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Innovation and Labour Productivity in BRICS Countries: Panel Causality and Co-integration

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Abstract

Schumpeter defined innovation as new goods which do not exist in the market, a new production method, a new market or raw material source, a new field of business, a new financial method or an new organization style. From Schumpeter's definition to today innovation appeared in different forms and was an important factor in economic growth equations. Although it is generally accepted that innovation increases the efficiency and productivity of capital, it can also be said that it increases the productivity of labour force as well. Recently the ease and prevalence of performing research through the internet, as well as developments in information and communication technologies had a positive effect on load and productivity of labour force accelerated workflow and also increased the efficiency of production processes and output amounts. Developments of information and communication technologies especially provided development opportunities for countries having high population and labour force and also a high development potential due to an increase in efficiency and productivity of labour force and helped them to have faster and easier economic growth or development. In this study, the aim is to research the effects of innovation on labour productivity for the 5 countries defined as BRICS (Brazil, Russia, India, China, South Africa) which have drawn attention in recent years due to their economic performances by using panel data and dynamic panel data methods. The stationarity of the variables were determined by annual data of the 2000-2012 period and the second generation unit root tests. Initially, labour productivity growth equations estimated, and then short-run relationships were researched by using VAR and Granger causality tests, while long-run relationships can't be analysed because labour productivity variable is stationary at level or namely I(0). The results of the study produced a positive relationship between innovation and labour productivity.

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Keywords: Innovation, Labour Productivity, BRICS, Panel Data

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1. Introduction

According to Joseph A. Schumpeter, who is the first economist who mentioned the importance of innovation, innovation is a new product which did not exist in the market, a new production method, a new raw material, a new business area, a new financial method or organization scheme (Schumpeter, 1934:66).Innovation is a production factor which is obtained by the use of outputs of R&D studies and their usage in daily life. This production factor has an importance in growth, development, productivity for country economics. Technological progress and innovation causes improvement of production processes and they became more efficient so they effect production and productivity directly. Moreover, in this process, significant changes happen in the labour force. Merge of technological improvements, innovation and labour, qualified labour emerges. It improves capital and productivity. Hence the innovation increases the productivity of labour both directly and indirectly. According to Schultz (1961) who made the first research on capital in literature, manpower is the most important notion which makes countries advanced. Productivity of manpower depends on education. In addition, experience, talent, skill and technological advancement are significant factors which affect the productivity of capital in a positive way. Relationship between technology and labour can be investigated in two ways: quality of labour and quality of work (Kocabaş, 2010:22-23). There are two opinions on how technology affects the quality of labour. First opinion states that if the advanced technology is included in production process, qualified labour is needed and so labour becomes qualified. Second opinion states that advanced technology makes the production process mechanized and money paid to qualified labour decreases which makes labour less qualified (Solow 1971). There are also two opposite opinion on how technology affects attribute of work. First opinion states that technology makes the work less qualified whereas second opinion states that loss of qualification becomes gain in long term. In addition to these opinions, another opinion states that technology is not enough alone to determine the quality of work, choices and strategies of managers affect the quality (Kocabaş, 2010:22-23).

2. Literature

Experimental work on effects of technological advancement on economy started with Solow (1956). Solow evaluates one sector under the assumptions of neo classical model and shows $Q = F(K, L; t)$ as production function with constant profit. Q is the output or profit, K and L are capital and labour inputs respectively, t is the time required for technological change. During his experimental work on USA economy in between 1909 and 1949, Solow showed that 87.5% increase in productivity comes from technological change and the rest is capital savings.R&D model, which is an important approach in internal growth model which was founded by Arrow (1962) and leaded by Lucas (1988) and Romer (1986, 1990), positive externalities, which arises as a consequence of capital and RE-DE, increases the marginal productivity of capital and accelerates the economic growth. In his research, Romer(1990)emphasized learning by doing and that new technical knowledge which emerges from this process goes to another stage as free input so that production increases and cost decreases. In consequence productivity increases. A model, which was developed by Grossman and Helpman (1991, 1994),Aghion and Howitt (1992, 1997), argues that firms in competition makes continual innovation to hold their monopoly power and thus their growth increases.In growth model which was formed by Lucas (1988), human capital is accepted as one of the production factors like physical capital. Human capital comes up from education or is formed by itself as a consequence of learning. Investments which are made in human capital are defined as opportunity cost of time spent on education. According to Lucas (1988), ascend in human capital increases productivity in addition to all production factors and government support on education and technological infrastructure.In Romer (1990)'s model named knowledge generation and spillover, technological advancement is accepted as internal, it is a side product of investments which increases technological knowledge and goes into other production processes as free input and this situation is spread to all sector by spillover. Romer accepted the current capital as the indication of generated information. In other words, more investment in a country means more economic information in that country. When the production function is produced in this way under certain assumptions efficiency is increased. Lucas (1988) states that externalities which are generated by knowledge production are in fact generated by human capital savings and private and public sectors' investments in human capital causes economic growth.In Barro's (1991) public politics model, goods and services produces in public sector are accepted as production factors. In the model, labour is subtracted from the production function and public good and service factor inserted instead. Here, only income of the government is assumed to be tax, only expense of the government is assumed to be public good supply and budget is assumed to be balanced. In this model, governments make investments and promote investments in private sector to support economic growth.

