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Journal of Emerging Knowledge on Emerging Markets
Volume 3
November 2011

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Recent waves of globalization are putting enormous competitive pressure on businesses across the world. The two main drivers behind this are Information and Communication Technologies (ICTs) and trade liberalization. This increase in global competition forces less competitive firms to cut back operations, move plants overseas, or close altogether. In order to survive and hopefully thrive in this challenging and increasingly integrated global economic landscape, firms and governments need to stay continuously innovative, both in production processes and product launching. For emerging economies, these challenges are perhaps particularly mounting because the current global economic recession will continue to test the sustainability of their labor-intensive, export-dependent growth.

DOI: 10.7885/1946-651X.1037

The recent financial crisis has made consumers more conservative in their spending and businesses more amenable towards newer ways to attract, retain, and expand local, regional, and global customer loyalty. For firms, success depends on continuous product and process innovation and the commercialization thereof. This paper studies a select set of macroeconomic determinants and their respective impacts on patented innovation in a select group of industrialized OECD countries (U.S., U.K., Germany, Japan, and Australia) and in some emerging economies known as BRICS (Brazil, Russia, India, China, and South Africa). The future economic capabilities of the BRICS countries will largely depend on their capacity for continuous innovation and the launching of new products and services in coming decades. Herein, we analyze the relative contributions of certain macro-variables in facilitating patented innovation.

The freshly minted acronym BRICS refers to five leading emerging economies: Brazil, Russia, India, China, and South Africa. On April 14, 2011, the leaders of these five countries met for the first time in Sanya, Hainan Province, China, and made a joint declaration confirming their increased economic cooperation. These five countries have experienced significant economic growth in the recent years relative to OECD countries.[1] In this paper, we will use patent counts as the innovation variable along with some more commonly known macroeconomic variables to develop an empirical model to distinguish variables that are particularly associated with growth in innovative activities in emerging versus developed economies. The organization of the paper is as follows: we discuss theoretical background in section 2, explore data and describe variable creations in section 3, analyze regression results in section 4, and make some concluding remarks in section 5.

Theoretical Background

There is a dearth of literature examining the macro-aspects of the determinants of innovation. Most studies on the determinants of innovation use either firm-level or industry-level data with variables such as firm size, R&D intensity, trade share of GDP, networking or inter-industry linkages, spillover effects of agglomerations, etc. (e.g., Battacharya and Bloch, 2004; Sun and Du, 2010; and Rogers, 2004).

[1] According to a Goldman Sachs forecast, GDP growth rates for four of these five countries between 2006 and 2050 will be particularly remarkable (879% in Brazil, 1,137% in Russia, 2,432% in China, and 2,550% in India). According to a study published by PricewaterhouseCoopers (2011), South Africa's GDP will grow by about 402% between 2009 and 2050. However, the same reports predict much humbler growth rates for most of the industrialized countries. According to the Goldman and Sachs report, between 2006 and 2050, the U.S. GDP is predicted to grow by 206%, The U.K. by 207%, Germany by 197%, and Japan by 197%. The PricewaterhouseCoopers (2011) study report predicts Australian GDP growth to be 169% using market exchange rate measure. The data suggests a clear repositioning of global economic growth centers, whereby emerging economies will move towards the forefront of global economic activities.

After analyzing firm-level innovation and employee diversity data, Ostergaard and Timmermans (2011) report a positive relationship between innovation and both gender diversity and educational diversity, but they did not find a significant positive effect of ethnic diversity on firm-level innovation. In this paper, we use a measure of ethnic diversity at the country level and examine its impact on national patented innovation activities. Sun and Du (2010) analyze Chinese firm-level data to study the relationship between patent grants and several economic variables such as new product sales, R&D, spillover effects of foreign investments, and amount of export and find in-house R&D to be the most important factor in innovative activities.

Wan et. al (2005) focus on qualitative factors and confirm positive correlations between innovation and factors such as decentralized structure, organizational resources, emphasis on innovative risk-taking, and exchange ideas. Love and Roper (1999) find a positive influence by R&D, technology transfer, and networking on innovation. Further, they report that technology transfer and networking are the more important factors in increasing innovation activities. After analyzing firm-level data from 27 emerging economies Gordonichenko, Svejnar, and Terrell (2010) arrive at a robust positive relationship between innovation and foreign competition.

