Pakistan Economic and Social Review
Volume 53, No. 1 (Summer 2015), pp. 97-112

AGGREGATE PRODUCTION FUNCTION FOR KNOWLEDGE ECONOMIES IN ASIA: SYSTEM GMM INFERENCE

BILAL MEHMOOD AND HAFEEZ UR REHMAN*

Abstract. Growth empirics usually overlook the importance of knowledge and technology as determinants of growth and their complementarities with other factors. This paper develops a model to explain the role of knowledge, capital formation, interaction effects of tertiary education with information and communication technology and knowledge as determinants of economic growth. Sample of Asian countries have been used to analyze this model called as Tech-Know Income Model. Using dynamic specification of panel data model, data of selected Asian countries from 2000-2010 is analyzed. In empirical results, knowledge is found to be a significant factor of growth. Tech-Know income model confirms the importance of traditional factor of growth like 'capital formation' and 'trade' in addition to newer factors like 'interaction effects' of information and communication technology and knowledge with human capital. Recommendations are made to improve the quality of tertiary education and to focus on economically productive research specific to local needs of developing countries for ameliorated macroeconomic performance.

Keywords: Growth empirics, Information and communication technology, Knowledge, Interaction effects

JEL classification: O15, O30, C33, O49

---

*The authors are, respectively, Assistant Professor at the Department of Economics, GC University, Lahore, and Professor/Chairman at the Department of Economics, University of the Punjab, Lahore-54590 (Pakistan).
Corresponding author e-mail: dr.bilalmehmood@gcu.edu.pk

I. INTRODUCTION

Knowledge-based economy has been considered a buzzword of recent times. But it has become a standard term in the field of development economics. It can be attributed to philosophical (epistemological), mathematical (cybernetic), economic (informational) and national accounting foundations provided in Machlup (1962). The term ‘knowledge-based economy’ has replaced ‘traditional economy’ due to increasing importance of knowledge in economic processes in every sector of an economy. For instance, in European Union, the launch of the Lisbon Strategy has initiated introduction of employment and productivity augmenting reforms in Europe “to become the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion” (European Commission, 2000). Such policy steps normally boost the information society via increased R&D and accelerates structural transformations for increased competitiveness.

Asian Region has been a target of focus of many researchers in recent times. Similar steps in this region may have interesting implications. Policies and investments associated with the transition to a knowledge-based economy (for instance Research and Development expenditures, skilled human resources, innovative capacity, diffusion of ICT and information society) can be linked with higher economic growth rates.

This paper considering the importance of this contemporary shift in Economic literature, estimates the impact of knowledge on macroeconomic performance in Asian countries. In addition to conventional factor of growth (capital formation), the model developed in this study includes role of technology and trade.

Knowledge is intangible and intermingling phenomenon. Literature resorts to knowledge by using various terminologies like ‘intangibles’, ‘intellectual capital’, ‘knowledge capital’ and ‘intangible assets’ among others. Knowledge becomes economically meaningful when converted into services or used to innovate (goods). In the post-industrial era, knowledge intensive industries have become an important part of macro-economy. Accordingly, this paper inquires knowledge as a determinant of national income among Asian countries.

II. EMPIRICAL REVIEW

As per empirical literature (Romer, 1986, 1990; Lucas, 1988), economically meaningful knowledge can create new businesses, employment opportunities and other positive externalities. Benhabib and Speigal (1994) find that countries that spend in education and skill formation are able to exploit new openings, and to invent and implement new technology. Harris (1999) is of the point of view that human capital is pivotal in nurturing productivity because it facilitates knowledge externalities and implementation of novel technology. In a micro-level study, Black and Lynch (1996) find a positive relationship between level of education and manufacturing productivity as well as non-manufacturing productivity.

