Fostering innovation in South Asia: Evidence from FMOLS and Causality analysis

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FOSTERING INNOVATION IN SOUTH ASIA: EVIDENCE FROM FMOLS AND CAUSALITY ANALYSIS

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Abstract

Innovation is at the core of fourth industrial revolution which is already under way. Both Sustainable growth and development depend on technological innovation. Traditional economic models/theories are now undermined because of new technologies like AI, automation,3D printing, robotics etc. Lack of innovation creates major socio-economic problems such as inequality, unemployment, poverty and many more. Therefore, in this competitive world, a country needs innovative people with innovative ideas to go forward. The aim of this study is to explain and critically examine the determinants of technological innovation across 5 South Asian countries using yearly data for 1980-2015 period. This paper employs several econometric techniques such as Cross sectional dependence to see if shocks that occur in one country affect another, Panel unit root test to check the stationary of the data and Panel Cointegration test to check long run relationship among the variables. This study also applies Fully Modified OLS to estimate long run coefficients and Dumitrescu and Hurlin panel causality test (2012) to see the causality between the variables. The findings suggest that democracy and human capital are negatively related to innovation, contrary to popular belief. The analysis also reveals that trade openness positively and significantly affects innovation and there exists a nonlinear, in particular an inverted U shaped relationship between innovation and financial development in South Asia. Findings from the Causality test reveals that there is bidirectional causality between total patent application and trade openness and also between financial development and human capital. This study, therefore, has several policy implications for South Asian countries.

Keywords: Innovation; South Asia; Cross sectional dependence; FMOLS; Causality

JEL Classification Codes: C01; C23; O31; O53; R11

1. INTRODUCTION

Innovation has been at the centre of development since the beginning of civilization. Sustainable growth as well as development depends on innovation. Without innovative people with innovative ideas, the countries lag far behind in terms of growth. This creates a trap where the innovative countries get richer and non-innovative countries get poorer. The inequality between them then further worsens. Apart from inequality, lack of innovation creates other socioeconomic problems as well such as poverty, unemployment and many more.

As the industry 4.0 or fourth industrial revolution(4IR) is already under way, hundreds and thousands of lives will be affected by this. Resource constraints will be lower through efficient and productive technology. Our daily tasks will become easier. People will have more access to information, thus innovation and technological advancement in this era of 4IR will have Significant effects on society.

Therefore, to foster innovation and innovation led growth, it is important that countries are ready for innovative friendly environment. More research and development sector, more patent grants should be available. Unfortunately, South Asia is failing to keep face with other regions in terms of these crucial factors. As the figure 1 in appendix reveals, apart from India, no of total patent application is very lower in other 4 countries such as Bangladesh, Nepal, Pakistan and Sri Lanka. South asia as a whole, therefore, are losing out the opportunity for a new growth momentum.

According to global innovation index report of 2018, South Asia's economies including Bangladesh, Nepal, Pakistan and Sri Lanka are listed among the least innovative countries of the whole world. The reason is most probably because unlike other regions, South Asia is unable to turn 4IR innovative idea into profitable wealth creation opportunities. Examining patterns of innovation of South Asia in details, Cirera and Cusolito(2019) recently stated that quality upgrading innovation or vertical innovation is higher in South Asia, but not the introduction of new products or horizontal innovation which is quite disappointing since introduction of new products is more likely to bring economic development at a faster rate.

Given this background, it is therefore important to understand the key factors that are responsible for technological innovation in South Asia. So this study makes an attempt to assess the determinants of innovation in South Asia, paying particular attention to the impact of democracy on innovation and nonlinear nexus of financial development and innovation. To the best of this author's knowledge, although a considerable amount of time series studies has been carried out for individual South Asian economies (e.g. Mishra,2007; Aftab,2017)), there have been few empirical investigations into evaluating the determinants of innovation for South Asia as a whole. This paper, therefore, seeks to fill that gap.

The remaining part of this paper is organized as follows: Section 2 presents literature review, section 3 is concerned with description of data and methodology and section 4 analyses the estimation results. Finally, section 5 gives a brief summary, implications and limitations of the study.

2. *Literature review*

Researchers and economists over the years have tried to link technological innovation with several important macroeconomic variables and in the process derived significant policy implications for their respective countries of study.

Varsakelis (2006) empirically tested the role that quality of education and governmental institutions plays on number of patents for 29 countries. Findings from random effect estimation suggests that if the efficiency of government institution can be included along with the qualitative education system, then the country will have a productive innovative system and this will improve the growth rate. Their findings support the result of Furman et al. (2002) who found that level of innovative capacity depends on the level of investment in human capital. Later, Teles and Joiozo(2011) also recommended that if the government increases educational expenditures, then it will be productive in the long run because it will spur innovation, technical progress and growth. But this is possible only if we are to accommodate a level structural break.

