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PANEL DATA ECONOMETRIC APPROACH FOR ASSESSING THE DETERMINANTS OF NATIONAL INNOVATION CAPACITY IN ASIAN GROWING ECONOMIES

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Abstract. The main objective of present study is to assess the factors influencing innovation capacity of selected Asian countries. The particular emphasis of analysis is placed on intangible and knowledge based factors to understand the knowledge based economic development. The panel data econometric approach is used to assess the impact of R&D, human capital, exposure to foreign technology, financial development, governance, Per capita income, information and communication technology, and population growth on innovation output over the period 1995-2020. For achieving the objective, we synthesized the indices of information & communication technology, innovation output, financial development and exposure to foreign technology by applying Principal Components Analysis (PCA) and Sphericity Bartlett's test. In this sense, present study introduces indicators to assess the innovation capacity of tested countries. For estimation, the fixed effects approach with robust standard errors is applied on the basis of variety of diagnostic tests. A variety of diagnostics tests, such as Redundant fixed effect, Lagrange Multiplier and Hausman test are used for selection of an appropriate model and estimation technique. The estimates obtained are econometrically robust and arbitrarily accommodate to contemporaneous correlation, serial correlation and heteroskedasticity. The results suggest that,

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human capital, research &development expenditure, per capita income, governance and financial sector development yield positive and significant impact on the innovation capacity. Based on results of estimated model, it is suggested that Asian countries should make substantial improvement in aforesaid factors in order to develop their innovative abilities.

Keywords: Panel data analysis, Econometrics, Innovation capacity, Asian Economies

JEL Classification: C33, C13, O31, O53

I. INTRODUCTION

National innovation capacity measures the capability of a country to create new technology and knowledge over the long period of time. National innovation capacity has a decisive role in determining the economic prosperity in the global arena. It is not the recognized level of output but it reflects basic drivers of innovation process. The variation in national innovation capacity is due to differences in economic geography as well as in innovation system. Innovation system can be defined as a set of institutions and organizations, such as firms, universities, public research centers, public laboratories and their connections through which development of innovation process is made. The history of most advanced countries shows that the public sector initially led the process of technological activities by promoting development in basic and applied research and building of long list of institutions to stimulate technological and innovation behavior. The public sector provided the telecommunication, transport services and energy along with public education and health system. This process established the enormous range of R&D institutions having equipment, skilled human power and budget for the task to develop the innovation base of countries. Along with public sector, private sector also helps for expanding the innovation infrastructure.

Innovation is very important for countries that are very near to frontiers of knowledge. Low-income countries can increase productivity by using existing technology, but the country which is at the stage of innovation, the existing technology is not sufficient for productivity growth. Investment in R&D both by the public and private sector, scientific research institutions for building of new technologies, collaboration between universities and industry regarding research and technological development, access to venture capital, intellectual property rights and financial development are the key for innovation and productivity growth. Technology can either be enhanced directly by investment in R&D capital or by indirectly by diffusion of technology from abroad. Investment in R&D affects the productivity by two ways; first by increasing the technology level through enhancing innovation capacity and second R&D investment increases the capacity of country to absorb the foreign technology. Griffith et al. (2004) found that the innovative and absorptive role of R&D investment is equally important for economic productivity. It has been recognized that not only the generation of knowledge at local level is the source of technological advancement but diffusion, spillover and imitation of new knowledge produced in other countries is also an important source of innovation. A country may be a big producer of technology but less user of it in the production while a country can benefit from new knowledge generated in other country through its diffusion. Therefore, only innovation and invention at domestic level is not the indicator of national innovation capacity but the indicators of diffusion and dissemination of knowledge are also its important source.

Most of Asian growing economies stand at a threshold level of development and require a new technology and new approach to growth. The selected sample of Asian economies are basically in a transition phase and near to the frontier of knowledge, advancing their technology and reinventing the rules in technology and innovation. The high economic growth of Asian countries during the last few decades has shifted Asia to middle income region but the real challenge for Asian is sustainability of this growth momentum which mainly depends on innovation and knowledge creative capacity. According to the ADB report 2016 “The Asia 2050” sustainability in growth is only possible if the countries of this region transform into knowledge based economies. Therefore, need for an innovation strategy is more real and immediate in Asia than in other developing regions of the World. The comparison of innovation capacity of Asian growing economies has been depicted in appendix (Table A1) of this study in terms of intellectual property variables from 1995 to 2020. The national level abilities of Asian tested countries across the nations are also depicted by Figures (A1 to A4). The difference in the ability to innovate reported in appendices raises the question for us as to what determines the innovation and knowledge creative capacity? In this globally connected World, stimulation of TFP through creation, dissemination and adoption of technology is a game changer for Asia. Therefore, selected sample of Asian countries in a phase of rapidly advancing catching up to the World technologically advanced knowledge based economies is good case study for complete and comprehensive analysis and effective policy recommendation for low income countries.