Broersma *et al.* (2003) show the impact of *ICT* infrastructure in easing reach to knowledge and stimulating the blowout of ideas. Firm related studies firmly back the opinion that *ICT* investment, when convoyed by organizational change and worker skills, increase firm productivity in manufacturing and services sector. Gera *et al.* (1999) maintain that international R&D externalities embodied in IT imports have a favorable impact on labor productivity growth. As regards to European Union and *ICT* exploitation, it is observed that its member states have not exploited *ICT* growth capabilities, as compared to USA (Colecchia and Schreyer, 2002).

A more consolidated macro-level study is by Karagiannis (2007) who has conducted regression analysis for European Union using knowledge as a determinant of economic growth. Author's deployment of empirics on European Union shows that R&D expenditure initiated from other countries contributes to GDP. Azari and Pick (2009) highlight the importance of intangible knowledge for developing countries and assert that access to *ICT* is an incomplete solution of problem. In their opinion, key to development is an environment that nurtures innovation and knowledge sharing. This paper is an attempt to quantitatively assess the role of knowledge capital in macroeconomic performance for Asian countries. In addition, to conventional determinants of growth (capital formation and trade), this paper includes contemporary ingredients of growth namely information and communication technology (*ICT*).

III. MODEL SPECIFICATION

Following dynamic model is to be estimated for testing Tech-Know Income hypothesis:

$$YCD_{i,t} = \varphi(YCD_{i,t-1}, KMI_{i,t}, K_{i,t}, ICTSERT_{i,t}, ICTKMI_{i,t}, TRD_{i,t}) \quad (1)$$

$$YCD_{i,t} = \alpha_i + \alpha'_{i,t}\,(YCD_{i,t-1}) + \beta_{i,t}\,(KMI_{i,t}) + \gamma_{i,t}\,(K_{i,t}) + \delta_{i,t}\,(ICTSERT_{i,t}) + \kappa_{i,t}\,(ICTKMI_{i,t}) + \lambda_{i,t}\,(TRD_{i,t}) + \Omega\,(T_t) + \varepsilon_{i,t} \quad (2)$$

Where $YCD_{i,t}$ is national income while $YCD_{i,t-1}$ is lagged form of national income fulfilling the requirement of a dynamic model. *KMI* is Knowledge Maturation Index. This study adopts the proximal method for the measurement of knowledge. Proxies including 'research and development expenditure (% of GDI)', 'researchers in R&D (per million people)' and 'scientific and technical journal articles' are used to surrogate the level of knowledge in selected countries. For measuring the complementary effects between knowledge and tertiary level education, *ICTSERT* as a product of *ICT* (information and communication technology) and *SERT* (tertiary school enrollment ratio) is included in regression. *ICT* is composed following Mehmood and Azim (2013, 2014), Mehmood *et al.* (2013*a*, 2013*b*), Mehmood *et al.* (2014*a*, 2014*b*, 2014*c*). *SERT* 'tertiary school enrollment (% gross)' as a proxy of human capital is used following Barro and Sala-i-Martin (1995). Tertiary school enrollment ratio (*SERT*) is chosen because knowledge created at tertiary levels of education is economically more productive. Capital formation '*K*' is included as one of the major determinant of national income. In addition to knowledge, *ICT* is also used in an interaction term with *SERT*, to incorporate the concurring effects of *ICT* and *SERT* in growth empirics. Cette and Lopez (2008) also advocate the role of *SERT* in improving *ICT* diffusion in an economy and hence likely to be a reinforcing factor for *ICT*-productivity nexus. It reveals the interaction effects of *ICT* and school enrollment rate at tertiary level. de Ferranti (2002) in his work, finds the association between *ICT*, knowledge and economic development. Therefore, it is worthwhile to include this interaction term of *ICT* and *KMI* '*ICTKMI*' in the regression. *TRD* shows the trade openness as a percentage of GDP. A vector of time dummies (T_t) is included. $\varepsilon_{i,t}$ shows the error term while '*i*' shows countries and '*t*' years.

IV. HYPOTHESIS

For investigating Tech-Know Income model, subjacent is the hypothesis:

H_A Knowledge, when complemented with information and communication technology, contributes to macroeconomic performance.