We contend that the major driving forces in the current wave of globalization are advances in ICTs and trade liberalizations. This new era of globalization began in the mid 1990s and was facilitated by the mass use of the Internet and the emergence of trade organizations such as the WTO, NAFTA, Mercosur, etc. In this paper, we use country-level data to examine the impact of trade, technology, R&D expenditure, higher education, and some control variables on patented innovations in the five OECD countries and the five BRICS. We attempt to identify the direction and magnitude of impact of some normalized macro-variables on the volume of patented innovations in the five industrialized countries and five emerging markets between 1997 and 2010.

DATA

We analyze a data set of ten countries over twelve years. We extract the patent volume data for these countries from U.S. Patent and Trade Organization database and the macroeconomic, fiscal, and other control variables from the World Bank database. We estimate the impact of determinants on innovation using the following baseline econometric specification:

$$
\begin{aligned}
(PatentCount)_{ct} &= B_0 + B_1(\ln InNet)_{ct} + B_2(\ln InNet \times BRICS)_{ct} + B_3(\ln Openness)_{ct} \\
&+ B_4(\ln Openness \times BRICS)_{ct} + B_5(\ln Power)_{ct} + B_6(\ln Power \times BRICS)_{ct} + B_7(\ln Diversity)_{ct} \\
&+ B_8(\ln Diversity \times BRICS)_{ct} + B_9(\ln R\&D)_{ct} + B_{10}(\ln R\&D \times BRICS)_{ct} + B_{11}(\ln TertiaryEd)_{ct} \\
&+ B_{12}(\ln TertiaryEd \times BRICS)_{ct} + \varepsilon_{ct}
\end{aligned}
$$

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DOI: 10.7885/1946-651X.1037

In the above model, all variables are normalized by taking their natural log values. The variables *PatentCount* and *GDP* are per capita. The variable *InNet* implies a percent of people with Internet access. The variable *Energy* implies per capita consumption of electricity. The variable *Openness* is the ratio of foreign trade to GDP, i.e.,

$$Openness = \left(\frac{Value\ of\ import + Value\ of\ \exp ort)}{GDP} \right)$$

The variable *Diversity* is calculated as an inverse ratio of the percent of the largest ethnic group to the percent of the rest of the people in the country, i.e.,

$$Diversity = \frac{Percent\ Sum\ of\ All\ Other\ Minorities}{Percent\ of\ L\arg est\ Ethnic\ Group} .$$

For example, if the largest ethnic groups in country A and country B are 60% and 75% respectively, then their diversity indices will be 66.67 and 0.33 respectively, and, in that case country A will be taken as more ethnically diverse than country B. The variable *R&D* is calculated as R&D expenditure as a percent of GDP. The variable 'TertiaryEd' implies enrollment in post-secondary education as a percent of all enrollment. All these variables are expected to display positive correlation with innovation.

The subscript *c* stands for the ten countries (the five OECD countries and the five BRICS), and the subscript *t* stands for the years from 1997 to 2010. A variant model includes some fiscal variables where the corporate income tax and income tax variables are representing highest marginal rates. Our main variables of interests are the coefficients of the variables that are a proxy for technology and trade liberalization - the two main drivers of the current wave of globalization. We are also interested in the coefficients related to the diversity variable. All the explanatory variables are interacted with a binary variable BRICS that takes on a value of one (1) if the country is represented in BRICS and a value of zero (0) if not. We expect the coefficients of these interaction variables to convey important information regarding the difference in the relative effectiveness of these variables to influence patented innovation activities in the BRICS versus OECD countries.

Our baseline regression specification is that of a random effect model. We run both random effect and fixed effect models with a variant specification (including some fiscal variables) for robustness check. Regression results of the fixed effect model will be more relevant under the assumption that there are some factors within each individual country that may impact or bias the predictor or outcome variables and we need to control for these. The random effect model regression results will be relevant under the assumption that the variations across countries are random and uncorrelated with the predictor or independent variables included in the model. As Green (2008) explains, the main distinction between fixed effect and random effect is whether the unobserved individual effect includes elements that are correlated with the regressors in the model, not whether these effects are stochastic or not. For each case, we report robust standard errors, and before describing the regression results, we explore the data graphically to better understand the underlying trends if any. Now, we briefly describe some of these charts and tables.