Considering these observations, the objective of present paper is to evaluate the determinants of innovation capacity of selected Asian countries. In this sense, we examine the impact of Exposure to foreign technology, Human capital, Information & Communication Technology, R&D, financial development and Governance on the innovation output capacity of Asian growing countries. For this purpose, the indices of Information & Communication Technology, Exposure to foreign technology, financial development and innovation output have been constructed in this paper by using the appropriate mathematical and statistical procedure. The innovation capabilities of selected countries is analyzed by construction of innovation output index based on multiple innovation proxies, such as patent registration, trademark registration, industrial design registration and number of scientific and technical publication. Hence, the construction of these indices is a distinctive contribution to the new knowledge and it introduces distinctive and comprehensive framework to evaluate the factors influencing the innovation abilities of Asian countries.

The organization of this study is as follows. The next section have brief review of literature related to the determinants of innovation capacity. The third section describes empirical analysis including model specification, variable description, panel data econometric specification, data sources and index composition and the fourth section presents results discussion. The last section presents the conclusion, policy implications with limitations and avenues for future research.

II. REVIEW OF LITERATURE

This section performs the review of literature related to the determinants of national level innovation ability in order to construct a frame for empirical examination and identify areas of more future research. Previously, many studies have analyzed the national innovation capacity Since the 1990s. The review of these studies reveals that there is lack of empirical work regarding the determinants of innovation capacity. The review of literature is given in the following discussion.

According to literature, the new knowledge can be summarized into three major categories: (a) embodied or disembodied; (b) codified or tacit and; (c) generation or diffusion. Embodied form of knowledge is embodied in machinery, capital goods, infrastructure and equipment whereas human skills, technical and scientific expertise is known as disembodied form of knowledge. There has been a debate regarding the relative importance of both forms of knowledge (Scott, 1989 & Evangelista, 1999). The form of knowledge represented by patents, trademarks, industrial designs and scientific and engineering publications is known as codified component and knowledge or technology acquired through learning by using and by doing is known as the tacit form. Tacit component of knowledge is much difficult to quantify or measure.

The identification of innovation output is not small work as there are number of variables measuring innovations and knowledge creation comprehensively. Patents have been frequently used as indicator of innovation output previously but there is lot of criticism on it as well. The patents not fully capture the whole innovation output because only fraction of knowledge generation process goes to patentable innovations. Moreover, inventors avoid patenting due to its cost or they prefer other source to protect their intellectual property. According to Cohen et al. (2000) the firms commonly pursue strategy of secrecy or go ahead of its competitors. The main reason of patents is the protection of potential from its rivals because patents give the innovator a right to exploit the invented technology for fixed period of time exclusively. However, patent is most commonly used indicator of innovation output despite its several shortcomings because its data is easily available. Furthermore, the most important inventions and innovations during the previous century were patented.

Caloghirou et al. (2004) analyzed the impact of internal capabilities and their interaction with foreign sources of technology and knowledge on innovativeness of firms. These capabilities depend on investment and accumulation of knowledge within the firms and also on absorptive capacity of firms. The absorptive capacity can be enhanced through the behavior of a firm rather than its environment. The data of seven European economics, Denmark, Italy, Greece, Germany, France Netherlands and the UK was collected through extensive survey for empirical analysis of relative importance of internal knowledge creation and foreign knowledge spillover. The results of study showed that both internal and foreign sources of knowledge are very important for innovation.

The National innovation capacity is the important driving force behind the productivity performance of a country. The first time the systematic framework to measure the national innovation capacity was developed by Furman, Porter and Stern in 2002 (FP&S). This framework was applied to the panel of OECD countries for the period 1973 to 1996. They measured the innovation capacity in terms of patenting rate of particular country in the "United States Patent and Trademark Office". However, we had provided distinctive contribution by including the other indicators of innovation in the analysis like trademark, patent, industrial design and S&E publication in the case technologically advanced OECD countries (Afzal, M. et al., 2020). The present study intended to apply the mentioned framework to evaluate the determinants of innovation capacity of Asian growing economies. Therefore the present study is intended to provide a mechanism for comparing the innovation capacity of selected Asian economies with the OECD countries by collecting comparable data over the comparable period of 1995 to 2020. The present research extends the framework by including number of potential factors not considered by FP&S study, in particular the impact of ICT, R&D, governance and exposure to foreign technology on national innovation capacity. In this way, it will shed a light on policy and process through which latecomer economies become able to reduce the gap with technologically advanced OECD economies by mobilizing potential resources towards the strengthening their innovation capacity.

Mani (2004) analyzed the role of Government in development of domestic technology in the case of developing countries. Two groups of developing counties were included in the analysis based on having or not having the potential to develop new technology. Fiscal and non-fiscal measures were examined for technological creation. It was found that in terms of research intensity Singapore is the country that had most effective innovation policy. He concluded that along with financial instruments, such as taxes and research subsidies and grants, non-fiscal measures like human resource development are required for the domestic technology development. The fine-tuning of non-financial measures is very vital for becoming an innovation country.

