Venture Capital as a Catalyst for Accelerating Innovation: Empirical Evidence from Bangladesh

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Abstract:

Bangladesh's ambition to become a knowledge-based, high-income economy by 2041 hinges on enhancing total factor productivity through innovation. With prior studies offering limited empirical evidence specific to its emerging VC ecosystem, this study examines the role of venture capital (VC) funding in driving innovation, proxied by patent applications, in Bangladesh over a 29-year period (1995–2023). Using data from VentureXpert, the World Bank, and Bangladesh's Department of Patents, Designs and Trademarks, we employ Negative Binomial regression and Autoregressive Distributed Lag (ARDL) models to analyze short- and long-run relationships between VC funding and innovation, while taking a vector of macroeconomic variables (GDP, market capitalization, domestic credit) as control. Negative Binomial Regression results indicate that domestic credit influences patenting, while VC funding shows a positive but insignificant effect. The ARDL model confirms a long-run equilibrium relationship, with GDP positively impacting patenting, but VC's long-run effect remains insignificant, supporting the hypothesis that VC prioritizes non-technological innovations in Bangladesh's weak innovation ecosystem. Aligning with Schmookler's demand-pull hypothesis and Romer's endogenous growth theory, these results suggest VC fosters market-driven innovations (e.g., Pathao, 10 Minute School) rather than patent-intensive R&D. Policy recommendations include strengthening regulatory frameworks, promoting non-technological innovation, and enhancing financial intermediation to bolster Bangladesh's innovation ecosystem and support its economic growth objectives.

Keywords: Venture Capital, Innovation, ARDL Model, Negative Binomial Regression

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1.0 Introduction

Bangladesh has been on a growth trajectory for the better part of the 21st century and is now poised to become the 24th largest economy in the world by the year 2030 to reach a size of $1 trillion[3]. The Government of Bangladesh has set a vision of becoming a "knowledge economy" and a "high-income country" by 2041[4]. Towards that end, the total factor productivity (TFP), driven primarily by innovation (both technological and non-technological), would be crucial to achieve those ambitious goals. In the discussion of innovation, academic literature suggests the existence of different facets of innovation, ranging from the more obvious technological innovation to the less obvious business innovation (Ramdani et al., 2019). Innovation, broadly defined as the development and commercialization of new products, processes, or business models, is a key driver of total factor productivity (Romer, 1990) and long-term economic growth (Porter, 1990; Nelson, 1993). Yet, Bangladesh has consistently lagged in global innovation rankings (105th among 132 economies in the Global Innovation Index – behind regional peers like India, Pakistan, and Sri Lanka[5]. This performance gap raises an urgent policy question: What financial and institutional levers can effectively stimulate innovation in Bangladesh's unique economic context?

One potentially powerful but rather underexplored lever is Venture Capital (VC). Empirical evidence exists, in the context of other countries, especially the ones graduating from low-income to middle- and high-income countries, that venture capital fuels innovation (Kortum and Lerner (2000)). By financing high-risk, high-reward ventures and providing hands-on managerial guidance, VC can overcome the financing and governance limitations of traditional sources (banks, public markets), especially for technology- and knowledge-intensive start-ups. Empirical studies in advanced economies demonstrate that VC-backed firms contribute disproportionately to patenting and new-product introductions (Kortum & Lerner, 2000; Lerner & Nanda, 2020). In emerging markets, nascent VC industries have been associated with higher rates of firm creation, employment growth, and GDP expansion (Samila & Sorenson, 2011; Greenwood et al., 2022). However, the

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[3] The Financial Express. (2023, December 27). *BD set to be 24th largest economy in 2033*. https://today.thefinancialexpress.com.bd/first-page/bd-set-to-be-24th-largest-economy-in-2033

[4] World Economic Forum. (2019, October 22). *How ICT is transforming Bangladesh's economy*. https://www.weforum.org/agenda/2019/10/bangladesh-ict-development-economic-growth/

[5] The Business Standard. (2023, September 28). *Bangladesh slips in innovation index, lags behind India, Pakistan, Sri Lanka*. https://www.tbsnews.net/bangladesh/bangladesh-slips-innovation-index-lags-behind-india-pakistan-sri-lanka-708442

evidence is limited and often inconclusive in contexts where innovation ecosystems are still nascent like that of Bangladesh.

In emerging economies such as Bangladesh, understanding the financial inputs of innovation is especially important for policymakers and investors aiming to foster a knowledge-based economy. While existing studies emphasize the roles of overall economic expansion, stock market development, and credit availability, the impact of venture capital funding, a relatively nascent but fast-growing source of innovation finance, remains underexplored in the context of Bangladesh. Despite the growing VC landscape in Bangladesh, empirical studies on its impact on innovation remain scarce, particularly compared to other emerging economies.

This study fills that gap by examining both the short- and long-run relationships between innovation and venture capital funding in Bangladesh with a data set spanning over 29 years. Specifically, the objectives are to:

a) Evaluate the short- and long-term effects of VC funding on innovation.

b) Classify the type of innovation being impacted by venture capital in the unique Bangladeshi context.

c) Understand the relative contribution of VC funding against other major macro enablers such as economic growth, private sector credit growth, and equity market depth.

By disentangling these dynamics, this paper offers policy insights for the policymakers by giving them specific inputs to target to ensure Bangladesh's economic growth is accelerated by the innovation channel.

This paper is organized in the following manner: The first section deals with the introductory ideas and rationale of the study. Section 2 presents a snapshot of the venture capital trends in Bangladesh till 2023; section 3 reviews the relevant literature, section 4 discusses research design and methodology. Section 5 contains results and discussion. Finally, the paper is concluded with crucial policy recommendations in section 6.