Private sector investments increase capital savings and also with the ascending taxes they increase public goods supply.Experimental researches which investigate relationship between information communication technologies and economy are intensified in 1990s. In Lichtenberg's study, that covers 74 countries from 1964 to 1989, a positive relationship between R&D investments which are financed by private sector and growth, productivity has been detected whereas there has been no relationship between R&D which are financed by public sector and growth.In their study for USA economy between 1972 and 1992, Oliner and Sichel (1994) calculated that computer hardware contributed 0.16% to economic growth in neo classical model whereas this percent is 0.36 in internal growth model.With the data of 27 Middle and West European countries between 1990 and 1995, Madden and Savage (1998) concluded that telecommunication sector has a positive effect on economic growth. In his work, Grilliches (1998) found out that a 10% increase in R&D expenditure causes 7% increase in productivity.

Pohjola (2000) could not determine the relationship between information communication technologies and growth for the 39 advanced and developing countries from which 23 are OECD countries. According to Pohjola, its reason is that the country's level of advancement has to be high so that information communication technologies could contribute to the economic growth. Colecchia and Schreyer (2002) detected that information communication technology capital savings contributed positively to economic growth in 9 OECD countries in between 1980 and 2000. Woerman, Meschi and Fuss (2005) detected bidirectional causality relation between mobile telecommunication investments and economic growth in developing countries in between 1995 and 2002. Driochi, Azelmod and Anders (2006) concluded that knowledge has a pushing power on economic performance in their research on 56 countries in between 1995 and 2001. Chackraborty and Banani (2003) detected a relationship between telecommunication investments and economic growth in long term however they could not detect and causality relation in their work which covers 12 Asian countries in between 1975 and 2001. Nasab and Aghei (2009) concluded that information communication technology has a positive effect on economic growth in OPEC countries in between 1990 and 2007. For USA economy in between 1988 and 2007, Yeo (2010) detected that innovation is the pushing force of the growth. With the dynamic panel data method, Kooshki and Ismail (2011) concluded that information communication technology has a positive effect on economic growth in OECD, BRIC and NIC countries in between 1990 and 2008.

4. Econometric Analysis

In this study, the relationships of innovation and labour productivity for BRICS economies investigated by using Panel Unit Root Test, Panel Co-integration and PVAR (Panel Vector Auto-Regression). The data of variables used in analysis is obtained from World Bank Database.

4.1.Data

In the study used yearly innovation and labour productivity variables of BRICS economies covering 2000-2012 period. As variables of innovation Patent Applications of Non-Residents as PANR, Patent Applications of Residents as PAR, Internet Users per 100 People as INTUSE used. As Labour Productivity variable Gross Domestic Product per Person Employed (1990=100, Purchasing Power Parity, US$) as PROEM used and as Control Variable Gross Fixed Capital Formation (2005=100, US$) as GFCF in Equation Growth used. L before the variables indicates that logarithms are taken, and Δ differences are taken.