Anokhin and Schulze (2009) considered 64 countries to see the relationship among innovation, corruption and entrepreneurship. Their findings suggest that if corruption can be controlled, then innovation and entrepreneurship can be improved.

Lau et al (2012) made a robust contribution in literature by examining the impact of corruption, foreign direct investment and education spending on innovation for Europe and Central Asia region (ECA). Their findings indicated that even though it seems that FDI has positive spillover effect but it disappears once corruption is introduced. This suggests that innovation activities in that region are not a true representation of innovation outcomes since the quality of patent application is extremely connected to bribery. So corruption/ bribery is a major constraint for real innovation and for the growth as well. Recent evidence has focused more on the effects of institutional quality on technological innovation.

For example, taking Popper's hypothesis as their initial objective, Gao et al. (2017) has explored the impact of democracy on innovation for 156 countries from 1964 to 2010.They used three measures of innovation namely patent application counts, patent citations and patent originality. They found that effect of democracy on innovation is not statistically significant; rejecting the Popper's hypothesis. Their results turned out to be the same for all three measures of innovation. They also found that GDP per capita and education significantly determine innovation.

In their seminal article of finance-innovation nexus, Law et al. (2018) argues that a nonlinear relationship exists between financial development and innovation but this relationship is also influenced by institutional quality. This inverted U shaped relationship was validated in their study. For the 75 developed and developing countries they studied, their results revealed that this inverted U shaped relationship differs with the institutional quality of different countries. A U shaped relationship was found between finance and innovation for the countries whose institutional qualities are weak whilst inverted U shaped relationship was found for the countries whose institutional quality are high.

Diebolt and Hippe (2019) took a long run regional level approach for Europe to inspect the effect of human capital on innovation and GDP per capita in long run. For human capital, they used their own dataset which they developed in 2017 over the period of 1850-2010.This large dataset helped them to conclude that human capital is significantly related to current patent applications per capita and current GDP per capita.

Studies also focused on innovation determinants of South Asian countries. For example, Mishra (2007) used data of Indian firms to identify the factors influencing their R&D expenditures. They found that human capital, market share of the firms, firm size and age can well explain R&D imitative among Indian firms. Similarly, Mahmud and Ahmed (2011) also found firm size to be a key factor of innovation activity in Pakistan.

Aftab(2017) analysed firms' level innovation for developing economies but paid a particular attention to Pakistani firms. While he finds that corruption hinders research investment but at the same time, skilled labour force can significantly and positively affect innovation activities among the Pakistani firms.

According to Cirera and Cusolito(2019),quality upgrading innovation or vertical innovation is higher in South Asia, but not the introduction of new products or horizontal innovation. They found that larger firms are more likely to be engaged in R&D as compared to small firms. Their findings also indicate that financial constraints negatively affect investment in R&D for all economies of South Asia except for Bangladesh. Surprisingly, their results showed that R&D adoption is negatively associated with technological innovation for the leaders (Bangladesh and India). ICT use acts as innovation enabler in at least two out the 4 countries. Except for Bangladesh, lack of skilled labour is negatively correlated with innovation intensity, even though correlation is only marginal. Knowledge spill overs positively affects innovation induced turnover for India and Bangladesh but not for Nepal and Pakistan.

So far investigations have been confined to time series studies of individual South Asian economies. Few attempts have been made in order to determine the factors responsible for South Asia's innovation dynamics as a whole. Therefore, we deem it necessary to model the determinants of technological innovation in South Asia. This study shall make an important contribution in the literature in the sense that it not only examines the link between democracy and innovation in South Asia, it also tries to establish a nonlinear relationship between finance and innovation.

3. *Data and Methodology*

This section focuses on model specification, data and variables description and also on estimation methodologies. The empirical analysis has been done with the help of several software packages such as EVIEWS & STATA.

3.1 Model Specification

Based on empirical literature review, the general equation for current account balance is as follows:

$$\text{Pat\_app}=f\,(\text{Dem, Hum\_cap, Open, FD, FD}^2) \quad (1)$$

Where Pat_app stands for Total patent application, Dem stands for democracy as proxied by political rights, Hum_cap stands for human capital as proxied by gross secondary school enrolment (%), Open indicates trade openness of the country proxied by sum of exports and imports as a share of GDP, FD stands for financial development as proxied by Domestic Credit to Private Sector (% of GDP) and FD^2 is the square of financial development.

3.1.1. Description of the Data

This study consists of 5 South Asian countries over the 1980-2015 period. The countries included in this study are Bangladesh, India, Nepal, Pakistan and Sri Lanka. The study period is chosen based on the availability of data. The dependent variable is innovation as proxied by total patent application. The reason for choosing patent application is because, according to Acs and Audretsch (1989), patents are a reliable proxy for an innovation rather than R&D expenditures.

The data for patent application is taken from WIPO statistics database.