V. DATA

Data availability limited the dataset to 15 countries spanning from 2000 to 2010, *i.e.* Brunei Darul Islam, China, Indonesia, India, Iran, Japan, Cambodia, Korea, Kuwait, Lao PDR, Malaysia, Pakistan, Philippines, Russia and Thailand.[1] World Development Indicators (WDI) and International Telecommunication Union (ITU) are resorted to data on relevant variables.[2] Countries like Malaysia are also undertaking local production of *ICT* hardware and software and undertaking extensive research on field of *ICT* (Madahi and Musavi, 2012).

Small sample panel data models produce biased estimates using OLS, FE and RE (Baltagi, 2008). GMM, attributed to Arellano and Bond (1991) which is improved to System GMM by Blundell and Bond (1998), overcomes this issue despite large cross sectional dimension and limited time series. System GMM is more suitable for macroeconomic variables.

SYS-GMM is a better estimation technique since (*i*) differencing eliminates the unobservable country-specific effects; (*ii*) instrumental-variable 'IV' approach deals with the endogeneity of explanatory variables; and (*iii*) 1st-differenced estimator is combined with the estimator in levels to form a more efficient 'system estimator'.

TESTS FOR ENDOGENEITY

Durbin-Wu-Hausman tests have been used for diagnosing endogeneity in the model:

TABLE 1

Tests for Endogeneity – Durbin-Wu-Hausman

Null Hypothesis (H_0): Regressor is Exogenous			
Test	Notation	Statistic	*p*-value
Wu-Hausman F test	F (1, 208)	18.441	0.000
Durbin-Wu-Hausman χ^2 test	$\chi^2(1)$	17.117	0.000

Statistically significance of the tests shows presence of endogeneity and hence need for instrumental variables.

TEST FOR HETEROSKEDASTICITY

Godfrey (1978), Breusch and Pagan (1979), White (1980), Koenker (1981) and Cook and Weisberg (1983) provide the touchstone for finding the better

[1]Due to small time dimension as compared to that in Barro and Lee (1994), GMM is employed, which is more reliable for datasets with smaller time dimension.

[2]Definitions of variables used in this study are tabulated in Annexure.

of the two, *i.e.* IV regression and GMM estimator. These tests statistics are as follows:

TABLE 2

Testing Heteroskedasticity in Presence of Instrumental Variables (Levels of IVs)

Null Hypothesis (H_0): Disturbance is Homoskedastic		
Test	$\chi^2(6)$	p-values
Pagan-Hall General Test Statistic	1.388	0.967
Pagan-Hall Test w/assumed Normality	1.394	0.966
White/Koenker $_nR_c^2$ Test Statistic	19.572	0.003
Breusch-Pagan/Godfrey/Cook-Weisberg	19.256	0.004

Majority of the tests reveal presence of heteroskedasticity, therefore it is safer to assume heteroskedasticity and GMM should be preferred. More specifically, System GMM is suitable since it incorporates the long run variation (in dynamic sense) and deals with endogeneity via the use of instruments.

GMM ESTIMATION RESULTS

System GMM is used for estimation of the panel dataset for Tech-Know Income model. Learning from literature it is recommended to use system GMM in place of difference GMM (Baltagi, 2008, Bond, 2002; Baum, 2006; Roodman, 2006; 2009).

TABLE 3

SYSTEM GMM Estimates (Tech-Know Income Model)

Dependent Variable: Gross National Income ($YPC_{i,t}$)				
	Coefficients	Standard Errors	*t*-statistic	*p*-values
$YCD_{i,t-1}$	0.8000	0.1822	4.39	0.000
$KMI_{i,t}$	0.1405	0.0628	2.24	0.027
$K_{i,t}$	1.1899	0.1640	7.25	0.000
$ICTSERT_{i,t}$	0.0385	0.0194	1.99	0.049
$ICTKMI_{i,t}$	0.0178	0.0069	2.58	0.011
$TRD_{i,t}$	–0.0204	0.0547	–0.37	0.710
C	0.2891	0.5500	0.53	0.600