A study which analyzed the parameters of knowledge creation by using the knowledge production function was conducted by Abdih and Joutz (2006). They used the time series data for estimation in the case of US economy for assessing the knowledge creation process and knowledge spillovers. The results of study revealed that positive and significant relationship between TFP and knowledge stock. Over the long run the stock of knowledge is measured by the proxy of patents. The results also suggested that the process of knowledge creation was strictly inter-temporal and was consistent with the model of Romer (1990). However, the impact of these knowledge spillovers on TFP growth turned out to be small. The study concluded that application and impact of knowledge on productivity is very complex and process of knowledge spillover is slow.

Drucker (2007) analyzed the traditional economies versus knowledge based economy of 21st century. He projected that mega projects will focus to investment in scientific and knowledge based capital, technology advances and innovations. The human capital development will be a key factor and knowledge and technology will be transferable source at different places on different prices. Thus effective application of knowledge will be a pre-requisite condition in Knowledge based economy to compete at national and international level in order to achieve sustainable economic prosperity.

Fu (2008) has investigated the impact of FDI on innovation capabilities by using panel data from China region. The results of study showed that FDI has positive and significant effect on innovation efficiency in the region. However, the effect of FDI depends on absorptive capacity of the host country and also on assets complementary to the innovation. Moreover, he also found that technological capabilities and innovation are contributors to the regional growth of China's coastal region. The study concluded that effectiveness of FDI as a driver of knowledge and productivity depends on its quality of local absorptive capacity and innovation complementary assets of the host country.

Lau et al. (2013) examined the impact of corruption, FDI and education on innovation in case of 57 countries of Europe and Central Asia over the period of 1995 to 2010. They highlighted that previous literature considered FDI as one of the potential determinants of innovation through technology spillover effect in the recipient country. They found no evidence of significant effect of FDI on innovation. Moreover, they found that education expenditure and corruption were positively related to innovation activities. They concluded that the impact of FDI on innovation of emerging economies was previously overestimated.

Hang (2017) has suggested that latest technologies such as artificial intelligence and Internet of Things will create mobility, growth and innovation, which will further promote openness and innovation integration initiatives to establish new ecosystem. Liu and Chen (2019) were of the view that biggest restriction in development of China's high-tech zones is the lack of innovation capacity. There are numbers of issues which are seriously restricting the China's innovation ability, such as imperfect innovation network, miss-allocation of innovation and knowledge based resources and lack of innovation environment system.

The literature aforesaid provides background of relationship between input and output of innovation and direction for its estimation. These studies pointed out the strong points and weak points of various proxies of innovation capacity. However, there are some limitations observed in the previous studies. For instance, only single variable like R&D or patent has been used by most of previous studies to measure the innovation and knowledge creative capacity. There are number of indicators of innovation, such as trademarks, patents, S&E publication and industrial designs. Single patent is not inclusive indicator of innovation because all innovations are not patented as most of innovators employ other methods to protect their inventions and innovations. Moreover, there are several inputs of innovation output along with R&D

such as ICT, exposure to foreign technology, governance, financial sector development and human capital. But the impact of these input on innovation capacity have not been examined previously. Therefore, we have developed a comprehensive framework for assessing the sources of innovation output by including numbers of innovation and knowledge based indicators to assess the determinants of national innovation capacity of selected Asian growing economies. We also have applied the same framework to assess the determinants of innovation in the case of technologically advanced OECD counties (Afzal, M. et al., 2020).

III. MODEL AND ESTIMATION METHODOLOGY

Model is the functional relationship of dependent and explanatory variables based on previous theoretical background. The model of present study is based on innovation output index as the dependent variable and number of potential factors influencing the national innovation capacity as explanatory variables. The innovation output index is estimated on the basis of different indicators of invention and innovation such as trademark, patent, industrial design and number of sacrifice and technical publication during tested period. This index measure the capacity of a country to create new technology and knowledge. Higher the value of this index reveals strong the national innovation capacity of the country. The following panel data function is used to estimate the determinants of innovation capacity.

$$(IO)_{i,t} = \beta_0 + \beta_1(RD)_{i,t} + \beta_2(ICT)_{i,t} + \beta_3(G)_{i,t} + \beta_4(FD)_{i,t} + \beta_5(EFT)_{i,t} + \beta_6(HC)_{i,t} + \lambda_{i,t}(C)_{i,t} + \varphi_i + \varphi_t + \varepsilon_{i,t} \quad (1)$$

Where the dependant variable is innovation output index and explanatory variables are information & communication technology, research &development expenditure, human capital, index of exposure to foreign technology, governance index, financial development index and various control variables. Per capita income and population growth are included as control variables. The country dummy φ_i captures the country specific conditions, time dummy φ_t captures the exogenous shocks that are common to every country and $\varepsilon_{i,t}$ reveals stochastic error variations. The description of variables is given in the Table 1.