Patent Count. For the five OECD countries, patent share is large yet decreasing. For the BRICS, however, patent share is meager yet rising. Charts 1A and 1B display the per capita patent count for the five OECD countries and for BRICS, respectively. Among five OECD countries, the U.S. led the way in 2009, followed by Japan, Germany, the U.K., and Australia respectively. Among the BRICS, South Africa is the most innovative economy, followed by Russia, Brazil, China, and India respectively. See Table 1, Chart 1A, and Chart 1B for detail.

TABLE 1

PATENT COUNT IN FIVE OECD COUNTRIES AND IN BRICS RELATIVE TO WORLD

Year	Patent Count			Patent Count World %	
	World	Five OECD	BRICS	Five OECD	BRICS
1997	111,984	95,048	383	84.88%	0.34%
1998	147,517	124,408	535	84.33%	0.36%
1999	153,485	128,624	584	83.80%	0.38%
2000	157,494	130,965	642	83.16%	0.41%
2001	166,034	136,919	837	82.46%	0.50%
2002	167,330	137,798	947	82.35%	0.57%
2003	169,023	139,376	1,084	82.46%	0.64%
2004	164,290	134,793	1,141	82.05%	0.69%
2005	143,806	118,041	1,098	82.08%	0.76%
2006	173,772	141,541	1,544	81.45%	0.89%
2007	157,282	126,488	1,678	80.42%	1.07%
2008	157,772	124,476	2,227	78.90%	1.41%
2009	167,349	131,278	2,726	78.45%	1.63%
2010	219,614	171,019	4,318	77.87%	1.97%

Source: Authors' creation using data from the U.S. Patent and Trademark Office database.

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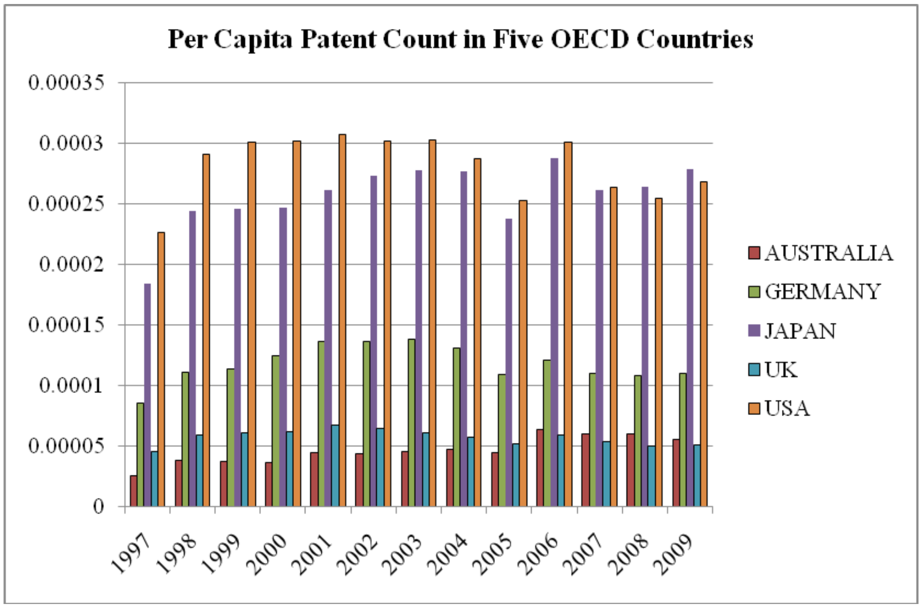
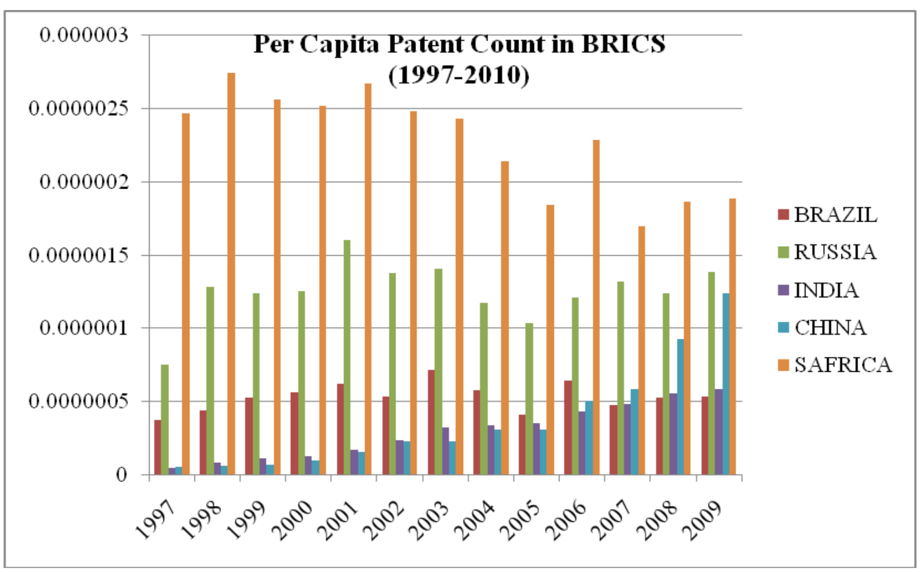
DOI: 10.7885/1946-651X.1037