Time Dummies				
yrtd_02	–0.0430	0.0343	–1.25	0.212
yrtd_03	–0.0315	0.0093	–3.40	0.001
yrtd_04	–0.0251	0.0289	–0.87	0.386
yrtd_05	–0.0172	0.0053	–3.23	0.002
yrtd_06	–0.0155	0.0228	–0.68	0.499
yrtd_07	–0.0138	0.0201	–0.69	0.493
yrtd_08	–0.0119	0.0160	–0.74	0.460
yrtd_09	–0.0053	0.0089	–0.59	0.553
Other Tests and Parameters				
Observations = 135		Countries = 15		
Instruments = 29		F (6, 15) = 4735 [p = 0.000]		
p-value: Hansen J-Test = 1.000		M_1: p = 0.713 and M_2: p = 0.311		
Difference in Hansen tests / C-tests: [p = 1.000, p = 1.000, p = 1.000 and p = 1.000]				

VI. INTERPRETATION

SGMM is valid since the coefficient of lagged dependent variable ($YCD_{i,t-1}$) is less than 1 (0.800) and is statistically significant. Tech-know Income model estimations affirm the relationship of the duo of *ICT* and knowledge stock with economic growth. The central variable Knowledge Maturation Index 'KMI' has a positive and significant relation with national income 'YCD' (0.1405% increase in national income due to 10% increase in KMI with 5% level of significance). Capital formation is convincingly found as positive contributor (1.1899% increase in national income due to 1% increase in *K* at 1% level of significance). Its contribution is beyond suspicion and is rightly the biggest contributor in this growth regression. The interaction between *ICT* and *SERT* (*ICTSERT*) has a significant positive effect on national income (0.385% increase in national income due to 5% increase in *ICTSERT* without statistical significance). Interaction term '*ICTKMI*' also contributes to national income (0.178% increase in national income due to 10% increase in *ICTKMI* at 5% level of significance). *TRD* has a negative relationship with economic growth (0.204% decrease in national income due to 10% increase in TRD).

Coefficient of *ICTSERT* is positive and statistically significant at 5% level of significance. The innovation in this regression is the interaction term of *ICT* and knowledge stock '*ICTKMI*'. *ICTKMI* term is devised to explore the coexisting influence of *ICT* and knowledge stock on economic growth. It is positive and statistically significant at 5%. The coefficient of *TRD* lacks statistically significance and negative impact on national income.

Inclusion of time dummies has rendered the model the ability to cope with cross sectional dependence. The overall significance of the model is satisfactory at 1% level of significance as per F-test of joint significance. Condition that number of observations > number of instruments also does not hold in this case, *i.e.* (135 > 29). Hansen test of correct specification and over-identifying restrictions has a *p*-value of greater than 0.05, *i.e.* (*p*-value =1.000 > 0.05) implying that all over-identified instruments are exogenous. In fact the value of Hansen test in this case is so-called 'telltale perfect value' of Hansen statistic equal to 1.000. The Arellano and Bond test for first order 'M_1' and second order 'M_2' correlation, *i.e.* AR(1) and AR(2) show p-value of greater than 0.000, *i.e.* $(M_1)_{\text{p-value}} = 0.713 > 0.05$ and $(M_2)_{\text{p-value}} = 0.311 > 0.05$. Hence there is no second order serial correlation in residuals.