2.0 Venture Capital Funding Trends in Bangladesh

VC funding has been gaining particular momentum in Bangladesh over the past decade as the number of early-stage companies, or startups, has been on the rise buoyed by the conducive factors like a young demographic and policy interventions.

Although a relatively new concept in the Bangladesh economic and financial systems, VC funding is slowly getting its foothold in this country. Both deal frequencies and deal sizes started getting bigger. Historically, up until 2011, most of the active private investors in Bangladesh were foreign (institutional) investors (and possibly with a development-focus). Then in early 2011, some local venture capital companies like BD Venture came into the picture with some decent investment deals. Therefore, Bangladesh's VC landscape can be divided broadly into two eras depending on the domiciles of the investors: Pre-2011 and post-2011. In 2015, Bangladesh saw its first-ever regulation with regards to venture capital investments called "Bangladesh Alternative Investment Rule 2015" which created the foundation for setting up a host of local venture capital firms in Bangladesh[6]. In a few years, the number of firms operating in Bangladesh and the number of deals being done started improving.

Figure-1: Venture Capital Activity in Bangladesh

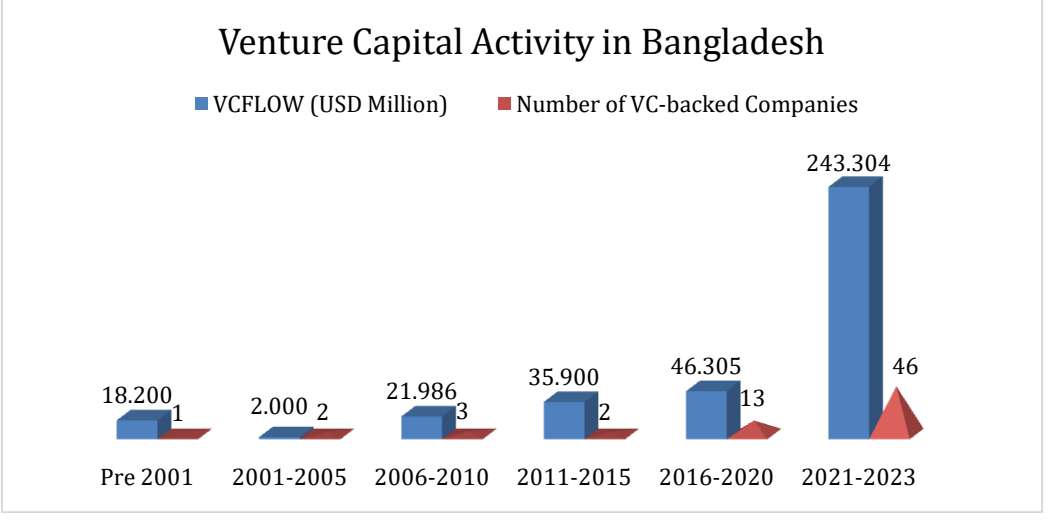

Figure 1 presents the growth of the venture-capital industry in Bangladesh. The blue columns indicate the amount of venture capital flow in Bangladesh in million US dollars. The orange cones show the number of VC-backed companies in the nation. There is a staggering 550% increase in the number of VC-backed companies during 2016-2020 from the previous period. Even though the amount of VC flow has grown modestly by 28%, the jump in the company counts reflect new

[6] OGR Legal. (2015, September 23). *Bangladesh gets first private equity & venture capital financing regulations*. https://resource.ogrlegal.com/bangladesh-gets-first-private-equity-venture-capital-financing-regulations/

entrepreneurial companies joining the VC landscape for the first time, also signaling new VC commitments and funding initiation. This is the period when start-ups like Pathao Ltd, 10 Minute School, Shohoj Ltd, Shikho Technologies Bangladesh Ltd etc. successfully raised venture capital in early and expansion stages for the first time. The next period of 2021-2023 can be considered the golden period of venture capital in Bangladesh as of today. In just 3 years, 46 Bangladeshi VC-backed companies raised around $243 million of venture capital ensuring a financing growth of 425% over the preceding 5 years' flow.

While this surge confirms higher VC commitments supporting more entrepreneurial endeavors at the demand side, it also establishes the popularity of venture capital as a significant source of financing in Bangladesh along with traditional sources. The attractiveness of the Bangladeshi investment pool could also provide a supply-side explanation behind the higher VC flow.

The last decade also saw a diverse investor ecosystem developing beyond the traditional VC firms and funds. Corporate venture capital, angels (both as individuals and as groups/networks), incubators and accelerators, impact funds, government-backed special purpose vehicles etc. started becoming more and more active during the same time using more sophisticated and innovative financing instruments beyond plain vanilla ordinary equity and/or debt.