CHART 1A



Source: Authors' creation using data from the U.S. Patent and Trademark Office database.

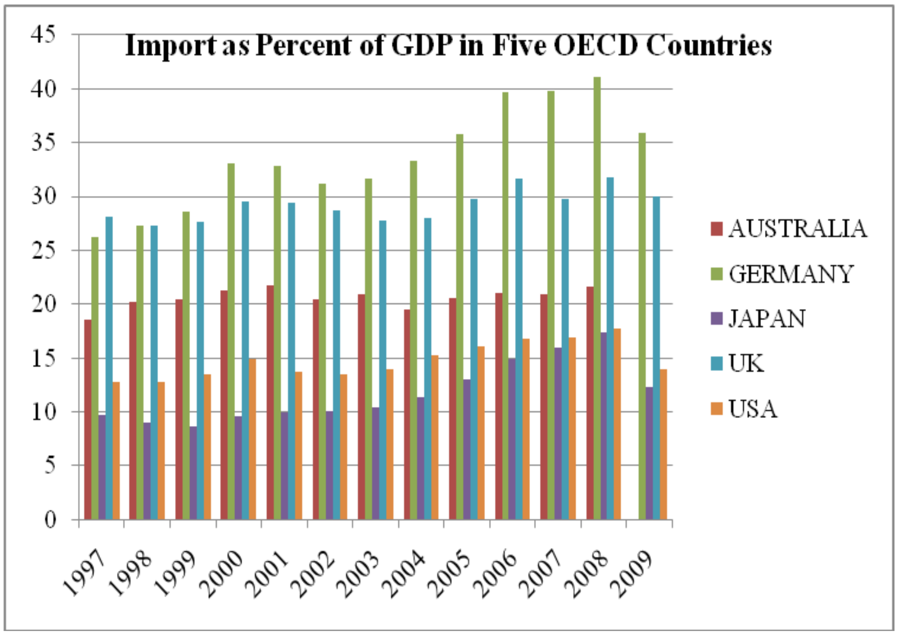
CHART 1B



Source: Authors' creation using data from the U.S. Patent and Trademark Office database.

Import / Export. Among the OECD countries, import as a percent of GDP in 2009 was highest in Germany, followed by the U.K., Australia, the U.S., and Japan. For export as a percent of GDP, however, Japan came in highest, followed by the U.K., Germany, and the U.S.[2] Among the BRICS, import as a percent of GDP was highest in South Africa, followed by India, China, Russia, and Brazil. Export as a percent of GDP was highest in Russia, followed by South Africa, China, India and Brazil. See Charts 2A, 2B, 3A, and 3B for detail.