We have included several explanatory variables for explaining the innovation scenario in South Asia.The data sources of the independent variables along with their expected relationship with innovation are described as follows:

- Democracy: Democracy is measured by political rights which is one of the two indicators developed by freedom house, other one is civil liberties. The political rights index takes value from 1 to 7.A value of 7 indicates lowest level of democracy and a value of 1 indicates the highest level of democracy. According to Karl Popper (2005,2012),democratic structures and liberal social structures are helpful in developing innovation.The positive impact of democracy on innovation is called Popper hypothesis.

- Human capital: To nurture innovation, investment in human capital is a must. Following Chowdhury et al. (2018),data of human capital as proxied by secondary enrolment (% gross), has been also taken from World development indicator(WDI). Human capital can contribute positively toward have innovation but the quality of education in the respected country matters too.

- Financial development: The data for domestic credit to private sector (% of GDP), which has been applied widely as a proxy for financial development in literature(e.g. Law et al.,2017), is obtained from World development indicator. The effect of financial development on innovation is found to be positive my many researchers including Aghion and Howitt (2005), We also include the squared form of financial development here to find a nonlinear relationship between financial development and innovation as suggested by Law and Chang (2017).
- Trade Openness: Trade share of GDP (sum of exports and imports expressed as a ratio of GDP) is a reliable measure of trade openness as trade performance of a country captures the most important dimension of a country's openness in general (Sakyi et al.,2012). Data of this variable has been extracted from World Development indicator(WDI). Trade liberalization has economically significant effect on innovation (Coelli et al.,2016).

A summary of data description and data source is given in table 1 of appendix. Descriptive statistics is also reported in table 2. From Jarque-Bera probability it is clear that 2 out of 6 variables are normally distributed. But violation of normality is not a major problem since we have sufficient observations.

3.2 Methodology

3.2.1. Cross Sectional dependence test

Cross sectional correlation/dependence has to do with impact of shocks in one country on another country when both countries belong in the same region (South Asia in this case). It can be checked via several tests such as Breusch-Pagan (1980) LM,Pesaran(2004) scaled LM , Pesaran(2004) CD test and a more recent test developed by Baltagi, Feng and Kao(2012).

When N is fixed and T→∞, the most appropriate test is that of Breusch-Pagan (1980). The test statistics can be written as:

$$LM=T_{ij}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}^{2} \longrightarrow \chi^{2}\,\frac{N(N-1)}{2}$$

Here $\hat{\rho}_{ij}$ denotes correlation coefficient derived from each residual. However, this test cannot be applied when N tends to infinite. So Pesaran (2004) proposed a test which is applicable for infinite T and N and it is also based on pairwise correlation coefficient $\hat{\rho}_{ij}$:

$$CD_{\text{scaled LM}}=\sqrt{\frac{1}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}(T\hat{\rho}_{ij}^{2}-1) \longrightarrow N(0,1)$$

But for N>T, Pesaran (2004) suggested another different test:

$$CD=\sqrt{\frac{2T}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}$$

A more recent test is Bias corrected scaled LM test advocated by Baltagi, Feng and Kao (2012). The test statistic is given as:

$$LM_{BC}=\sqrt{\frac{1}{N(N-1)}}\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}(T\hat{\rho}_{ij}^{2}-1)-\frac{N}{2(T-1)} \longrightarrow N(0,1)$$

3.2.2. Panel Unit Root test:

Cross sectional correlation or in other words cross sectional dependence means the residuals of entities or panels (e.g. countries in the panel data) are significantly correlated across entities. When residuals are correlated across the cross sections, it simply means that shocks to one of the entities has impact on one or more of the others. Two generations of unit root tests can be distinguished depending on whether they allow for correlation across residuals of panel units or not (Hurlin and Mignon 2007). The tests which assume cross sectional correlation to be zero are first generation panel unit root and those which do not assume are second generation unit root tests. First generation tests do not allow cross sections to be dependent while second generation tests do.

A second generation unit root test called Pesaran (2007) unit root test has been applied in this study.His test is augmented version of basic Dicky-Fuller (CADF) regression given by:

$$\Delta y_{it}=a_i+b_i y_{i,t-1}+c_i\bar{y}_{t-1}+d_i\,\Delta\bar{y}_{t-1}+e_{it} \quad (2)$$

Here , $\bar{y}_{t-1}$ represents laggled level form of the mean value and $\Delta\bar{y}_t$ is also mean but in first differenced form.

Pesaran's test is augmented version of Im,Pesaran and Shin test and can be written as :

$$CIPS(N,T)=N^{-1}\sum_{i=1}^{N} t_i(N,T)$$

3.2.3. Panel Cointegration Test

The next step after doing unit root tests involves checking long run relationship among the variables that is if they move together in the long run or not. Here we apply Westerlund(2007), which allows cross sections to be dependent.