Figure-2: Number of venture capital firms active in Bangladesh

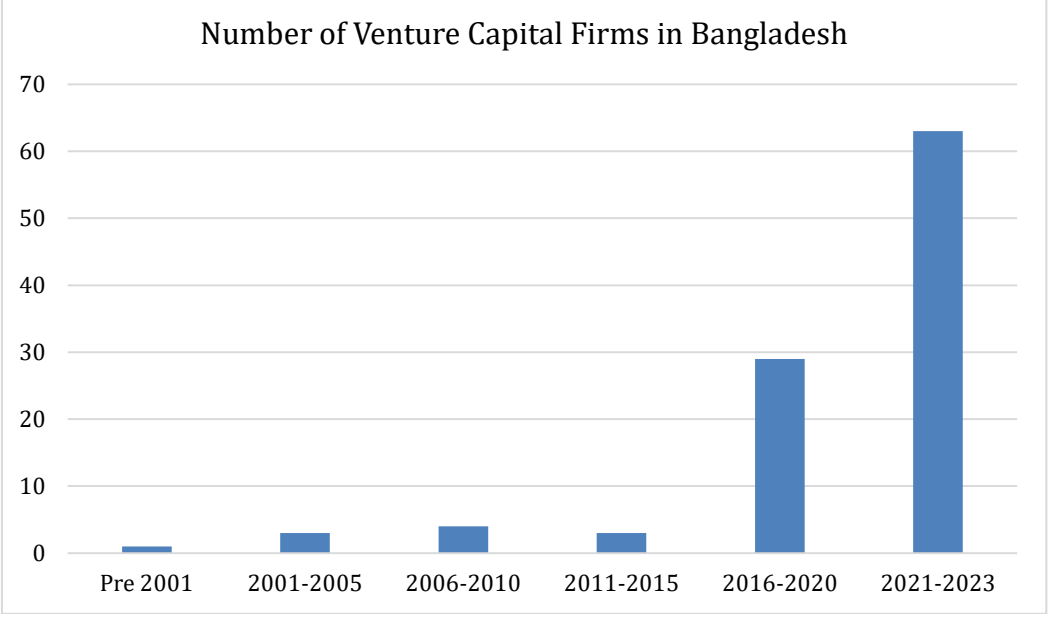

Figure 2 depicts the growth of the venture capital firms actively investing in Bangladesh over the years. The bars show significant jump in their presence post-2015. We further classify those investors as foreign versus local investors and across institutional types such as investment PE firms, accelerators, corporate venture capital firms, etc. We expect to identify particular economic factors responsible for attracting different categories of VC investors in Bangladesh.

3.0 Literature Review

3.1 Innovation and Venture Capital

A robust body of research across advanced economies establishes VC as a major driver of invention and commercialization. Kortum and Lerner (2000) find that, in the United States, industries experiencing growth in VC activity see significant increases in patenting rates despite VC accounting for less than 3% of total R&D funding. Lerner and Nanda (2020) synthesize decades of evidence, highlighting that VC-backed firms contribute 8–14% of industrial innovations and that VC is uniquely positioned to fund projects with high uncertainty and long horizons, which traditional financiers typically avoid. Samila and Sorenson (2011) further demonstrate regional spillovers: U.S. metropolitan areas with higher VC supply exhibit greater patenting, firm births, and subsequent entrepreneurial ecosystems. The impact of VC extends beyond capital provision to include value-added services that amplify innovative potential. Lerner and Nanda (2020) emphasize the importance of VC's managerial expertise, board governance, and network connections in accelerating product development and market entry. Greenwood et al., (2022) argue that VC contributes to economic growth by streamlining commercialization pathways and catalyzing entrepreneurship, thereby boosting aggregate output.

3.2 Contextual Variations and Limitations

The VC-innovation link varies across national contexts. Bertoni and Tykvová (2015) find that in Europe, independent VC boosts patenting in biotech firms, while government-backed VC (GVC) plays a stabilizing role without directly enhancing invention. This suggests that VC market structures shape its impact. Jeng and Wells (2000) identify institutional factors such as IPO activity, labor market flexibility etc. as critical enablers, implying that weaker ecosystems may dilute VC's effectiveness. Peneder (2010) cautions that VC's innovation impact might reflect selection bias, with investments targeting firms already poised for innovation, rather than VC initiating it – a critique that questions causality. Limitations also arise in VC's scope.

Lerner and Nanda (2020) note that VC concentrates on high-growth sectors (e.g., ICT, biotech), potentially skewing national innovation toward specific industries. Ueda and Hirukawa (2011) find that VC's patenting effect weakens when pre-investment innovation is controlled, suggesting its role may be to amplify rather than originate innovation.

3.3 VC and Non-Technological Innovation in Low-Capacity Contexts

In countries with limited technological innovation capacity (marked by weak R&D infrastructure, scarce human capital, or underdeveloped IP systems), VC may not primarily drive technological innovation but instead foster market- and business-model innovation. Furman, Porter, and Stern (2002) argue that national innovative capacity hinges on robust ecosystems, absent in many emerging or smaller economies. In such settings, VC adapts to constraints by prioritizing innovations that leverage existing resources over R&D-intensive pursuits. Beyond the most commonly used measures of innovation (R&D and patens), Kleinknecht et al. (2002) highlight non-technological innovations such as new products, processes, or market strategies as viable outputs, measurable via surveys like the Community Innovation Survey done in the Netherlands. Mairesse and Mohnen (2010) distinguish product innovation (market-facing) and process innovation (efficiency-driven), noting their economic impact without requiring technological novelty. In Africa, VC-backed M-Pesa exemplifies this, using existing mobile technology to create a transformative payment model (Jack & Suri, 2011). Similarly, India's Flipkart, fueled by VC, innovated through logistics and market access rather than tech R&D (Singh, 2019), aligning with Radjou et al.'s (2012) "frugal innovation" framework. These different types of non-technological innovation focuses suggest that venture capital funding providers' adaptive role beyond just providing the financing is key depending on the specific capacity-based contexts they are operating in. Lerner and Nanda (2020) suggest that its expertise and networks can steer firms toward scalable business models when technological paths are limited. Ueda and Hirukawa (2011) find weaker patenting effects in less innovative firms, implying VC amplifies market or operational strengths in low-capacity contexts. However, investor preferences for tech-driven exits (Lerner & Nanda, 2020) might temper this shift, and empirical studies on this dynamic remain sparse, particularly outside advanced economies.