CHART 2A

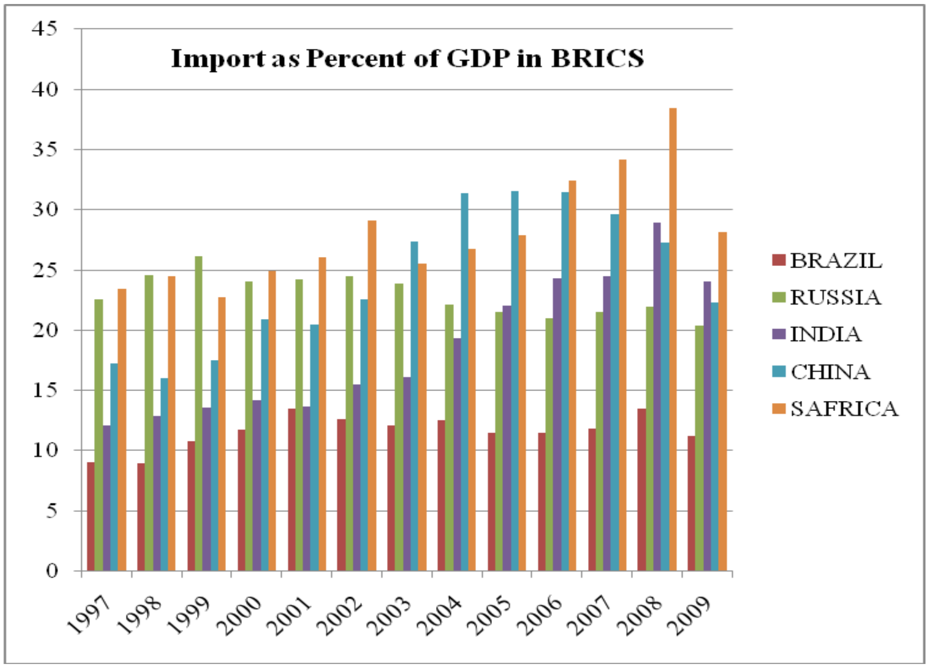


Source: Authors' creation using data from the World Bank database.

[2] Australian export data for 2009 was not available in the database used at the time of writing this paper.