Westerlund (2007) test proposes four error correction based test statistics. Two of them are ‘group mean’ and other two are ‘pooled mean’ estimation. Apart from allowing cross sections to be dependence, another beauty of Westerlund (2007) is that it is also applicable in the heterogeneous panel.

The following model is suggested by Westerlund (2007):

$$\Delta y_{it} = \delta_i' d_t + \alpha_i y_{i,t-1} + \lambda'_i x_{i,t-1} + \sum_{j=1}^{p_i} \alpha_{ij} \Delta y_{i,t-j} + \sum_{j=-q_i}^{p_i} \Upsilon_{i,j} \Delta x_{i,t-j} + u_{it}$$

Here α_i is the error correction term. Westerlund(2007) tests whether this term is different from zero or not. For example, if this term equals zero that would indicate no cointegration but if it is less than zero then it means there is cointegration. The alternative hypothesis for the first two test statistics (group mean tests) is that one unit is coitegrated at least. The other two, pooled panel tests, has the alternative that as a whole panel is cointegrated. They just differ according to their structure of alternative hypothesis; null hypothesis is same

3.2.4. Long Run Estimation

When evidence of cointegration is confirmed, we estimate the long run coefficient by using Fully modified OLS(FMOLS) which developed by Phillips and Hansen (1990).

The seminal work of Phillips and Hansen (1990) was later extended to panel setting by Phillips and Moon(1999), Pedroni(2000),Kao and Chiang(2001).

One of the superiority of FMOLS over other estimators is that it controls for endogeneity and serial correlation problems(Ramirez,2007). The superiority of FMOLS over other existing models is that when it estimates the long run relationship, it allows for country specific fixed effect (Pedroni,2000).

We consider the following model:

$$y_{it}=\alpha_i+x_{it}\beta+u_{it}$$

i=1…N represents cross section units and t=1…T represents time series units.

The FM_{OLS} estimator is defined as:

$$\hat{B}_{FM}=[\sum_{i=1}^{N}\sum_{t=1}^{T}(x_{it}-x_i)']^{-1}[\sum_{i=1}^{N}(\sum_{t=1}^{T}(x_{it}-x_i)'\hat{y}_{it}^{*}+T\hat{\Delta}_{\varepsilon\mu}^{*})]$$

here, $\hat{y}_{it}^*$ is endogenous variable in transformed form and $\hat{\Delta}_{\varepsilon\mu}^{*}$ represents the parameter for autocorrelation adjustment.

3.2.5. Causality test

After getting long run relationship, causality test helps us to see whether there is any unidirectional or bidirectional causality. Here we employ Dumitrescu and Hurlin panel causality test (2012). Their panel statistics have the ability to increases the power of Granger non causality when both time and cross sectional units are small. When cross sectional dependence exists,this test produces unbiased result (Anoruo and Elike 2015).

Consider the following linear model:

$$y_{i,t}=\alpha_i+\sum_{k=1}^{k}\Upsilon_i^{(k)}y_{i,t-k}+\sum_{k=1}^{k}\beta_i^{(k)}x_{i,t-k}+\varepsilon_{i,t}$$

where K is optimal lag length. The individual effects denoted by α_i are fixed in time dimensions and lag order K are identical for all cross section units. Further, $\Upsilon_i^{(k)}$ and $\beta_i^{(k)}$ differ across groups.

Individual Wald statistics in average is given by:

$$W_{N,T}^{Hnc}=1/N\sum_{i=1}^{N} W_{i,T}$$

The null hypothesis is that of no causal relationship. However, there are two subgroups for alternative hypothesis: one says that x to y have causal relationship and another one identifies no relationship.

According to Dumitrescu and Hurlin(2012),all coefficients are heterogeneous across cross sections.

4. *Results and Discussions*

4.1. Empirical Results for Cross Sectional Dependence Test

Before checking the stationarity of the variables, it is necessary to check for cross sectional dependence since all the countries in this study are of same region and shocks in one country may affect the other ones. Ignoring cross sectional correlation in panels can have serious consequences. (Badi H. Baltagi, 2016). Cross sectional dependence is analyzed through the means of BreuschPagan LM test (1980),Pesaran scaled LM test(2004),Bias corrected scaled LM test(2012) and Pesaran CD(2004) tests.

Table 1: Test results for Cross Sectional Dependence of the Variables

Variables	Breusch-Pagan LM	Pesaran scaled LM	Biascorrected scaled LM	Pesaran CD
Pat_app	269.4123***	58.00635***	57.93492***	16.39268***
Dem	52.49418***	9.501988***	9.501988***	-1.439826
Hum_cap	288.2509***	62.21879***	62.14736***	16.95103***
Open	87.91941***	17.42331***	17.35188***	1.321137
FD	161.6962***	33.92031***	33.84888***	5.351656***
FD^2	161.6964***	33.92034***	33.84891***	5.351647***

Note: ***,**,* denotes rejection of null hypothesis of no cross sectional dependence at 1%,5% and 10% level.

