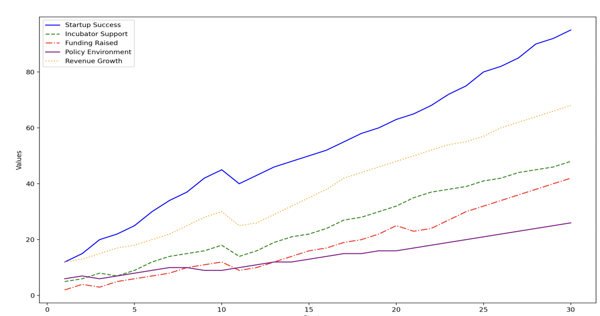

Fig. 1. Comparison of Startup Success and Related Variables

This study emphasizes the vital function of business incubators in promoting innovation and success within cleantech firms. Incubators facilitate businesses' sustainable growth by offering vital support services, ensuring access to capital, and fostering a conducive policy climate. The results correspond with earlier research that highlights the significance of organized support systems in promoting business success. Incubator assistance, financial backing, and a conducive policy framework substantially improve startup efficacy. The results demonstrate the critical role of incubators in enabling cleantech startups to achieve success across financial, operational, and innovation metrics. The study highlights the importance of mentorship, financial access, regulatory support, and digital transformation in driving startup performance. These findings provide a foundation for evidence-based recommendations aimed at strengthening the cleantech incubation ecosystem.

V. Conclusion

The research examines the function of business incubators in promoting the growth and success of cleantech startups. It discovered that incubators offer essential support systems such as mentorship, technical aid, and strategic networking possibilities, which markedly enhance startup results. The Incubator Support Score correlated with increased revenue growth, patent filings, and market share. The Policy Environment Index indicated that advantageous legislative frameworks, like green tax incentives and innovation subsidies, enhance the efficacy of incubator programs. The research emphasized the increasing significance of digital transformation within the startup ecosystem, as capabilities such as AI, big data, and IoT empower firms to improve operational efficiency. The case studies of Tesla and Proterra corroborated the quantitative findings, underscoring the significance of collaboration among incubators, investors, and governments in fostering a resilient ecosystem for cleantech advancement. Future study may concentrate on longitudinal studies, sector-specific analysis, and comparative studies assessing the efficacy of various types of incubators in promoting innovation.

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