C-test (Baum, 2006; Roodman, 2009) for the validity of subsets of instruments for level and difference equations are also satisfactory. These tests are four in number and have same criteria, *i.e.* the *p*-value should be greater than 0.05:

$(\text{C-test})_{\text{Ho: GMM-differenced instruments are exogenous}} = 1.000 > 0.05$

$(\text{C-test})_{\text{Ho: system GMM instruments are exogenous and they increase Hansen J-test}} = 1.000 > 0.05$

$(\text{C-test})_{\text{Ho: GMM instruments excluding IV-instruments are exogenous}} = 1.000 > 0.05$

$(\text{C-test})_{\text{Ho: Standard IV-instruments are exogenous and they increase Hansen J-test}} = 1.000 > 0.05$

There is not enough evidence to reject the null hypotheses set in these four tests of difference-in-Hansen/C-tests. Strengthening the case in rejecting the null hypothesis(s) are the four 'telltale perfect values' of 1.000 as listed above. These results are in similar to that in Karagiannis (2007) who conducted empirical analysis for European Union using knowledge as a determinant of economic growth. Similar findings were also documented in Azari and Pick (2009) who highlight the importance of intangible knowledge for developing countries.

VII. CONCLUSION AND RECOMMENDATIONS

The role of knowledge in contributing to national income is found positive. Its level of contribution, however, can be improved by reassigning the direct of research in these countries. Research that is applied and specific to the local issues should be given priority. Parachute science researches conducted in DCs should be avoided in UDCs. Mere replication of such researches does not fix the economic problems in UDCs. The jargon of Parachute science is referred to such research activities in which researchers in DCs conduct researches that have least relevance with the real life problems of people in UCSs. Such researches usually yield research papers for such researchers and benefit their research careers. Such researches might not even be useful for scientists in UDCs. The scientific research conducted in developing countries needs to be scrutinized on the basis of their social acceptability, direct relevance and responsiveness to the local environment. Furthermore, the propensity to commercialize new ideas (knowledge creation) into innovative goods and services also determines the ability of knowledge to become economically meaningful. UDCs, in this regard, are laggards. In addition, most of the knowledge is transferred from DCs to the UDCs. Rather UDCs (most of Asian countries) are characterized by 'knowledge transfer' from DCs. Such adopted knowledge might not be as suitable for UDCs as it is in innovating DCs.

Results of this study coincide with that in Sveikauskas (2007) who believes that in UDCs, technology is adopted and modified from advanced countries. It can be attributed to poor allocation of R&D expenditure which is not generating economically productive results (innovations). R&D expenditures can become contributive to economic growth through innovation systems which are the sets of firms, universities and public laboratories and their linkages.[3]

Usually R&D expenditure is less effective in UDCs due to inability to select beneficial research projects, unneeded bureaucracy and barriers in importation of scientific material. R&D expenditure is a policy matter that is exogenously determined and requires the attention of policy makers. In majority of UDCs policy making is not free of vested interests. Such frictions usually render the R&D spending less efficient or some case counterproductive where the existing resources are very scarce and have high opportunity costs. For these policy interventions, modern tools of cost benefit analysis should be applied before decision making to avoid wastage of scare resource.

---

[3]See OECD (1999) for more on innovation systems in developed countries.

REFERENCES

Arellano, Manuel and Stephen Bond (1991), Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies*, Volume 58, Issue 2, pp. 277-297. http://dx.doi.org/10.2307/2297968

Azari, R. and J. B. Pick (2009), Understanding global digital inequality: The impact of government, investment in business and technology, and socioeconomic factors on technology utilization, HICSS, pp. 1-10, 42nd *Hawaii International Conference on System Sciences*. http://dx.doi.org/10.1109/HICSS.2009.478

Baltagi, B. H. (2008), *Econometric Analysis of Panel Data*: *Econometric Theory*, 4th edition. John Wiley and Sons, Ltd.

Barro, R. J. and X. Sala-i-Martin (1995), *Economic Growth*. London: The MIT Press.

Barro, Robert J. and Jong-Wha Lee (1994), Sources of economic growth. *Carnegie Rochester Conference Series on Public Policy*, Volume 40,pp. 1-46. http://dx.doi.org/10.1016/0167-2231(94)90002-7

Baum, F. C. (2006), *An Introduction to Modern Econometrics Using Stata*. Texas: Stata Press.