Table 1 reports the results of Cross Sectional Dependence of the respective variables in our study. Breusch -Pagan LM, Pesaran scaled LM and Bias-corrected scaled LM tests all reject the null hypothesis of no cross sectional dependence at conventional level of significance for all the variables. However Pesaran's CD test (2004) cannot reject the null hypothesis of cross sectional independence for democracy and trade openness.

Since null hypothesis of cross sectional independence can be rejected for majority of the CSD tests here, it implies that there is cross sectional dependence and we need to take it into account while doing further analysis.

4.2. Panel Unit Root Test Results

First generation panel unit root tests are not reliable when there exists cross sectional dependence indata. Therefore, it is necessary to conduct second generation panel unit root tests which can account for cross sectional dependence. In order to analyze the stationary characteristics of the variables, Pesaran's CIPS unit root test has been applied. Table 2 reports the result of CIPS panel unit root test.

Table 2: Panel Unit Root Test Results

Variables Name	CIPS test				
	Intercept	Intercept+trend	Intercept		Intercept+trend
Pat_app	-2.489	-2.738	ΔPat_app	-5.813***	-6.089***
Dem	-2.211	-2.183	ΔDemoc	-5.635***	-5.588***
Hum_cap	-2.111	-1.654	ΔHum_cap	-4.446***	-4.566***
Open	-1.804	-1.738	ΔOpen	-5.446***	-5.477 ***
FD	-2.039	-2.012	ΔFD	-4.734***	-4.834***
FD^2	-2.486	-2.492	$\Delta F\ D^2$	-4.986***	-4.957***

Note: *** denotes rejection of null hypothesis of unit root at 1% level.

The test is calculated for both ‘Intercept’ and ‘Intercept and trend’ specifications and lag order is set at maximum equal to 1(p=0,1). The null hypothesis of non-stationarity cannot be rejected for all the variables at level when both Intercept and Intercept and trend specifications are taken into account. But all the variables become stationary at first difference which tells us that all the variables under this study are I(1).

4.3. Panel Cointegration Test Result

Since all our variables are I(1),we can now perform cointegration tests for checking long run relationship among the variables. To tackle the cross sectional dependence problem, we use Westerlund(2007) Panel Cointegration test.

The result of Westerlund(2007) Cointegration test based on 800 bootstrap replications is reported in table 3. When we use robust P values and thereby making allowance for cross sectional dependence, the null hypothesis of no cointegration is rejected for 2 out of 4 statistics.

Therefore, we can strongly conclude that there is strong evidence of long run cointegrating relationship within the variables across the 5 countries under study.

Table 3: Westerlund (2007) Cointegration test result

Statistic	Value	P value	Robust P value
Gt	-3.753	0.036	0.014
Ga	-4.883	1.000	0.596
Pt	-6.188	0.517	0.036
Pa	-4.742	0.997	0.501

Note: Trend Assumption: Intercept and Trend. The width of the Bartlett kernel window is determined according to the rule 4(T/100) ^2/9.AIC with maximum lag (1) and leads (1) have been used for optimal lag length. Bootstrapped p values are obtained using 800 replications.

4.4. FMOLS results

To tackle the cross sectional dependence problem, the demeaning procedure has been used for FMOLS estimation.

Given the evidence of cointegration among the variables, we can now proceed further to estimate long run coefficients via FMOLS. We have included the results of DOLS for the sake of the comparison. Table 4 reports the results of Panel weighted FMOLS.

Table 4: Panel Fully Modified OLS result

Variables	Coefficient value	P value
Dem	.177821	.0042
Hum_cap	-.295174	.0000
Open	.919495	.0000
FD	7117.817	.0000
FD_2	-3558.788	.0000

The impact of democracy, as measured by political rights, on innovation is positive and statistically significant at even 1% level as found by FMOLS, rejecting the proposition of Popper's hypothesis. That means that countries with higher level of democracy tend to have lower volume of innovation. This result contrasts starkly with the findings of much of the empirical literatures. However, this is fully in line with Jones and William (2000). They found that a decentralized economy is more likely to underinvest in innovation (as measured by R&D) as compared to socially efficient level.

This underinvestment happens because 2 distortions: the surplus appropriability problem (innovators cannot appropriate the entire consumer surplus of their innovation), knowledge spillovers (standing on the shoulders of past innovators). This might also be because it is easier for the autocratic countries to invest more in some specific fields such ads military and defence research, science and technology research. Democratic transitions may take time for intuitional reforms to fuel innovation (Gao et al.,2017).

Financial development as proxied by Domestic credit (% of GDP) has a positive and statistically significant effect on innovation but its square has a significant negative effect on innovation. This implies that Financial development and innovation has a inverted u shaped relationship. This means that innovation increases at the initial stage with a developed financial system, but as the financial sector develops into a mature stage, financial development will then negatively affect innovation activities in South Asia(Law et al.,2018).