TABLE 1

Variable Description

Variables	Description
IQ	Innovation Output Index
RD	Research and Development expenditure
ICT	Information & Communication Technology index
G	Governance index
FD	Financial Development index
EFT	Exposure to Foreign Technology index
HC	Human Capital
C	Control Variables
φ_i	Country dummy
φ_t	Time dummy
$\varepsilon_{i,t}$	Error term

DATA AND INDEX COMPOSITION

The selected sample for this study contains a panel of nine Asian countries (China, Hong Kong, India, Korea, Malaysia, Pakistan, Singapore, Thailand and Turkey) over the period: 1995-2020. A yearly balanced panel data was taken from multiple sources such as Penn World Tables, World Governance Indicators, Technological Indicators, ITU, World Development Indicators (WDI), UNCTAD, OECD Main Science, and WIPO. The indices of innovation output (IQ), exposure to foreign technology (EET) information & communication technology (ICT), Governance and financial development (FD) based on various indicators of innovation and technology were constructed by using the method of normalization and Principal Component Analysis. The detail of whole conceptual framework along with variable description and index composition expressed graphically is given in appendix (Figure A5).

ADVANTAGES OF PANEL DATA

The econometric methods are applied to estimate the economic relationships. Panel data is generally obtained when entities (e.g. countries, firms, companies or individuals) are observed over time. Panel data gives more accurate estimates because of its additional information.

The panel data analysis is less problematic and requires fewer assumptions as compared to other simpler methods. The panel data in which every cross-sectional unit (subject has equal number of observations) is called balanced panel whereas if some cross-sectional units (subjects) have different number of observations then this case is known as unbalanced panel data. The size of cross-sections is obtained by monitoring the same time series across all subjects (Wooldridge, 2009). One advantage of panel data set is that it provides more variability, more information, more degrees of freedom, more efficiency and less collinearly amongst the tested variables (Baltagi, 2010). Its main superiority is analyzing the repeated cross sectional units. Due to this advantage panel data analysis can better measure and detect those effects which cannot be detected in pure time series or cross sectional data (Gujarati and Porter, 2001).

PANEL DATA ECONOMETRIC SPECIFICATION

If the unit-specific effects are assumed as random and has no correlation with independent variables, then it becomes random effect model. These Cross-sectional effects are included in random effects model as an error term. When time specific effects or unit specific effects are present in the model and these effects are assumed to be fixed parameters, the model is known as fixed effects model. The fixed effects mean nonrandom quantity is corrected for heterogeneity (Baltagi, 2010). The panel data model having no lagged values of explanatory or dependent variables is known as static panel model. In the case of countries based panel data set if no country specific effects are present then the model becomes pooled OLS. If country specific effects are present in the model but are not correlated with the regressors they are called random effects. On the other hand, if these effects are correlated with regressors, then they are called fixed effects.

The general panel model can be expressed as under.

$$y_{i,t} = \alpha_i + \beta_0 + \beta_1 x_{1i,t} + \beta_2 x_{2i,t} + \beta_3 x_{3i,t} + \cdots + \beta_k x_{ki,t} + \varepsilon_{i,t} \quad (2)$$

$i = 1,2,3...,n \quad t = 1,2,3\ldots,T$

Where α_i are specific for each entity. A panel model allows managing the heterogeneity across entities. The component which is specific to each individual or entity can be fixed or random for each individual. This makes the basis for fixed effects and random effects model which are two important and major panel models. The part of heterogeneity is explained by the individual specific component which decreases the value of squared error by reducing the unexplained variation in the data. This makes the panel data estimates more efficient as compared to estimates through other models. The pooled model is the same as a common simple regression model. It ignores the panel information and can be expressed as under.

$$y_{it} = \beta_0 + \beta_1 x_{1,it} + \beta_2 x_{2,it} + \beta_3 x_{3,it} + \cdots + \beta_k x_{k,it} + \varepsilon_{it} \quad (3)$$

i =1, 2,3...,n t = 1, 2,3…,T

The problem with pooled model estimation is that all the advantages and benefits of panel data could not be achieved with pooled model estimation. It is also more restricted as compared to random effects or fixed effects models. It is used only in the case when fixed effects model is not appropriate otherwise pooled OLS model gives inconsistent estimates.