3.4 VC Funding and Innovation: Bangladesh Context

Empirical work on the venture capital landscape in Bangladesh is almost absent primarily due to the lack of data on VC financing and the opacity of private sector

enterprises. A few non-empirical studies, primarily qualitative, review the venture capital evolution on a case-by-case basis and often provide comparative statistics.

A study by Adhikary (2009) emphasizes the importance of venture capital financing to support the growth of Small and Medium Enterprises (SMEs) and fill the financing and governance needs unmet by traditional capital providers such as banks and capital markets. One study by Khan and Chen (2015) provides comparative data on the traditional financing sources for SMEs in Bangladesh and argues for the necessity of government support to establish a healthy venture capital industry in Bangladesh as a financing vehicle for technological innovation.

Another follow-up study by Khan et al. (2017) gathers qualitative primary data through interviews at three Bangladeshi venture capital companies and their investee companies. They identify three broad factors: lack of regulatory support, non-uniform operating process, and uncertainty of the industry's future development as the main challenges obstructing the growth of the venture capital industry in Bangladesh. No prior study has investigated the impact of venture capital investment on the innovation and entrepreneurial endeavors in Bangladesh.

3.5 Hypothesis

H_1: Given Bangladesh's unique context as an emerging economy, increased venture capital funding **does not lead to** a higher number of patent applications (as in countries with weak innovation ecosystems, venture capital adapts to constraints by prioritizing innovations that leverage existing resources over R&D-intensive pursuits.)

4.0 Data and Methodology

4.1 Sources of Data

For this study, we collect data on relevant variables for the sample period of 1995-2023. We gather data on venture capital investment in Bangladesh from VentureXpert from 1995 to 2023. It is to be noted this data set includes the population of VC investment deals in Bangladesh and contains observations on several variables describing the portfolio companies, venture capital firms and investment rounds. While VentureXpert is frequently used in the US VC academic studies, no prior study has used this comprehensive data on Bangladesh venture capital investments with deal-level information. Data has also been aggregated on several macro-economic variables of Bangladesh from the World Bank Open database. Finally, we obtain yearly data on patents and trademarks applications in Bangladesh from the Department of Patents, Designs and Trademarks, Ministry of Industries, Bangladesh.

4.2 The Empirical Model

In this study, the dependent variable is innovation. The study measures innovation using number of patent filings (applications) annually. On the other hand, the primary independent variable is taken as annual venture capital funding in USD million. Following standard literature, we employ a vector of control variables such as economic development (as measured by GDP)[7], stock market development (market capitalization)[8], and domestic credit to private sector (measured in million USD)[9].

Table-1: Variable Definitions

Variable Type	Variable	Definition (Proxy)
Dependent	Innovation	Number of patent filings (applications) annually
Independent	Venture Capital	Annual venture capital funding in million USD
Control	Economic Development	GDP in million USD
Control	Stock Market Development	Market Capitalization in million USD
Control	Domestic Credit to Private Sector	Domestic Credit to Private Sector in million USD

With the objective of understanding what drives the innovation in Bangladesh in the context of financial and economic inputs, we employ two time-series regression models:

i) A Negative Binomial regression and ii) Autoregressive Distributed Lag (ARDL) model in our study.

For both of those models, the dependent variable is the number of annual patent filings. While the annual venture capital funding is the main independent variable, the regression model also contains other macro-economic variables as control variables such as GDP, market capitalization of stock market, and domestic credit to private sector. These variables have empirically demonstrated to exert a significant impact on national innovation output. We expect to see whether venture capital

[7] See (Schmookler, 1966; Coe & Helpman, 1995)

[8] See (Greenwood et al., 2022)

[9] See (Beck, Levine & Loayza, 2000)

funding in a country like Bangladesh with weak innovation ecosystems drives technological innovation as measured by patent applications in Bangladesh. The following general equation represents the economic relationship that we evaluate in this study:

$$Innovation_t = f(VC_t, GDP_t, MCAP_t, DomCredit_t)$$

where $Innovation_t$ is equal to the number of patent application in year t, VC_t is the annual venture capital financing received by startups or other local business headquartered in Bangladesh, GDP_t is the national Gross Domestic Product in year t, $MCAP_t$ is the annual market capitalization of the overall equity of Bangladesh and $DomCredit_t$ is measures the annual flow of total domestic credit to the private sector in Bangladesh. In our regression models, we naturally log-transform our unscaled continuous variables: $VC_t, GDP_t, MCAP_t$ and $DomCredit_t$ to address skewness and ensure a more linear relationship among the variables[10].

5.0 Data Analysis

5.1 Univariate Statistics:

The univariate statistics of the main variables of interest of our study in presented in this section. These variables are subsequently used in several estimation models to gauge empirical evidence about the relationship between venture capital financing and innovation output in Bangladesh.

Table-2: Descriptive Statistics

Variable	N	Mean	Std. Dev.	Min	Max
Patent Applications	29	295.62	112.82	0	447
Annual Venture Capital (in thousand USD)	29	12,679.14	28,666.92	0	139,583.40
Gross Domestic Product (in million USD)	29	164,000.00	137,000.00	37,900.00	460,000.00
Market Capitalization (in million USD)	29	33,100.00	33,300.00	978.00	109,000.00
Domestic Credit to Private Sector (in million USD)	29	61,300.00	56,300.00	7,920.00	179,000.00

[10] We do not log-transform $DomCredit_t$ when it is a % of GDP but only when it is measured in US dollars.