This study finds that trade openness has positive and significant effect on innovation. The primary reason why trade openness might increase innovation is because a large market size creates incentives for innovating (Acemoglu and Linn,2004; Desmet and Parente,2010). For any innovators, what is necessary is an initial investment and this can be recovered by the profits they accrue. Therefore, a larger market will imply greater profit level. This can also be explained by

'preference effect' which says that foreign competition may exert more efforts to innovate for domestic innovators. Coe and Helpman (1995) showed that TFP growth depends equally on foreign R&D investment as it depends on domestic investment on R&D.

FMOLS estimation of human capital, as proxied by secondary school enrolment, shows that human capital has a negative and robustly significant effect on innovation which indicates that increase in human capital results in the reduction of innovative activities. This is in line with Pratono (2014) who found that human capital negatively affects innovation success using factor analysis and OLS regression. The reason maybe is because quality of the education matters, not the quantity as we have measured here by attainment of specific educational level (Hanushek and Woessmann 2012,)

4.5 Causality test result

To determine the causal association between the variables, Dumitrescu and Hurlin(2012) panel causality has been applied.The lag selection is based on Schwarz information criterion(SIC). Table 5 reports the result of Dumitrescu and Hurlin(2012) panel non-causality test.

Table 5: Dumitrescu and Hurlin(2012) panel causality test result

Direction of Causality	W-Stat	Z-bar Stat	Prob
Pat_app → dem	1.0738	0.0100	0.9920
Dem → Pat_app	1.3907	0.4564	0.6481
Pat_app → open	39.2627	1.8801	0.0601
Open → Pat_app	6.2871	4.0002	0.0001
Pat_app → Hum_cap	1.4574	.5505	0.5820
Hum_cap → Pat_app	4.1345	4.3219	0.0000
Pat_app → FD	2.2524	1.6705	0.0948

FD → Pat_app	1.9880	1.2980	0.1943
Dem → Hum_cap	2.5541	2.0954	0.0361
Hum_cap → dem	0.8488	-0.3069	0.7589
Dem → open	1.0919	0.0356	0.9716
Open → Dem	1.7462	0.9573	0.3384
Dem → FD	1.5089	0.6230	0.5333
FD → Dem	0.5577	-0.7170	0.4734
Hum_cap → Open	1.9136	1.1931	0.2328
Open → Hum_cap	31.2982	1.2174	0.2234
Hum_cap → FD	3.1163	2.8874	0.0039
FD → Hum_cap	3.3095	3.1596	0.0016
Open → FD	1.8129	1.0513	0.2931
FD → Open	3.2912	3.1339	0.0017

It is apparent from the above table that there exists a bidirectional causality between total patent application and trade openness, human capital and financial development. Unidirectional causality runs from human capital to total patent application, patent application to financial development, democracy to human capital, from financial development to trade openness.

5.Conclusion and Policy Recommendations

Traditional economic models/theories are now undermined because of new technologies like AI, automation,3D printing, robotics etc. The 4IR is radically changing the relationship between individual societies and institutions. 4IR is supposed to bring changes in our lives at a scale unlike anything we have ever experienced before. Given this importance of innovation in 4IR era, this study takes an attempt to figure out what are the key factors that can foster innovation in South Asia.

The findings of the study can be summarized as follows, First, contrary to expectations, the study finds that democracy negatively affects innovation. So Popper's hypothesis is not valid for South Asia. Second, like democracy, human capital has also turned out to have negative impact on innovation.

Third, trade openness is found to have significant positive impact on innovation. This is because as countries become more and more open, foreign competition increases and so does the innovative production capacity of domestic producers.

Fourth, this study finds that financial development and innovation has a nonlinear relationship between them. In particular, at the initial stage, a developed financial system increases innovation but at the later stage it hinders innovation which implies an inverted U shaped relationship. Findings from the Causality test reveals that there is bidirectional causality between total patent application and trade openness and also between human capital and financial development. There also exists Unidirectional causality from human capital to total patent application, patent application to financial development, democracy to human capital, from financial development to trade openness.

The analysis has several policy implications also. Since trade openness leads to an increase in national innovation, it is necessary to promote liberalisation policies more often in south Asia. This study also finds that finance-innovation nexus in South Asia is nonlinear and therefore policymakers need to take this into account while designing policies related to country's financial system.

The findings also have several limitations. Our study finds that democracy negatively affects innovation which was rather unexpected, this might have happened due to our measure of democracy. Our measure of human capital also suffers from the same problem as that of democracy variable, Future research that investigates the innovation dynamics incorporating other measures of democracy and human capital would provide an interesting contribution to the existing literature.