One advantage of panel data analysis is that it can handle unobservable heterogeneity in the model by using fixed effect technique to estimate the model. Hsiao (2012) and Wooldridge (2005) have shown that fixed effects model is a very powerful tool for managing endogeneity problem in panel data estimation due to its validity in several situations where endogeneity is important, for instance, this approach becomes an important means to handle the situation of selection bias between observable and unobservable characteristics. The general expression of fixed effects model is as under:

$$y_{it} = \alpha_i + \beta_1 x_{1,it} + \beta_2 x_{2,it} + \beta_3 x_{3,it} + \cdots + \beta_k x_{k,it} + \varepsilon_{it} \quad (4)$$

i = 1,2,3...,n t = 1, 2,3…,T

In this model there is no constant term instead it has an individual specific component (α_i) which indicates an intercept for each individual or entity. In fixed effects model slopes (β) are the same for all entities or countries.

In random effects model individual component (α_i) are not treated as parameters, therefore, not being estimated. Instead, individual specific component is assumed as a random variable having μ as mean and σ^2 as variance. The random effects model can be expressed as under.

$$y_{i,t} = \mu + \beta_1 x_{1i,t} + \beta_2 x_{2i,t} + \beta_3 x_{3i,t} + \cdots + \beta_k x_{ki,t} + (\alpha_i - \mu) + \varepsilon_{it} \quad (5)$$

i =1,2,3...,n; t = 1,2,3, …, T

Where μ is average individual effect.

Let $\mu_{it} = (\alpha_i - \mu) + \varepsilon_{it})$

So

$$y_{i,t} = \mu + \beta_1 x_{1i,t} + \beta_2 x_{2i,t} + \beta_3 x_{3i,t} + \cdots + \beta_k x_{ki,t} + \mu_{i,t} \quad (6)$$

i = 1,2,3...,n ; t = 1,2,3…,T

However, if the individual specific component (α) is correlated with explanatory variables then the compliance of condition of Exogeneity needs to be verified. If there exists correlation between explanatory variables and error term (u_{it}) means either pooled or fixed effects model is appropriates.

Across autocorrelation is expected to be present in panel data models, which causes biased estimation. A robust standard errors approach is used to overcome this problem. The method of robust standard errors and covariance assumes that the error terms are cross-sectional (contemporaneously), heteroskedastic and serially correlated. The results obtained through this approach become robust and accommodate to heteroskedasticity, contemporaneous correlation and cross section serial correlation arbitrarily[1]. In this method the formula for estimator of coefficient covariance is as under:

$$\left(\frac{N^*}{N^* - K^*}\right)\left(\sum_t X_t' X_t\right)^{-1}\left(\sum_t X_t' \hat{\varepsilon}_t \hat{\varepsilon}_t{}' X_t\right)\left(\sum_t X_t' X_t\right)^{-1}$$

Where the first term of above equation is degree of freedom which depends on total number of observation in the data. N* is number of

[1] Wooldridge (2002) P 148-153, Arellano, (1987) & E-views user Guide Ix.

observation and K* is number of estimated parameters. The method basically computes period clustered robust standard errors.

IV. RESULTS AND DISCUSSION

First step is to compare the pooled and fixed effects estimation approaches by using redundant fixed effect test. The results of this test given in Table 2 reveal that p-values of likelihood ratios and F-statistic strongly reject the null hypothesis of fixed effects are redundant. Hence the result of redundant test confirmed that fixed effects are statistically significant and should retained in estimation.

TABLE 2

Redundant Test

Tests	Statistic	Prob.
Cross Section (F)	51.59*	0.00
Cross Section (Chi-square)	227.13*	0.00

Source: Author's estimates

The result given in the Table 3 indicates that value of Pesaran scaled LM test, Breusch-Pagan LM test and Bias Corrected Scaled LM test statistic reject the null hypothesis (absence of cross sectional dependence in residuals) significantly. whereas, Pesaran CD test fails in rejecting of this null hypothesis. The results of these tests shows that the estimation with pooled OLS model is not appropriate as it hide the heterogeneity of cross-sections which requires the standard errors should be robust.

TABLE 3

Cross Section Dependence Test (Pooled OLS estimation)

Tests	Statistic	Prob.
Pesaran scaled LM Test	8.59*	0.00
Breusch Pagan LM Test	117.86*	0.00
Bias Corrected LM Test	8.35*	0.00
Pesaran Test	0.32	0.75

Source: Author's own estimates

The result reported in Table 4 indicates that there are uncounted for random effect in the residual of model if estimated by pooling the data.

The p values of all tests are well below and reject the null hypothesis of pooled OLS model significantly. The findings of all testes performed above provide strong evidence that the model of Asian countries case study can be estimated with fixed effects in the model and without effects (pooled OLS) approach will generate inappropriate and inconsistent estimates.

TABLE 4

Lagrange Multiplier Tests

Test Hypothesis	Cross-section	Time	Both
Breusch Pagan	298.81	0.27	299.08
	(0.00)	(0.60)	(0.00)
Honda	17.29	-0.52	11.85
	(0.00)	--	(0.00)
King Wu	17.29	-0.52	14.22
	(0.00)	--	(0.00)
Standardized Honda	33.83	-0.33	11.55
	(0.00)	--	(0.00)
Standardized King-Wu	33.83	-0.33	17.03
	(0.00)	--	(0.00)

Source: Author's own estimation

Hausman test is used for checking the what type of effects (fixed or random) are appropriate for the model after rejecting the pooled estimation approach. The result of this test given in Table 5 below strongly rejects the null hypothesis which confirms that the estimation with fixed effects approach is appropriate as compare to random effects.