4.2. Panel Unit Root and Co-Integration Test

Panel unit root tests are the methods used to analyse the stationarity of the variables. Levin Lin and Chu (LLC) (2002) and Im, Pesaran and Shin (IPS) (2003) which are the first generation unit root tests and this tests often used studying stationarity of variables. In LLC panel unit root test assumed that all individuals have a common unit root process and in IPS test assumed that individuals have a individual unit root process. On the other hand LLC and IPS tests don't take into account cross-section dependence but Pesaran (2007) developed a test that takes into account cross-section dependence. Pesaran (2007) test assumes cross-section dependence is in form of a single unobserved common factor. Null hypothesis of Pesaran (2007) test can be described as series have unit root process and isn't stationary.

Table 1: Pesaran Panel Unit Root Test

Variables	Pesaran Test Z[t-Bar] Value	
	Intercept	Intercept-Trend
LPROEM	-1.80(1)^{b}	1.16(1)
LGFCF	-0.85 (1)	-0.13(1)
LPANR	-1.02 (0)	2.85 (1)
LPAR	1.76(1)	-0.28(0)
LINTUSE	-1.56(1)^{c}	-0.44(1)
ΔLGFCF	-1.30 (0)^{c}	-0.32 (0)
ΔLPANR	-2.71 (0)^{a}	-1.34 (0)^{c}
ΔLPAR	-3.57(0)^{a}	-2.78 (0)^{a}

a and b respectively significant at %1 and %5. The values in parentheses are the optimal lag length by Akaike Information Criteria. Newey-West bandwidth selection using Bartlett Kernel.

Pesaran (2007) test results are summarized in Table 1. As it shown in the table, LPROEM and LINTUSE variables are stationary at level that is I(0), other variables are stationary at I(1).

Since Panel co-integration analysis is a research method of long term relationship between non-stationary variables and LPROEM variable is stationary at the level namely I(0), co-integration analysis cannot be made between labour productivity and other variables.

4.3 Panel Labour Productivity Growth Model

A neoclassical growth model can be written simply as function of output (Y), Labour (L) and Capital (K).

$$Y = f(L, K) \quad (1)$$

In this model if both sides of equation is divided by L, then equation is

$$\frac{Y}{L} = f(K) \quad (2)$$

On the left side of the equation Y/L can be named as labour productivity and upon adding innovation variable to right side of the equation in order to search for the effect of innovation on labour productivity function can be written as below.

$$\frac{Y}{L} = f(K, INNOV) \text{ or } PROEM = f(K, INNOV) \quad (3)$$

$$\Delta LPROEM_{it} = \beta_0 + \beta_1 \Delta LGFCF_{it} + \beta_2 \Delta LINNOV_{it} + e_{it} \quad (4)$$

Table 2: Labour Productivity Growth Equation

Independent Variables	For Patent Applications	For Internet User
ΔLGFCF	0.0021[a] (6.99)	0.0023[a] (8.75)
ΔLPANR	-0.0017 (-0.08)	--
ΔLPAR	0.0706[b] (2.16)	--
ΔLINTUSE	--	0.0266[b] (2.40)
Constant	0.0236[a] (7.01)	0.0189[a] (4.09)
R^2	0.87	0.85
DW stat.	1.93	1.96
RFE Test	5.59[a]	30.79[a]
Hausman Test	22.32[a]	7.85[b]
JB Test	1.05	5.34

RFE: Redundant Fixed Effect (F test). JB: Jarque Bera Normality Test. a and b respectively significant at %1 and %5. t stat. in parenthesis. Linear estimation after one-step cross-section weighting matrix. Cross-section SUR (PCSE) standard errors & covariance (d.f. corrected). Crisis dummy variable 2001 and 2008 are 1 and others are 0 added to equations but is insignificant.

The results of RFE and Hausman (1978) tests shows that fixed effect model must be estimated for both innovations variable model. In the table 2 capital growth has an positive effect on labour productivity growth. Additionally, while the effect of PANR as innovation indicator is statistically insignificant, the effects of PAR and INTUSE growth are statistically positive and significant on labour productivity growth is confirmed. Seen that patent applications of residents growth and increasing number of internet users stimulate labour productivity. The determination coefficient of equation is around 80% which is very high, DW statistics is around 2. For any autocorrelation or heteroskedasticity problem corrected standard errors and covariance values are used. Both equation error terms distributed normally.