Table 2 presents the descriptive statistics for the key variables used in the analysis. The sample consists of 29 observations. The average number of patent applications is approximately 296 per year, with a standard deviation of 113, indicating moderate variation across observations. Annual venture capital (VC) investment averages to of $12.68 million, but with a large standard deviation of $28.67 million, suggesting a right-skewed distribution with some years receiving disproportionately high VC funding. This evidence also points to the fact that Bangladesh does not have a regular inflow of VC financing every year. Gross Domestic Product (GDP), on average, is $164 billion over the sample period, while market capitalization and domestic credit to the private sector average $33.1 billion and $61.3 billion, respectively. The high standard deviations for GDP, market capitalization, and domestic credit reflect substantial time variation, likely attributable to economic policy uncertainty, political uncertainty, stock market debacle, financial market reforms, among others.

Table-3: Correlation Matrix

Variable	Patent Applications	Annual VC	GDP	Market Cap	Dom. Credit to Private Sector
Patent Applications	1.000				
Annual VC	0.369**	1.000			
GDP	0.562***	0.633***	1.000		
Market Cap	0.509***	0.505***	0.807***	1.000	
Dom. Credit to Private Sector	0.5794 ***	0.6133 ***	0.9957 ***	0.8405 ***	1.0000

*Note: Pearson correlation coefficients are presented. P-values are in italics within parentheses. Significance levels: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.*

Table 3 reports the pairwise Pearson correlation coefficients among the variables. Patent applications are positively and significantly correlated with all financial variables. Notably, GDP and domestic credit show strong correlations with patenting activity, suggesting a potential link between macroeconomic size and innovation output. Annual VC investment is moderately correlated with patent applications and shows stronger correlations with GDP and domestic credit. Overall, the correlations point to significant interdependencies among macroeconomic indicators and innovation-related variables on a univariate basis.

5.2 Negative Binomial Regression

This section discusses the first empirical evidence of a potential relationship between innovation and VC in the context of Bangladesh. In that context, we employ a Negative Binomial regression model which is well-suited for count data, particularly in the presence of overdispersion, a common feature in the data sets of innovation proxies. The Negative Binomial model allows unobserved heterogeneity across observations and is therefore less restrictive than a Poisson model. This specification provides more robust and reliable estimates of the relationship between the explanatory macro-variables and the count of the patent applications. The following equation shows the estimated relationship, and the results are presented in Table 4.

$$Ln(E[Innovation]_t]) = \beta_0 + \beta_1 log(VC_t) + \beta_2 log(GDP_t) + \beta_3 log(MCAP_t) + \beta_4 log(DomCredit_t)$$

Table-4: Negative Binomial Regression Output

Panel A:					
Variable	**Coefficient**	**Std. Error**	**Z**	***p*-value**	**95% Confidence Interval**
Annual VC (Log)	0.021	0.014	1.45	0.146	[-0.007, 0.049]
GDP (Log)	0.339	0.257	1.32	0.186	[-0.164, 0.842]
Market Cap (Log)	-0.368	0.278	-1.33	0.185	[-0.913, 0.177]
Domestic Credit to Private Sector (% of GDP)	0.074	0.045	1.63	0.103	[-0.015, 0.163]
Constant	3.025	2.859	1.06	0.290	[-2.578, 8.628]

Panel B: Model Summary Statistics — Negative Binomial Regression	
Statistic	**Value**
Number of Observations	29
Wald Chi-Square (df = 4)	8.18
p-value (Model)	0.0852
Log Pseudolikelihood	-191.8425
Pseudo R^2	0.0133
ln(α)	–0.197
α (Dispersion)	0.821

Table 4 reports the results from a negative binomial regression estimating the determinants of patent applications, Among the variables considered, the results suggest that domestic credit to the private sector has the strongest association with patent applications. Specifically, a 1% increase in credit availability is associated with a 7.4% increase in the expected number of patent applications, holding other factors constant. Although this coefficient is only marginally significant ($p = 0.103$), it is economically meaningful and consistent with the hypothesis that financial intermediation facilitates innovation through improved capital access. In contrast, the coefficient on venture capital (log-transformed) is positive but not statistically significant ($p = 0.146$), implying that while increased venture capital is associated with more patenting, the relationship is not strong enough to rule out random chance in this sample. It may also reflect measurement noise or limited sample variation given the relatively small panel ($N = 29$). Similarly, GDP exhibits a positive but insignificant effect ($p = 0.186$), whereas market capitalization has a negative and also insignificant coefficient ($p = 0.185$), potentially reflecting a decoupling of public equity market depth from early-stage innovation outputs such as patents. The overall model fit, while modest (Pseudo $R^2 = 0.0113$), provides preliminary evidence that financial development, particularly through credit to the private sector, may play a more substantial role in supporting innovation than broader macroeconomic indicators.

5.3 ARDL Test

This section dives deeper to examine the long-run and short-run dynamics among the selected macroeconomic variables, VC and innovation. In that context, we employ the Autoregressive Distributed Lag (ARDL) Bounds Testing approach to cointegration, developed by Pesaran et al., (2001). The ARDL methodology is particularly appropriate in this context as it accommodates variables that are integrated of different orders, i.e., I(0) and I(1), but not I(2). Given the relatively small sample size and the possibility of mixed integration orders, the ARDL model provides a more flexible and efficient estimation framework. It also allows us to simultaneously estimate both short-run dynamics and long-run equilibrium relationships among the variables within a single equation setup. Prior to conducting the bounds test, we verify that none of the series are integrated beyond the first order. We also check for the stationarity of the variables even though ARDL model can be applied on non-stationary variables as well. The following equation presents the relationship aim to measure with the ARDL model. The terms with Δ measures (any) short-term relationship while the terms with λ estimate the long-run dynamics among the variables:

$$\Delta Innovation_t = \alpha + \sum_{i=1}^{p} \beta_i \Delta Innovation_{t-1} + \sum_{j=0}^{q1} \delta_j \Delta VC_{t-j} + \sum_{k=0}^{q2} \varphi_k \Delta GDP_{t-k} + \sum_{l=0}^{q3} \gamma_l \Delta MCAP_{t-l} + \sum_{m=0}^{q4} \theta_m \Delta DomCredit_{t-m} + \lambda_1 Innovation_{t-1} + \lambda_2 VC_{t-1} + \lambda_3 GDP_{t-1} + \lambda_4 MCAP_{t-1} + \lambda_5 DomCredit_{t-1} + \varepsilon_t$$

Where, Δ denotes first difference operator, p, $q1, q2, q3, q1$ are the lag orders for respective variables, λ coefficients capture the long-run relationship and $\beta, \delta, \varphi, \gamma, \theta$ capture short-run dynamics.