References

Acemoglu D, Linn J (2003) Market Size in Innovation: Theory and Evidence from the Pharmaceutical Industry. SSRN Electronic Journal. doi: 10.2139/ssrn.457440

Aghion P, Howitt P, Mayer-Foulkes D (2005) The Effect of Financial Development on Convergence: Theory and Evidence*. Quarterly Journal of Economics 120:173-222. doi: 10.1162/qjec.2005.120.1.173

Anokhin S, Schulze W (2009) Entrepreneurship, innovation, and corruption. Journal of Business Venturing 24:465-476. doi: 10.1016/j.jbusvent.2008.06.001

Anoruo E (2015) Human Capital-Economic Growth Nexus in Africa: Heterogeneous Panel Causality Approach. International Journal of Economics and Financial Issues 5:1017-1023.

Baltagi B, Kao C, Peng B (2016) Testing Cross-Sectional Correlation in Large Panel Data Models with Serial Correlation. Econometrics 4:44. doi: 10.3390/econometrics4040044

Breusch T, Pagan A (1980) The Lagrange Multiplier Test and its Applications to Model Specification in Econometrics. The Review of Economic Studies 47:239. doi: 10.2307/2297111

Chowdhury, M. N. M., Uddin, M. J., Uddin, N., & Uddin, S. (2018) Human Capital Development and Economic Growth in Bangladesh. Journal of World Economic Research 7:52-63.

Coelli F (2016) Better, faster, stronger: Global innovation and trade liberalization (No. w22647). National Bureau of Economic Research.

Coe D, Helpman E (1995) International R&D spillovers. European Economic Review 39:859-887. doi: 10.1016/0014-2921(94)00100-e

Desmet K, Parente S (2010) Bigger is better: Market size, demand elasticity, and innovation. International Economic Review 51:319-333. doi: 10.1111/j.1468-2354.2010.00581.x

Diebolt C, Hippe R (2018) The long-run impact of human capital on innovation and economic development in the regions of Europe. Applied Economics 51:542-563. doi: 10.1080/00036846.2018.1495820

Dumitrescu E, Hurlin C (2012) Testing for Granger non-causality in heterogeneous panels. Economic Modelling 29:1450-1460. doi: 10.1016/j.econmod.2012.02.014

Furman J, Porter M, Stern S (2002) The determinants of national innovative capacity. Research Policy 31:899-933. doi: 10.1016/s0048-7333(01)00152-4

Granger C (1969) Investigating Causal Relations by Econometric Models and Cross-spectral Methods. Econometrica 37:424. doi: 10.2307/1912791

Hanushek, E. and Woessmann, L. (2012). Do better schools lead to more growth? Cognitive skills, economic outcomes, and causation. *Journal of Economic Growth*, 17(4), pp.267-321.

J. Acs, Z. and Audretsch, D. (1989). Patents as a Measure of Innovative Activity. *Kyklos*, 42(2), pp.171-180.

Jones C (2000) Too much of a good thing? The economics of investment in R&D. Journal of Economic Growth 5:65-85

Hurlin C, Mignon V (2007) Second Generation Panel Unit Root Tests. Working Papers, HAL

Kao C, Chaing M (1999) On the Estimation and Inference of a Cointegrated Regression in Panel Data. SSRN Electronic Journal. doi: 10.2139/ssrn.1807931

Lau C, Yang F, Zhang Z, Leung V (2015) Determinants of Innovative activities: Evidence from Europe and Central Asia region. The Singapore Economic Review 60:1550004. doi: 10.1142/s0217590815500046

Law S, Lee W, Singh N (2018) Revisiting the finance-innovation nexus: Evidence from a non-linear approach. Journal of Innovation & Knowledge 3:143-153. doi: 10.1016/j.jik.2017.02.001

Mishra V (2007) The determinants of R&D expenditures of firms: Evidence from a cross section of Indian firms. Economic Papers: A journal of applied economics and policy 26:237-248. doi: 10.1111/j.1759-3441.2007.tb00433.x

Pedroni P (2004) Panel Cointegration: Asymptotic and finite sample properties of pooled time series test with an application to PPP hypothesis. Econometric Theory. doi: 10.1017/s0266466604203073

Pedroni P (2001) Fully Modified OLS for Heterogeneous Cointegrated Panels. Advances in Econometrics 15

Pesaran M (2004) General Diagnostic Tests for Cross Section Dependence in Panels. Cambridge Working Papers in Economics 0435, Faculty of Economics, University of Cambridge.

Pesaran M (2007) A simple panel unit root test in the presence of cross-section dependence. Journal of Applied Econometrics 22:265-312. doi: 10.1002/jae.951

Phillips P, Moon H (1999) Linear Regression Limit Theory for Nonstationary Panel Data. Econometrica 67:1057-1111. doi: 10.1111/1468-0262.00070

Phuc Canh N, Schinckus C, Thanh S (2019) Do economic openness and institutional quality influence patents? Evidence from GMM systems estimates. International Economics 157:134-169. doi: 10.1016/j.inteco.2018.10.002

Popper K (2005) The Logic of Scientific Discovery. Routledge, New York. Popper K (2012) The open society and its enemies. Routledge.