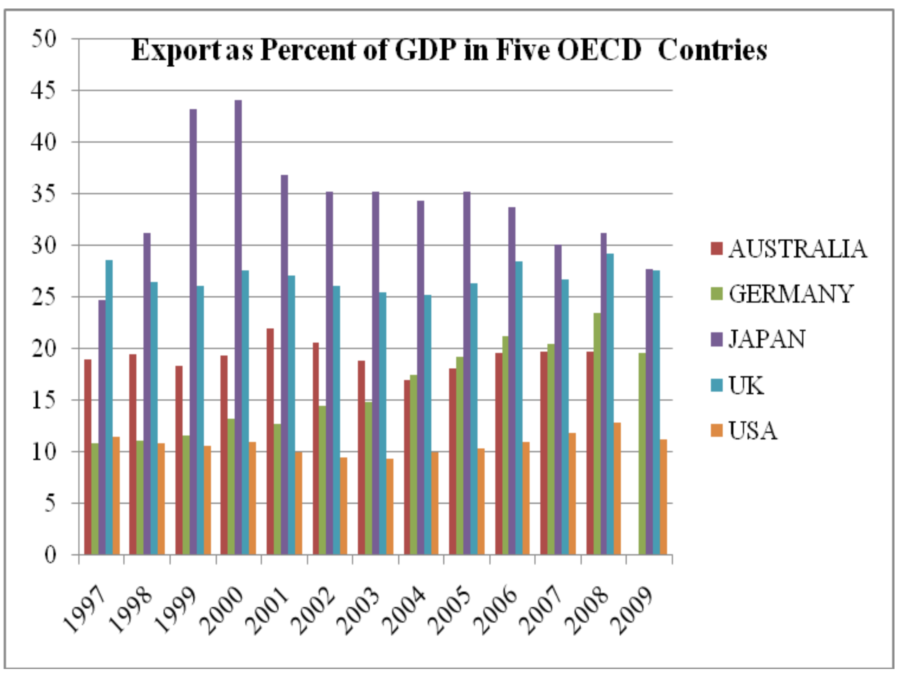
DOI: 10.7885/1946-651X.1037

CHART 2B



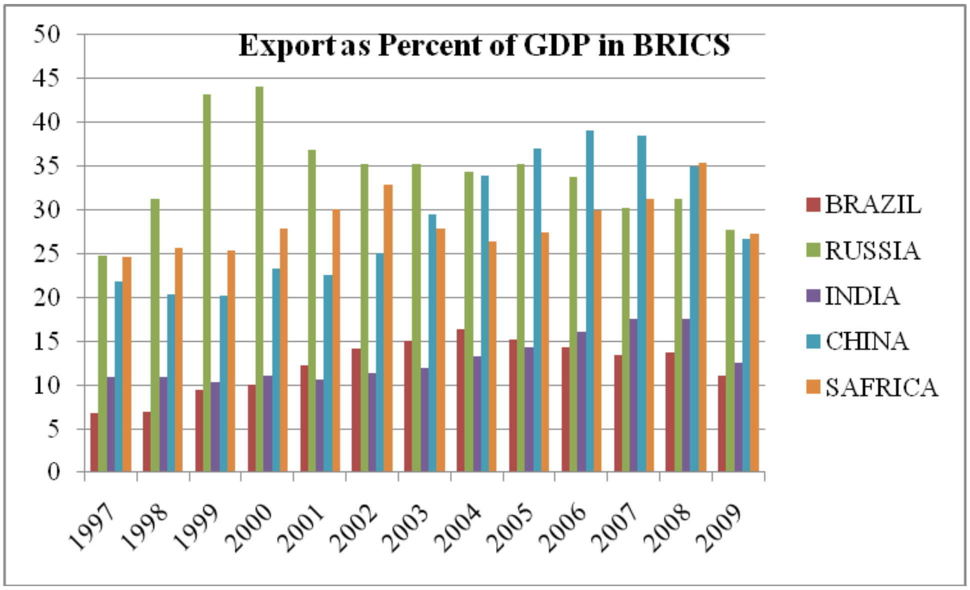
Source: Authors' creation using data from the World Bank database.

CHART 3A



Source: Authors' creation using data from the World Bank database.

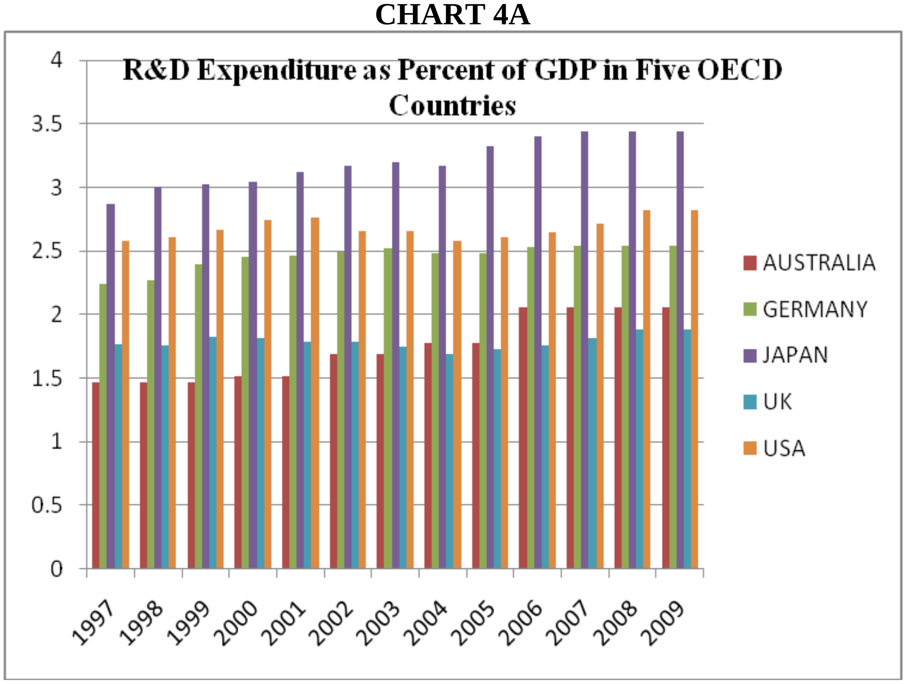
CHART 3B



Source: Authors' creation using data from the World Bank database.

R&D Expenditure. Japan's R&D expenditure was the highest among the five OECD countries followed by that of the U.S. and then Germany. The U.K. ranked fourth beating Australia for the years 1997 through 2003, after which Australia superseded the U.K. See Charts 4A and 4B for detail.

CHART 4A



Source: Authors' creation using data from the World Bank database.