5.3.1 Checking the Stationarity and Optimum Lag Selection

In this section we present results on two diagnostics tests on the underlying time series data before performing the ARDL model. Specifically, we examine the stationarity properties of all variables to confirm that none are integrated of order two, I(2), as the ARDL bounds testing approach requires that variables be either I(0) or I(1). Augmented Dickey-Fuller (ADF) tests are employed to determine the order of integration. The results of the ADF test are presented in Table 5.

Table-5: Augmented Dickey Fuller Test

Variable	Test Statistic	1% Critical Value	MacKinnon p-value	Stationarity	
				Level	1st Difference
Patent Applications	–2.968	–3.730	0.0380	Stationary	Stationary
Annual VC (Log)	–3.602	–3.730	0.0057	Stationary	Stationary
GDP (Log)	0.545	–3.730	0.9862	Non-stationary	Stationary
Market Cap (Log)	–1.734	–3.730	0.4135	Non-stationary	Stationary
Dom. Credit to Private Sector(Log)	1.901	–3.730	0.9985	Non-stationary	Stationary

From the Table 5, it is confirmed that the variables are stationary either at the level or at their first difference. Therefore, they fulfill the condition of being integrated at I(0) or I(1), a necessary condition to estimate the relationship among a given set of variables with the ARDL model.

Next, the optimal lag structure for the ARDL model is determined using a range of standard lag selection criteria, including the Final Prediction Error (FPE), Akaike

Information Criterion (AIC), Hannan–Quinn Information Criterion (HQIC), and Schwarz–Bayesian Information Criterion (SBIC). Table 6 below reports the lag length selection statistics for a VAR model including number of Patent Applications, Annual Venture Capital (Log), GDP (Log), Market Capitalization (Log), and Domestic Credit to Private Sector (Log).

Table-6: Lag Order Selection Criteria

Lag	Log-Likelihood (LL)	LR Stat	df	p-value	FPE	AIC	HQIC	SBIC
0	-961.486	—	—	—	2.6×10^{27}	77.3188	77.3865	77.5626
1	-863.198	196.570	25	0.000	7.8×10^{24}	71.4559	71.8616	72.9185
2	-844.998	36.402	25	0.066	1.8×10^{25}	71.9998	72.7435	74.6813
3	-806.271	77.454	25	0.000	1.4×10^{25}	70.9017	71.9835	74.8021
4	-250.485	1111.600*	25	0.000	7.0×10^{7}*	28.4388*	29.8587*	33.5581*

*Asterisks * indicate the optimal lag length based on each criterion.**

The results in Table 6 strongly support the inclusion of four lags. Specifically, all four criteria (FPE, AIC, HQIC, and SBIC) attain their minimum values at lag 4, indicating superior model fit relative to more parsimonious specifications. Additionally, the likelihood ratio (LR) test statistic for lag 4 versus lag 3 is highly significant ($LR = 1111.600$; $p < 0.001$), rejecting the null hypothesis that a three-lag specification is sufficient. The maximum lag length is particularly appropriate given the dynamic nature of the underlying macro-financial variables, where delayed responses and intertemporal feedback effects are theoretically and empirically plausible. Next, we perform additional tests to identify the individual lags for each of the dependent and independent variables suitable for the ARDL test. We identify the lag structure of [2 0 2 0 1] to be optimal in identifying any long-term relationship and short-run dynamics among the variables through the co-integration test. Any variable whose optimal lag is not 0 will be incorporated as a differenced variable in the model ($\Delta Variable$).

5.3.2 Short-term and long-term relationship between Innovation and Venture Capital

This section contains the discussion on the short-term and long-term economic relationship between innovation and venture capital as estimated with ARDL model (Table 7) and the Bounds test approach to cointegration (Table 8).

Table-7: ARDL Model Estimating the Short- and Long-Run Determinants of Patent Applications

ARDL (2,0,2,0,1) Estimation Results

Dependent variable: ⊿Patent Applications Sample: 1997–2023 (N = 27)

Variable	Coefficient	Std. Error	t-Statistic	p-Value	95% Confidence Interval
Adjustment (ADJ)					
L.Patent Applications	−0.6154***	0.1121	−5.49	0.000	[−0.8520, −0.3788]
Long-run Effects (LR)					
Log(VC)	−1.0977	4.4495	−0.25	0.808	[−10.4854, 8.2900]
Log(GDP)	426.0336**	159.8884	2.66	0.016	[88.6985, 763.3687]
Log(Market Cap)	−47.0954*	23.8058	−1.98	0.064	[−97.3212, 3.1303]
Log(Domestic Credit)	-4.14×10^{-11}**	1.89×10^{-11}	−2.19	0.043	$[-8.12\times10^{-11}, -1.50\times10^{-12}]$
Short-run Dynamics (SR)					
L.D.Patent Applications	−0.1190	0.1653	−0.72	0.481	[−0.4678, 0.2297]
ΔLog(GDP)	−313.4905	216.3664	−1.45	0.166	[−769.9837, 143.0026]
L.D.Log(GDP)	−642.5644***	163.0112	−3.94	0.001	[−986.4879, −298.6410]
ΔLog(Domestic Credit)	5.91×10^{-11}***	1.93×10^{-11}	3.05	0.007	$[1.82\times10^{-11}, 9.99\times10^{-11}]$