4.4 Panel VAR

PVAR model is an autoregressive equation system where any variable in the system considered endogenous (dependent) respectively, other variables exogenous (independent). In order to determine lagged and dynamic and Granger Causality relationships between the variables PVAR analysis can be used. PVAR equations with two variables can be shown as below.

$$Y_{it} = \beta_0 + \sum_{j=1}^{m} \beta_j Y_{it-j} + \sum_{j=1}^{m} \alpha_j X_{it-j} + \gamma\mu_i + u_{it} \tag{5}$$

$$X_{it} = \delta_0 + \sum_{j=1}^{m} \delta_j X_{it-j} + \sum_{j=1}^{m} \theta_j Y_{it-j} + \gamma\mu_i + \varepsilon_{it} \tag{6}$$

Here Y and X shows variables, μ individual fixed effect, $\beta, \alpha, \delta, \theta, \gamma$ coefficients of variables, m optimal lag length, u *and* ε IID random error term. PVAR model is estimated with the method of both Panel OLS and Arellano and Bond (1991) dynamic panel data GMM method. The results obtained are shown down below.

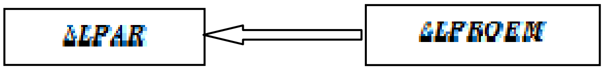

Fig. 1. PVAR-GMM Causality Relationships

Optimal lag length of PVAR-GMM according to the sequential modified LR test statistic, the Schwarz and Akaike information criterions are determined as 1. The results obtained from PVAR-GMM show a Granger causality relationship from labour productivity to patent applications of residents.

The results show that while the growth in patent applications of residents have positive influenced labour productivity in the same period, the growth in labour productivity is effecting patent applications of residents in a lagged way. This is to say the effect of labour productivity on patent applications of residents occur in time.

5. Conclusion

Innovation was an important factor in economic growth equations. Although it is generally accepted that innovation increases the efficiency and productivity of capital, it can also be said that it increases the productivity of labour force as well. Recently the ease and prevalence of performing research through the internet, as well as developments in information and communication technologies had a positive effect on load and productivity of labour force accelerated workflow and also increased the efficiency of production processes and output amounts. Developments of information and communication technologies especially provided development opportunities for countries having high population and labour force and also a high development potential due to an increase in efficiency and productivity of labour force and helped them to have faster and easier economic growth or development. BRICS countries have drawn attention in recent years due to their economic performances. The aim of this study is to research the effects of innovation on labour productivity for BRICS counties.

Test results of Pesaran (2007) showed labour productivity and internet user variables are stationary at level that is I(0), patent applications of residents and non-residents are stationary at I(1). Because of this reason co-integration analysis cannot be made between labour productivity and other variables. According to result of labour productivity growth model, the capital growth has an positive effect on labour productivity growth. Additionally, while the effect of patent applications of non-residents as innovation indicator is statistically insignificant, the effects of patent applications of residents and internet user growth are statistically positive and significant on labour growth is confirmed. Seen that patent applications of residents growth and increasing number of internet users stimulate labour productivity. The results obtained PVAR-GMM show a Granger causality relationship from labour productivity to patent applications of residents. The all results show that while the growths in patent applications of residents have positive influenced labour productivity in the same period, the growth in labour productivity is effecting patent applications of residents in a lagged way. This is to say the effect of labour productivity on patent applications of residents occur in time. As a result, innovation is a important factor for labour productivity growth and development and because of the feedback effect between innovation and labour productivity, innovation must always be encouraged.

References

Aghion, P. and Howit, P. W. (1992). A Model of Growth Through Creative Destruction, *Econometrica,* Vol:60, No:2, pp.323-351.

Aghion, P. and Howit, P. W. (1997*). Endogenous Growth Theory*, UK: MIT Press. ISBN: 9780262011662

Arellano, M., and S. Bond. (1991). Some Tests of Specification for Panel Data, Monte Carlo Evidence and an Application to Employment Equations. *Review of Economic Studies* Vol:58, No:2, pp.277–297.

Arrow, K. (1962). The Economic Implication Learning by Doing, *The Review of Economic Studies*, Vol:29, No:3, pp.155-173.

Barro, R. J. (1991). Economic Growth in a Cross Section of Countries, *Quarterly Journal of Economics,* Vol:106, No:2, pp. 407 – 443.

Chakraborty, C. and Banani, N. (2003), Privatization Telecommunications and Growth in Selected Asian Countries: An Econometric Analysis*, Communications and Strategies,* No:52, pp.31-47.