TABLE 5

Correlated Effect Test (Hausman Random Effects)

Explanatory Variables	Fixed effect $(\hat{a}^{FE})$	Random effect $(\hat{a}^{RE})$	Difference $[Var(\hat{a}^{FE}) - Var(\hat{a}^{RE})]$
R&D	0.397268	0.392045	0.003508
Information & Communication Technology index	-0.146692	-0.066797	0.000584

Explanatory Variables	Fixed effect $(\hat{a}^{FE})$	Random effect $(\hat{a}^{RE})$	Difference $[Var(\hat{a}^{FE}) - Var(\hat{a}^{RE})]$
Governance index	0.39353	0.046641	0.019465
Financial Development index	0.141783	-0.006559	0.00415
Exposure to foreign technology index	-0.158759	-0.277266	0.004059
Human Capital	0.643546	-0.095682	0.02553
Per-capita income	0.766943	1.176184	0.012916
Population Growth	-0.044759	-0.274765	0.000295
H0: The Random Effect estimators are consistent (Difference of coefficients is not systematic) $\chi^2 = (\hat{a}^{FE} - \hat{a}^{RE})'[Var(\hat{a}^{FE}) - Var(\hat{a}^{RE})]^{-1}(\hat{a}^{FE} - \hat{a}^{RE}) = 412.70^{*}$			

On the basis of variety of diagnostic tests applied above, it is suggested that estimation through fixed effects with robust standard errors approach is consistent and appropriate for this model. The results obtained through fixed effects approach are robust and accommodate to heteroskedasticity, contemporaneous correlation and cross sectional serial correlation arbitrarily [2].

TABLE 6

The Sources of National Innovation Capacity

Dependent variable: Innovation Output index	
Explanatory variables	Coefficient (t-statistic)
R&D	0.40(6.65)*
Information & Communication Technology index	-0.15 (-3.79)*
Governance index	0.39(3.11)*
Financial Development index	0.14(1.69)***
Exposure to foreign technology index	-0.16(-2.25)**
Human capital	0.64(5.02)*
Control variables	
Per capita income	0.77(6.37)*
Population Growth	-0.04(-1.29)
Intercept	-13.80(-9.62)*
R Squared: 0.97Adj. R Squared : 0.97 F Statistic: 388.31 *P-value: 0.00	

** significance at 1% level, **at 5% level & ***at 10% level.*

[2] Wooldridge (2002), P 148-153, Arellano, (1987) & E-views user Guide IX.

Table 6 presents estimated results of relationship between innovation output index and different sources of national innovation capacity. The reported results show that the model as a whole is good fit and significant as the value of adjusted R^2 is 0.97 which reveals that 97 percent variation in innovation output is explained by the explanatory variables. The results express that research and development expenditure (R&D) and human capital play significant role in promoting innovation which is consistent with the finding by supporters of endogenous growth theory. The results suggest that both R&D and HC affect innovation output significantly with expected positive sign. The value of coefficients of human capital and R&D indicate that 1percent increase in the value leads to 0.64 percent and 0.40 percent increase in innovation output index respectively. Research &Development which is another input measure of innovation has significant impact on innovation in Asian selected economies and is consistent with the finding of Griffith et al., 2006 and Hall et al., 2009. It implies that the country with high level of R&D spending has been able to be more innovative. The per capita income also appears to be positive contributor to the innovation with the highest coefficient value among all the determinants of innovation capacity. It implies that people with higher income spend more on innovation activities, suggesting the role of demand in encouraging innovation. This indicates that people of this region have more incentive to spend in innovation activities. It also reflects that higher per capita income leads to higher demand for more advanced goods and services encouraging innovation consistent with the study by Furman and Hayes (2004). The value of its coefficient is 0.77 which indicates that 1percent increase in the value leads to 0.77percent increase in innovation output index. The governance and financial sector development (FD) also have positive and significant role in promoting innovation. The value of coefficients of governance and FD index indicate that 1percent increase in the value leads to 0.39 percent and 0.14 percent increase in innovation output index respectively. Positive and significant role of governance in raising the level of productivity growth was also advocated by Maurice and Wang (2004). Similarly, result reveals that the Country's financial system plays an important role in mobilizing resources for technological advancement which is consistent with the views of King & Levine, (1993) and Levine & Zervos, (1998). Information and communication technology (ICT) and foreign imported technology negatively affect the innovation ability of people of this region possibly due to abuse of this technology and lack of absorptive capacity. The impact of population growth is not significant in this case. The overall results of model indicate that human capital, R&D, financial sector development, per capita income and governance play positive and important role in developing the innovation capacity of Asian growing countries.