*Notes: *, **, and *** denote significance at 10%, 5%, and 1% levels, respectively. $R^2 = 0.7284$, Adjusted $R^2 = 0.5846$, Root MSE = 36.48, Log Likelihood = −129.18*

Table 7 reports the results from an ARDL(2,0,2,0,1) regression model analyzing the short-run and long-run effects of Annual Venture Capital (Log), GDP (Log), Market Capitalization (Log), and Domestic Credit to Private Sector (Log) on the change in Patent Applications. Coefficients, standard errors, t-statistics, p-values, and 95% confidence intervals are presented. The adjustment coefficient (ADJ) reflects the speed of adjustment toward long-run equilibrium.

The ARDL(2,0,2,0,1) model reveals a statistically significant long-run relationship between patent applications and the explanatory variables. The adjustment coefficient on the lagged level of patent applications is negative and highly significant, indicating a strong error correction mechanism whereby approximately 62% of the deviation from long-run equilibrium is corrected within one period. Among the long-run regressors, Log(GDP) exerts a statistically significant and positive influence on patent applications, suggesting that higher economic output is associated with increased innovation activity. This result also supports our findings from the negative binomial regression. Log(Market Capitalization) shows a negative but marginally insignificant impact on innovation reinforcing precious evidence from the negative binomial regression. The coefficient on Log(VC) is negative and not statistically significant at conventional levels. Log(Domestic Credit) has a negative and statistically significant long-run effect, implying that increases in credit availability may not necessarily translate into higher patenting in the long-run, potentially due to allocation inefficiencies or lagged innovation effects.

The study finds that in the short run, the first lag of ΔLog(GDP) is negatively associated with changes in patent applications, indicating a transitory negative response of innovation activity to GDP changes, possibly reflecting adjustment costs or cyclical dynamics. Contemporaneous changes in Log (Domestic Credit) positively affect patenting in the short run, highlighting a short-term stimulative effect of credit expansion. This is in line with our previous evidence of the relationship between innovation and domestic credit from the negative binomial regression. The model's overall fit is acceptable (Adj. $R^2 = 0.5846$), confirming a robust relationship between financial and macroeconomic variables and innovation outputs over the sample period. However, there is no short-run result between innovation and venture capital because the optimal lag length for Log(VC) was selected as zero based on the lag selection criteria in section 5.3.1.

In order to assess possibility of a transitory relationship between innovation and venture capital, the ARDL test was repeated with a lag structure of [2 1 2 0 1]. The

short-term coefficient on ΔLog(VC) is negative and statistically insignificant. However, the absence of any short-run impact of VC on innovation can be due to the gestation lags in innovation. This aligns with several strands of literature whereby academic studies have consistently supported the need for lagged treatment of VC input when it comes to estimating effects on patent output (See Kortum & Lerner (2000), Alvarez-Garrido & Dushnitsky (2013) etc.)

Finally, the ARDL Bounds Testing approach to cointegration proposed by Pesaran et al., (2001) is employed to determine whether a long-run relationship exists among the variables in the model. This method is particularly suitable for small sample sizes and allows for variables to be integrated into different orders (i.e., I(0) or I(1)), making it well-suited for the current analysis. The bounds test evaluates the joint significance of the lagged level variables in the ARDL model using an F-statistic and a corresponding t-statistic. Rejection of the null hypothesis of no level relationship indicates the presence of cointegration among the regressors and the dependent variable. The test results are presented in Table 8.

Table-8: ARDL Bounds Test Results for Cointegration

Pesaran/Shin/Smith (2001) ARDL Bounds Test results:

Statistic	**F-statistic**	**t-statistic**
Test Value	8.812	-5.663

Critical Values for F-statistic (k = 4)

Significance Level	**I(0) Bound**	**I(1) Bound**
10%	2.45	3.52
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.74	5.06

Table 8 reports the results of the ARDL bounds test. The calculated F-statistic is 8.812, which exceeds the upper bound critical value at the 1% significance level (I(1) = 5.06) for the case with unrestricted intercept and no trend with four regressors (k = 4). This provides strong evidence against the null hypothesis of no long-run relationship. Additionally, the corresponding t-statistic for the lagged level of the

dependent variable was −5.663, which also falls below the 1% lower bound (I(1) = −4.60), reinforcing the conclusion of cointegration. Collectively, these results confirm the presence of a statistically significant long-run equilibrium relationship between innovation and the financing and economic variables in the model.

These findings resonate with Schmookler's (1966) demand-pull hypothesis, which posits that innovation is driven by market demand rather than purely technological advancements. In Bangladesh, the surge in VC-backed firms (e.g., Pathao, 10 Minute School) reflects demand-driven innovations in logistics, education, and e-commerce, leveraging existing technologies rather than generating new patents. This is consistent with Kleinknecht et al., (2002), who highlight the importance of non-technological innovations in low-capacity contexts. Similarly, our results echo Radjou et al.'s (2012) concept of frugal innovation, where resource-constrained environments foster scalable business models, as seen in India's Flipkart (Singh, 2019) and Africa's M-Pesa (Jack & Suri, 2011).