Colecchia, A. and Schreyer P. (2002), ICT Investment and Economic Growth in the 1990s: is the United States a Unique Case? A Comparative Study of Nine OECD Countries, *OECD Science, Technology and Industry Working papers*, Vol.5, No:2, pp. 1-31.

Grilliches, Z. (1998), Introduction to R&D and Productivity: The Econometric Evidence, University of Chicago Press, ISBN: 0-226-30886-3, pp.1-14.

Driouchi, A., Azelmad, E. M., and Anders, G. C., (2006), An Econometric Analysis of the Role of Knowledge in Economic Performance, *Journal of Technology Transfer*, Vol:31, pp.241–255.

Grossman, G. M. and Helpman, E. (1991). Quality Ladders in the Theory of Growth, *Review of Economic Studies*,Vol:58, No:1, pp.43-61.

Grossman G.M. Helpman. E. (1994) Endogenous Innovation in the Theory of Growth, *Journal of Economic Perspective,* Vol:8, No:1, pp.23-44.

Hausman, J.A. (1978). Specification Tests in Econometrics. *Econometrica*, Vol: 46, No: 6, pp.1251–1271

Im, Pesaran and Shin (2003).Testing for Unit Roots in Heterogeneous Panels, *Journal of Econometrics*, Vol:115, No:153-74.

Kocabaş ,G. (2010). Teknolojinin İşgücü Üzerindeki Etkileri (Türkiye'de İmalat Sanayinin İncelenmesi), Yayınlanmış Yüksek Lisans Tezi, Çukurova Üniversitesi Sosyal Bilimler Enstitüsü.

Kooshki, F. M. and Ismail, R. (2011), The Impact of Information and Communication Technology Development on Economic Growth, *IPEDR*, No:10, pp. 235- 239.

Madden, G.G. and Savage S.J. (1998), CEE Telecommunications Investment and Economic Growth, *Information Economics and Policy*, Vol:10, No:2, pp.173-195.

Nasab, E. H., and Aghaei, M., (2009), The Effect of ICT on Economic Growth: Further Evidence, *International Bulletin of Business Administration,* No: *5,* pp. 46-56.

Levin, Lin and Chu (2002), Unit root tests in panel data: Asymptotic and finite-sample properties, *Journal of Econometrics,* Vol: 108, No 1, pp.1–24.

Lucas, R.(1988) On the Mechanics Of Economic Development, *Journal of Monetary Economics,* No:22, pp.3-42.

Oliner S.D. and Sichel D.E. (1994) Computers and Output Growth Revisited: How Big Is the Puzzle? Brookings Papers on Economic Activity, No:2, pp.273-334.

Pesaran, M. H. (2007). A Simple Panel Unit Root Test in the Presence of Cross-Section Dependence, Journal of Applied Econometrics, Vol:22, No:2, pp. 265-312.

Pohjola, M. (2000).Information Technology and Economic Growth: A Cross- Country Analysis, World Institute for Development, *Economics Research Working Papers*, No: 173, pp.1-20.

Romer, P. (1986). Increasing Returns and Long Run Growth, *Journal of Political Economy,* Vol: 94, No:5, pp.1002-1037.

Romer, P. M. (1990). Endogenous Technological Chang, *The Journal of Political Economy*, Vol:98, No:5, pp.71-102.

Schumpeter, J. (1934), *The Theory of Economic Development, with a new introduction by: An Inquiry Into Profits, Capital, Credit, Interest, and the Business Cycle*, Transaction Publishers, ISBN:0878556982.

Schultz T. W. (1961), Investment in Human Capital, *The American Economic Review,* Vol:51, No1, pp.1-17.

Solow, R. (1956), A Contribution to the Theory of Economic Growth." *Quarterly Journal of Economic,* Vol:70, No.1, PP.65-94.

Solow, R. (1971), Technical Change and the Aggregate Production Function, *The Economics of Technological Change*, ed. Nathan Rosenberg, Harmondsworth: Penguin Books.

Waverman, L., Meschi M. and Fuss M. (2005), The Impact of Telecoms on Economic Growth in Developing Countries, *Vodafone Policy Paper Series* No:2, pp.10-23.

Yeo, B. J. K. (2010), Driving the Knowledge Economy: Explaining the Impact of Regional Innovation Capacity on Economic Performance, *Contemporary Management Research,* Vol.: 6, No:1, pp.71-86.