Benhabib, J. and M. M. Spiegel (1994), The role of human capital in economic development: Evidence from aggregate cross-country data. *Journal of Monetary Economics*, Volume 34(2), pp. 143-173. http://dx.doi.org/10.1016/0304-3932(94)90047-7

Black, S. E. and L. M. Lynch (1996), Human-capital investments and productivity. *The American Economic Review*, Volume 86(2), pp. 263-267. http://www.jstor.org/stable/2118134

Blundell, Richard and Stephen Bond (1998), Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, Volume 87, No. 1, pp. 115-143. http://dx.doi.org/10.1016/S0304-4076(98)00009-8

Bond, Stephen R. (2002), Dynamic panel data models: A guide to micro data methods and practice. *Portuguese Economic Journal*, Volume 1, Issue 2, pp. 141-162. http://dx.doi.org/10.1007/s10258-002-0009-9

Breusch, T. S. and A. R. Pagan (1979), A simple test for heteroskedasticity and random coefficient variation. *Econometrica*, Volume 47, Issue 5, pp. 1287-1294. http://dx.doi.org/10.2307/1911963

Broersma, L., R. H. McGuckin and M. P. Timmer (2003), The impact of computers on productivity in the trade sector: Explorations with Dutch microdata. *De*

Economist, Volume 151(1), pp. 53-79.
http://dx.doi.org/10.1023/A:1022962831344

Cette, G. and J. Lopez (2008), What explains the ICT diffusion gap between the major industrialized countries: An empirical analysis? *International Productivity Monitor*, Volume 17 (Fall), pp. 28-39.

Colecchia, A. and P. Schreyer (2002), ICT investment and economic growth in the 1990s: Is the United States a unique case? A comparative study of nine OECD countries. *Review of Economic Dynamics*, Volume 5(2), pp. 408-442.
http://dx.doi.org/10.1006/redy.2002.0170

Cook, R. Dennis and Sanford Weisberg (1983), Diagnostics for heteroscedasticity in regression. *Biometrika*, Volume 70, No. 1, pp. 1-10.
http://dx.doi.org/10.1093/biomet/70.1.1

de Ferranti, D. (2002), *From Natural Resources to Knowledge Economy*. World Bank.

European Commission (2000), COM 7 "An agenda of economic and social renewal for Europe". The Commission's Contribution to the Lisbon European Council, 23-24 March.

Gera, S., W. Gu and F. C. Lee (1999), Information technology and productivity growth: An empirical analysis for Canada and the United States. *The Canadian Journal of Economics*, Volume 32(2), pp. 384-407.
http://dx.doi.org/10.2307/136428

Godfrey, Leslie G. (1978), Testing for multiplicative heteroskedasticity. *Journal of Econometrics*, Volume 8, No. 2, pp. 227-236.
http://dx.doi.org/10.1016/0304-4076(78)90031-3

Harris, R. G. (1999), Determinants of Canadian productivity growth: Issues and prospects. *Discussion Paper* # 8, Industry Canada Research Publications Program.

ITU (2003), World telecommunications development report 2003: Access indicators for the Information Society. Geneva: ITU. Retrieved from www.itu.int/ITU-D/ict/publications/wtdr_03/index.htm

ITU (2005), Measuring digital opportunity. Geneva: ITU. Retrieved from http://www.itu.int/itu-wsis/2005/DOI%20V2.pdf

ITU (2010), Measuring information society. Geneva: ITU. Retrieved from http://www.itu.int/ITU-/ict/publications/idi/material/2010/MIS_2010_without_annex_4-e.pdf

Karagiannis, S. (2007), Knowledge-based economy, convergence and economic growth: evidence from the European Union. *The Journal of Economic Asymmetries*, Volume 4(2), pp. 65-85.
http://dx.doi.org/10.1016/j.jeca.2007.02.005

Koenker, Roger (1981), A note on studentizing a test for heteroskedasticity. *Journal of Econometrics*, Volume 17, No. 1, pp. 107-112. http://dx.doi.org/10.1016/0304-4076(81)90062-2

Lucas, Robert E. (1988), On the mechanic of economic development. *Journal of Monetary Economics*, Volume 22(1), pp. 3-42. http://dx.doi.org/10.1016/0304-3932(88)90168-7

Machlup, F. (1962), *The Production and Distribution of Knowledge in the United States*. Princeton University Press.