Suyanto S, Pratono A (2014) The Impact of Entrepreneurship Orientation, Human Capital, and Social Capital on Innovation Success of Small Firms in East Java. Jurnal Manajemen Teknologi 13:117-125. doi: 10.12695/jmt.2014.13.2.1

Ramirez M (2007) A Panel Unit Root and Panel Cointegration Test of the Complementarity Hypothesis in the Mexican Case: 1960–2001. Atlantic Economic Journal 35:343-356. doi: 10.1007/s11293-007-9078-6

Sakyi D (2012) Trade openness, growth and development: evidence from heterogeneous panel cointegration analysis for middle-income countries. Cuadernos de Economía 31(SPE57),:21-40.

Teles V, Joiozo R (2011) Human capital and innovation: evidence from panel cointegration tests. Applied Economics Letters 18:1629-1632. doi: 10.1080/13504851.2011.556584

Varsakelis N (2006) Education, political institutions and innovative activity: A cross-country empirical investigation. Research Policy 35:1083-1090. doi: 10.1016/j.respol.2006.06.002

Westerlund J (2007) Testing for Error Correction in Panel Data. Oxford Bulletin of Economics and Statistics 69:709-748. doi: 10.1111/j.1468-0084.2007.00477.x

Appendix

Figure 1: Total patent application of South Asian Countries

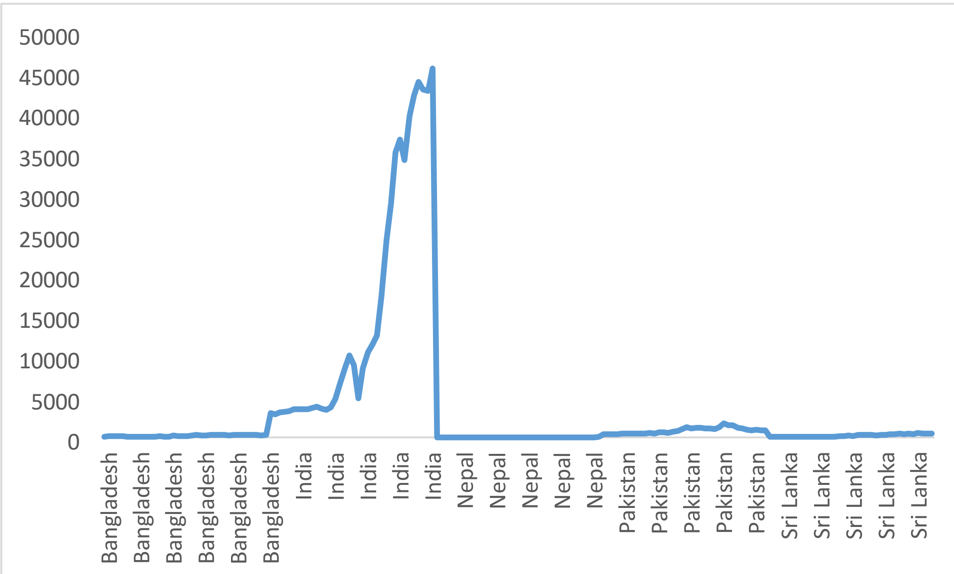

Table 1: Description of the data and data source

Variables	Abbreviation	Description	Source
Patent Application	Pat_app	Total Patent application (direct and PCT national phase entries)	WIPO
Democracy	Democ	Political rights	Freedom house
Human capital	Hum_cap	Secondary school enrolment(% gross)	WDI
Trade openness	Open	Ratio of exports plus imports to GDP	WDI
Financial development	FD	Domestic credit to Private Sector(% of GDP	WDI

Table 2: Descriptive Statistics

	Pat_app	Open	Dem	Hum_cap	FD	FD^2
Mean	5.715142	3.605441	1.195934	3.740268	3.177408	6.354817
Median	5.811069	3.573914	1.098612	3.785645	3.206738	6.413478
Maximum	10.72893	4.484543	1.945910	4.603445	4.170518	8.341036
Minimum	0.000000	2.513826	0.693147	2.762545	1.752904	3.505810
Std. Dev.	2.442976	0.468520	0.356574	0.498242	0.477674	0.955348
Skewness	-0.156817	-0.272752\	0.060380	-0.023726	-0.488166	-0.488166
Kurtosis	2.923832	2.521796	2.198275	2.112614	3.302060	3.302061
Jarque-Bera	0.781254	3.946898	4.930091	5.922790	7.833476	7.833488
Probability	0.676633	0.138977	0.085005	0.051747	0.019906	0.019906
Sum	1028.726	648.9794	215.2682	673.2483	571.9335	1143.867
Sum Sq. Dev.	1068.296	39.29243	22.75894	44.43580	40.84286	163.3714
Observations	180	180	180	180	180	180