V. CONCLUSION

The core objective of present study was to assess the sources of innovation capacity of selected Asian growing countries. The particular emphasis of analysis was placed on intangible and knowledge based factors. For this purpose, the impact of R&D, human capital, information and communication technology, exposure to foreign technology, financial development and governance was examined on innovation output by using panel data econometric estimation approach. Fixed effects with robust standard errors approach was applied on the basis of variety of diagnostic tests performed in this study. The results obtained through aforesaid approach were robust and arbitrarily accommodate to heteroskedasticity, contemporaneously correlation and serial correlation. Indices of innovation output, exposure to foreign technology, information & communication technology, governance and financial development were constructed by applying Principal Components Analysis (PCA) and Sphericity Bartlett's test. The construction of indices in the present study was an essential step for understanding relative position of tested economies.

Estimated results of econometric model suggested that research and development expenditure human capital, financial sector development, per capita income and governance appeared to be the positive and significant contributors to the national innovation capacity. This implies that the country with higher level of R&D expenditure and education has been able to be more innovation. Per capita income also appeared to be a positive contributor to the innovation with the highest coefficient value among the all determinants of national innovation capacity. It means that people with more income spend more on innovation activates suggesting that the role of demand in promoting innovation. This indicates that people of this region have more incentive to spend in innovation activities. It also reflects that higher per capita income leads to higher demand for more advanced goods and services encouraging innovation. The governance and financial sector development also yielded positive and significant impact on innovation output. Governance affects the innovation by maintaining rule of law, political stability, protection of property rights and control of corruption in the country. Similarly, financial sector reforms for increasing savings and better allocation of these savings to innovation and R&D activities affects the national innovation capacity. Financial sector also facilitates people to invest more in innovative activities. However, adoption of information and communication technology and exposure to foreign technology negatively affected the national innovation capacity possibly due to abuse of this technology and lack of absorptive capacity in these countries.

The empirical findings of this study enable us to suggest a number of policy recommendations with a general relevance as well as specific to Asian emerging economies. Overall, human capital, R&D, financial sector development, per capita income and governance appear to be the most significant sources of the national innovation capacity of Asian growing countries. The Asian growing economies need to make substantial investments in above mentioned pillars of knowledge based economies (KBE) in order to go along the path similar to advanced economies. Knowledge based economic development will uniquely serve the future needs of rapidly growing emerging economies. Policy attention must be committed to understanding and tracking the new advancement in different fields of technology.

The previous efforts for assessing the determinants of innovation capacity are very small. If we want to understand the knowledge based sources of economics growth over long run beyond factor accumulation, the focus should be on efforts to analyze and understand innovation capacity like patent grant, R&D, trademark registration, penetration of ICT, number of scientific and technical articles published and industrial designs. However, data on aforesaid abilities is not available for most of developing and low income countries which limited the analysis to a specific panel of economies. Therefore, the efforts are still required to extend the analysis toward the developing and low income countries.

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APPENDIX

TABLE A1

Intellectual property indicators (Average from 1995 to 2020)

Countries	Patent		Trademark		Industrial Design		Publications
	App.	Grants	App.	Reg.	App.	Reg.	
China	186116	44625	583083	368988	194928	129929	147234
Hong-Kong	106	47	7649	5324	1291	1273	2423
India	4757	878	89145	42303	3183	2467	37239
Malaysia	555	125	9220	4266	453	449	5209
Pakistan	78	22	8454	1686	295	222	2750
Korea	90332	41653	87013	40369	39463	26863	25994
Singapore	599	242	4099	3302	450	408	5396
Thailand	647	61	18181	9917	1871	627	3368
Turkey	1486	311	42718	25018	4207	3536	13676

FIGURE A1

Trends in Number of Publications (Per Million Persons)

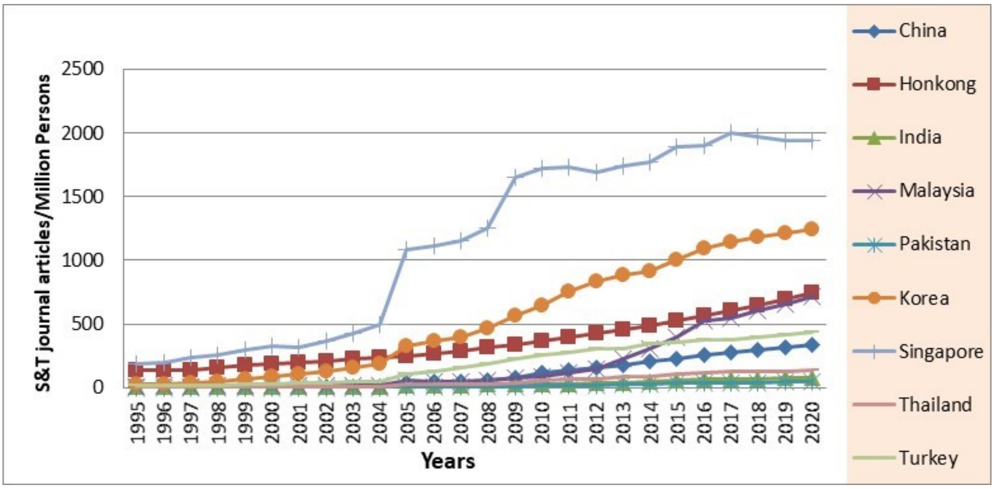

FIGURE A2

Trends in Patent Grants (per Million Persons)