The insignificant effect of VC on patenting also aligns with Schumpeterian creative destruction, where innovation disrupts existing markets but may not always manifest in patentable outputs, especially in emerging economies with weak intellectual property (IP) systems (Lerner & Nanda, 2020). Romer's (1990) endogenous growth theory further contextualizes our findings, suggesting that innovation drives long-term growth through knowledge spillovers. However, in Bangladesh, the limited impact of VC on patenting indicates that knowledge spillovers may be constrained by structural barriers, such as inadequate R&D infrastructure and human capital, as noted by Furman et al. (2002). The significant role of domestic credit suggests that broader financial intermediation supports innovation, possibly by enabling incremental improvements rather than the high-risk, high-reward ventures typically associated with VC (Kortum & Lerner, 2000).

6.0 Conclusion and Policy Implication

6.1 Conclusion

This study investigates the relationship between venture capital (VC) funding and technological innovation (proxied by number of patents) in Bangladesh using a 29-year data set. Utilizing both Negative Binomial regression and Autoregressive Distributed Lag (ARDL) models, this study explores whether VC funding plays any role in driving patentable innovation, while controlling for macro-financial variables such as GDP, market capitalization, and domestic credit to the private sector.

The findings suggest that venture capital funding does not have a statistically significant effect on patentable innovations in either the short or the long run. We find that the relationships in both the regression models are positive, the coefficients are not robust ($p = 0.146$ in Negative Binomial and $p = 0.808$ for ARDL). However, domestic credit to the private sector emerges as a strong driver of technological innovation from the Negative Binomial regression results (1% increase in credit availability linked to a 7.4% increase in expected patent filings) whereas GDP growth also exerting a positive and significant long-run effect on patenting ($p = 0.016$) from the ARDL model. These outputs support our hypothesis (H1) that increased VC funding does not lead to higher patent applications in Bangladesh.

These findings lead to four major insights:

1. In line with findings from Furman et al., (2002), absent a strong national innovation capacity, VC funding in Bangladesh is prioritizing non-technological innovations such as scalable business models or market strategies, service-delivery innovations, platform-based startups etc. over R&D-intensive technological breakthroughs. These findings resonate with Schmookler's (1966) demand-pull hypothesis and the surge in VC-backed firms like Pathao, 10 Minute School etc.

2. Bangladesh's realities are consistent with the ideas of frugal innovation (Radjou et al., 2012) and Schumpeterian creative destruction whereby innovation manifests through adaptive solutions pertaining to resource-constrained environments as seen in India's Flipkart (Singh, 2019) and Africa's M-Pesa (Jack & Suri, 2011).

3. Systemic barriers in Bangladesh's innovation ecosystem such as inadequate R&D infrastructure and human capital, as noted by Furman et al. (2002), maybe limiting the role of VCs in driving patentable innovation. The significant role of domestic credit likely suggests that broader financial intermediation supports innovation, possibly by enabling incremental improvements rather than the high-risk, high-reward ventures typically associated with VC (Kortum & Lerner, 2000).

4. There may be existence of gestation lags in VC-driven innovation in Bangladesh, supporting Alvarez-Garrido and Dushnitsky (2013) and Kortum and Lerner (2000), who emphasize gestation lags in VC-driven innovation. This suggests that VC's impact in Bangladesh may be delayed, potentially materializing in non-patent outputs like firm creation or employment growth,

as observed in other emerging markets (Samila & Sorenson, 2011; Greenwood et al., 2022).

Overall, our findings underscore that while VC has fueled entrepreneurial activity in Bangladesh, its role in driving technological innovation remains limited, reflecting the country's early-stage VC ecosystem and institutional constraints.

6.2 Policy Recommendations

To enhance Bangladesh's innovation ecosystem and align with its vision of becoming a knowledge economy by 2041, policymakers should address the structural and institutional barriers identified in this study and prior literature (e.g., Khan et al., 2017). Below, we propose targeted recommendations to strengthen the VC-innovation nexus and boost total factor productivity (TFP):

1. Strengthen regulatory frameworks for VC: The introduction of the Bangladesh Alternative Investment Rule 2015 marked a significant step, but further regulatory clarity is needed. Khan et al. (2017) highlight the lack of regulatory support and non-uniform operating processes as key challenges. Policymakers should streamline licensing, taxation, and exit mechanisms (e.g., IPOs) to attract both local and foreign VC investors, as suggested by Jeng and Wells (2000). Clear guidelines on investor protections and fund structures can enhance VC market maturity, enabling more consistent funding flows.

2. Promote non-technological innovation: Policymakers should encourage VC investments in non-technological innovations, such as business models and process improvements, which are more feasible in Bangladesh's resource-constrained environment (Mairesse & Mohnen, 2010). Incentives like tax breaks or grants for startups focusing on frugal innovation (Radjou et al., 2012) can amplify VC's economic impact without relying on R&D-intensive outputs.

3. Enhance financial intermediation: The significant role of domestic credit in driving patent applications suggests that broader financial access supports innovation. Policymakers should expand credit availability to SMEs and startups through targeted lending programs in collaboration with banks or public-private partnerships, addressing the financing gaps noted by Adhikary (2009).

4. Build innovation ecosystem infrastructure: Given the insignificant VC-patenting link in Bangladesh, investments in R&D infrastructure, IP protection, and human capital development (e.g., STEM education) are critical to enable VC-backed

firms to pursue technological innovation. Public funding for incubators and accelerators, as seen in the diverse investor ecosystem post-2015, can bridge this gap.

These recommendations aim to align Bangladesh's VC ecosystem with its economic goals, leveraging insights from endogenous growth theory (Romer, 1990) to prioritize knowledge creation and Schumpeterian creative destruction to foster disruptive entrepreneurship. By addressing regulatory, financial, and infrastructural barriers, Bangladesh can enhance VC's role in driving both technological and non-technological innovation, paving the way for sustainable economic growth.

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