Madahi, A. and S. Musavi (2012), The effect of global advertisement strategy on brand image in laptop industry in Malaysia. *Caspian Journal of Applied Sciences Research*, Volume 1(12), pp. 60-72.

Mehmood, B. (2014), An Inquiry into Solow's Paradox: Case of Knowledge Economies in Asia with Emphasis on Complementary Factors and Further Corollaries. Unpublished doctoral dissertation, GC University, Faisalabad, Pakistan.

Mehmood, B. and P. Azim (2013), Does ICT participate in economic convergence among Asian countries: Evidence from dynamic panel data model. *Informatica Economică,* Volume 17(2), pp. 7-16.

Mehmood, B. and P. Azim (2014), Total factor productivity, demographic traits and ICT: Empirical analysis for Asia. *Informatica Economică,* Volume 18(1), pp. 8-16.

Mehmood, B., H. Rehman and S. H. H. Rizvi (2014*a*), From information society to knowledge society: The Asian perspective. *Pakistan Journal of Information Management and Libraries*, Volume 15(1), pp. 37-46.

Mehmood, B., P. Azim and N. Asghar (2013*a*), Demographic and welfare related covariates of macroeconomic performance in a digital age in Asia. *Pakistan Economic and Social Review*, Volume 51(2), pp. 139-158.

Mehmood, B., P. Azim and S. Anwar (2013*b*), Economic convergence in context of knowledge economies in Asia: Instrumental variable estimation. *Oeconomics of Knowledge*, Volume 5(1), pp. 15-28.

Mehmood, B., P. Azim, S. H. Raza and H. Sohaib (2014*b*), Labor productivity, demographic traits and ICT A demo-tech productivity model for Asian region. *International Journal of Economics and Financial Issues*, Volume 4(4), pp. 773-783.

Mehmood, B., S. H. H. Rizvi and S. S. H. Rizvi (2014*c*), Governance and information and communication technology in Islamic countries: A generalized method of moments inference. *Journal of Emerging Economies and Islamic Research*, Volume 2(2), pp. 1-10.

Mileva, E. (2007), Using Arellano-Bond dynamic panel GMM estimators in Stata. Economics Department, Fordham University, New York. Retrieved from: http://www.fordham.edu/economics/mcleod/Elitz-UsingArellano%E2%80%93BondGMMEstimators.pdf

Romer, Paul M. (1986), Increasing returns and long run growth. *Journal of Political Economy*, Volume 94, No. 5, pp. 1002-1037. http://www.jstor.org/stable/1833190

Romer, Paul M. (1990), Endogenous technological change. *Journal of Political Economy*, Volume 98(5), pp. S71-S102. http://www.jstor.org/stable/2937632

Roodman, D. (2006), How to do xtabond2: An introduction to "Difference" and "System" GMM in Stata. *Working Papers* 103, Center for Global Development.

Roodman, D. (2009), A note on the theme of too many instruments. *Oxford Bulletin of Economics and Statistics*, Volume 71, Issue 1, pp. 135-158. http://dx.doi.org/10.1111/j.1468-0084.2008.00542.x

Sveikauskas, L. (2007), R&D and productivity growth: A review of the literature, US Bureau of Labour Statistics *Working Paper* 408, BLS, Washington, DC. Retrieved from: http://www.bls.gov/osmr/pdf/ec070070.pdf

White, Halbert (1980), A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica*, Volume 48, Issue 4, pp. 817-838. http://dx.doi.org/10.2307/1912934