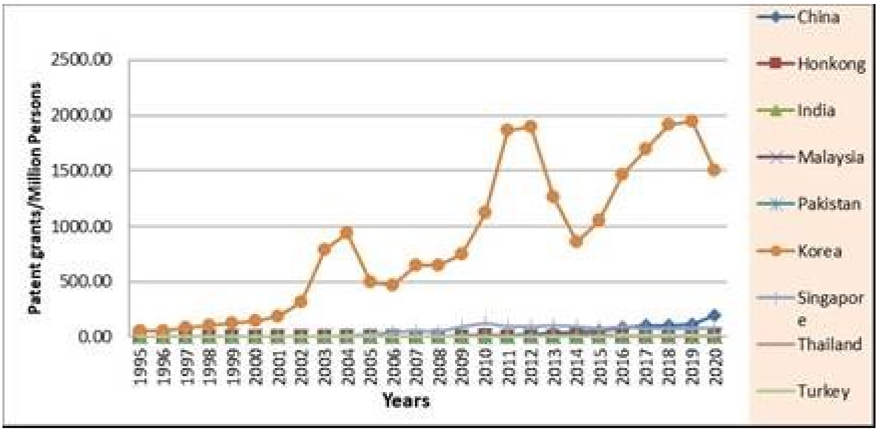

FIGURE A3

Trends in Trademarks Registration (per Million Persons)

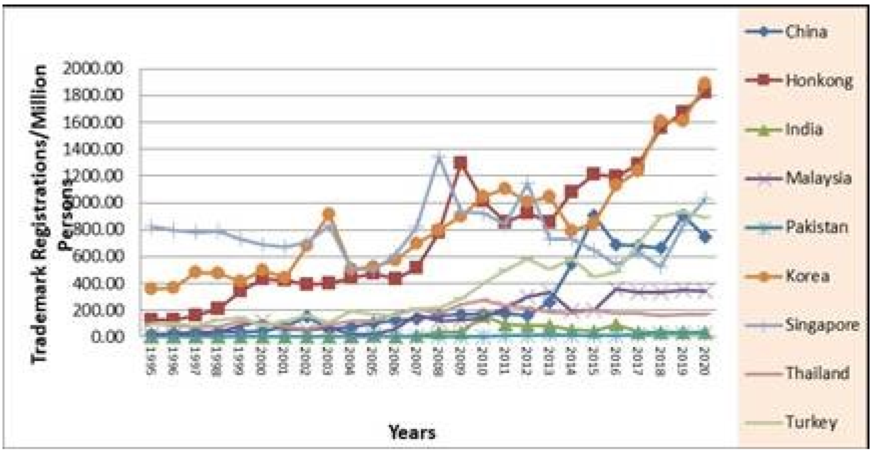

FIGURE A4

Trends in Design Registrations (per Million Persons)

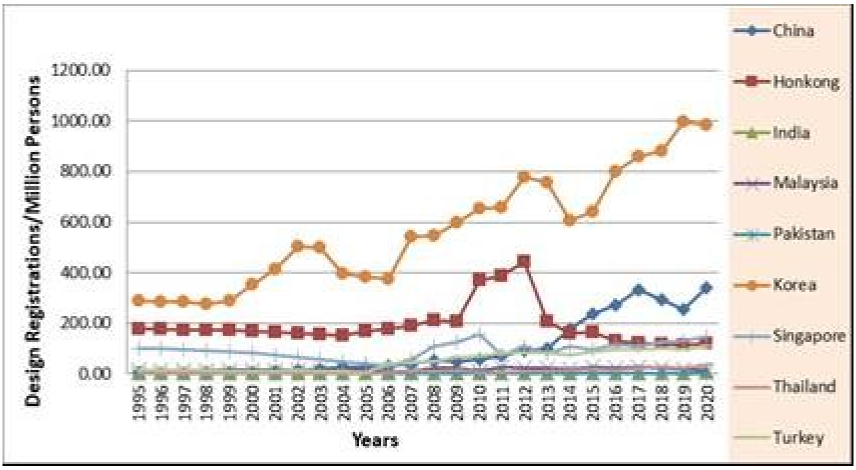

FIGURE A5

Detail of index composition