ANNEXURE

S. No.	Name	Notation (in Models)	Definition	Source
1	Logarithm of GDI	$YCD_{i,t}$	"Gross domestic income is derived as the sum of GDP and the terms of trade adjustment. Data are in constant 2000 US dollars."	WDI
2	Logarithm of Gross Fixed Capital Formation (current US $)	$K_{i,t}$	"Gross fixed capital formation (formerly gross domestic fixed investment) includes land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. According to the 1993 SNA, net acquisitions of valuables are also considered capital formation. Data are in current US dollars."	WDI
3	Fixed Telephone Lines per 100 inhabitants	$FTL_{i,t}$	"It refers to the number of fixed telephone lines in a country for each 100 inhabitants." Calculation: by dividing the number of fixed telephone lines by the total population and then multiplying by 100.	ITU
4	Mobile Cellular Telephone Subscriptions per 100 Inhabitants	$MBLC_{i,t}$	"It refers to the number of mobile cellular telephone subscriptions in a country for each 100 inhabitants." Calculation: by dividing the number of mobile cellular telephone subscriptions by the total population and then multiplying by 100.	ITU
5	Fixed Broadband Internet Subscribers	$FBBS_{i,t}$	"It refers to the number of fixed broadband internet subscribers in a country for each 100 inhabitants." Calculation: by dividing the number of fixed broadband Internet subscribers by the total population and then multiplying by 100.	ITU
6	Fixed Internet Subscribers per 100 Inhabitants	$FIS_{i,t}$	"It refers to the number of fixed internet subscribers in a country for each 100 inhabitants."	ITU

S. No.	Name	Notation (in Models)	Definition	Source
			Calculation: by dividing the number of fixed Internet subscribers by the total population and then multiplying by 100.	
7	Internet Users per 100 Inhabitants	$INTU_{i,t}$	"It refers to the number of internet users in a country for each 100 inhabitants." Calculation: by dividing the number of mobile broadband subscriptions by the total population and then multiplying by 100.	ITU
8	Electric Power Consumption (kWh)	$ELTKW_{i,t}$	"Electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants."	ITU
9	Research and Development Expenditure (% of GDP)	$RDY_{i,t}$	"Expenditures for research and development are current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications. R&D covers basic research, applied research, and experimental development."	WDI
10	Researchers in R&D (per million people)	$RCHRD_{i,t}$	"Researchers in R&D are profess-sionals engaged in the conception or creation of new knowledge, products, processes, methods, or systems and in the management of the projects concerned. Postgraduate PhD students (ISCED97 level 6) engaged in R&D are included."	WDI
11	Scientific and Technical Journal Articles	$SCPUB_{i,t}$	"Scientific and technical journal articles refer to the number of scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences."	WDI

S. No.	Name	Notation (in Models)	Definition	Source
12	Information and Communication Technology Maturation Index	$ICT_{i,t}$	= (Fixed telephone lines per 100 inhabitants) + 0.2 * (Mobile cellular telephone subscriptions per 100 inhabitants) + 0.2 * (Fixed broadband Internet subscribers) + 0.2 * (Fixed Internet subscribers per 100 inhabitants) + 0.2 * (Internet users per 100 inhabitants)	Author's own
13	Knowledge Maturation Index	$KMI_{i,t}$	= 0.33 * (Research and development expenditure (% of GDP)) + 0.33 * (Researchers in R&D (per million people)) + 0.33 * (Scientific and technical journal articles)	Author's own
14	School Enrollment, Secondary (% gross)	$SERS_{i,t}$	"Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Secondary education completes the provision of basic education that began at the primary level, and aims at laying the foundations for lifelong learning and human development, by offering more subject- or skill-oriented instruction using more specialized teachers."	WDI
15	School Enrollment, Tertiary (% gross)	$SERT_{i,t}$	"Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Tertiary education, whether or not to an advanced research qualification, normally requires, as a minimum condition of admission, the successful completion of education at the secondary level."	WDI
16	ICT Goods Imports (% total goods imports)	$ICTM_{i,t}$	Information and communication technology goods imports include telecommunications, audio and video, computer and related equipment; electronic components; and other information and communication technology goods. Software is excluded.	WDI