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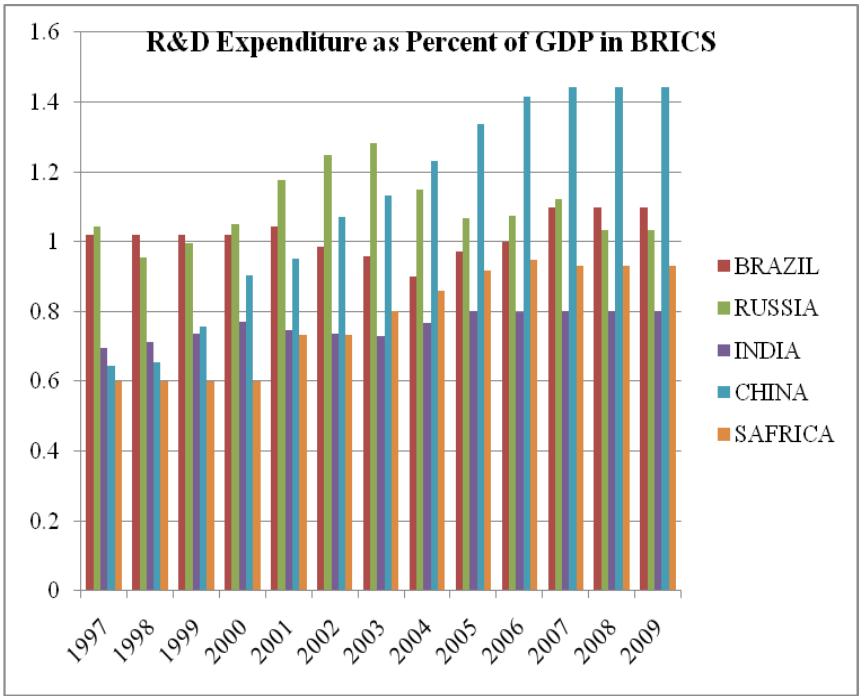
CHART 4B



Source: Authors' creation using data from the World Bank database.

Internet Access. Although BRICS countries are lagging in terms of percent of population with Internet access, the gap seems to be closing at a very fast rate. From 1997 to 2009, average annual growth rate in Internet access in BRICS was an astounding 1,831% compared to current annual average of 57.6% in the five OECD countries. China is spearheading this tremendous growth with expanding access. In 1979, only 0.79% of Chinese people had Internet access, whereas, by 2009, 39.2% of Chinese people had Internet access. In terms of percent of people with Internet access, Russia was top on the chart in 2009 with 42.09% of Russian people having Internet access followed by 39.20% in Brazil, 28.84% in China, 8.96% in South Africa, and 5.31% in India. It is surprising that despite India's significant progress in ICT-based global outsourcing, its Internet penetration remains the lowest among BRICS. This also signals tremendous opportunity of future growth in this area.[3] See Table 2 and Charts 5A and 5B for detail.

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[3] The 2011 Strategic Review of India's National Association of Software and Services Companies (NASSCOM) writes, "As a proportion of national GDP, the sector revenues have grown from 1.2 per cent in FY1998 to an estimated 6.4 per cent in FY 2011. Its share of total Indian exports (merchandise plus services) increased from less than 4 percent in FY1998 to 26 percent in FY2011. " (NASCOMM Report 2011, p. 5.[Web link to download the full report: http://www.nasscom.in/upload/Publications/Research/140211/Executive_Summary.pdf]

TABLE 2

INTERNET ACCESS AVAILABLE TO PERCENT OF POPULATION

Country Name	1997	1999	2001	2003	2005	2007	2009	Average Annual Growth Rate from 1997 to 2009
Five OECD Countries								
Australia	16.37	40.83	52.67	59.50	63.25	67.86	72.03	28.33
Germany	6.70	20.83	31.58	53.54	68.66	75.23	79.54	90.57
Japan	9.16	21.37	38.46	48.26	66.75	74.08	77.72	62.38
United Kingdom	7.39	21.30	33.50	60.92	69.62	74.99	83.19	85.47
United States	22.01	36.55	50.10	63.10	69.57	73.52	78.14	21.26
Five OECD countries' yearly average								57.60
	BRICS							
Brazil	0.79	2.04	4.53	13.21	21.02	30.88	39.20	407.23
China	0.03	0.71	2.65	6.17	8.58	16.13	28.84	7,382.50
India	0.07	0.28	0.68	1.74	2.47	4.09	5.31	601.47
Russian Federation	0.48	1.03	2.95	8.30	15.23	24.63	42.09	729.71
South Africa	1.71	4.24	6.44	7.12	7.63	8.22	8.96	35.33
BRICS yearly average								1,831.25

Source: Authors' creation using data from the World Bank database.

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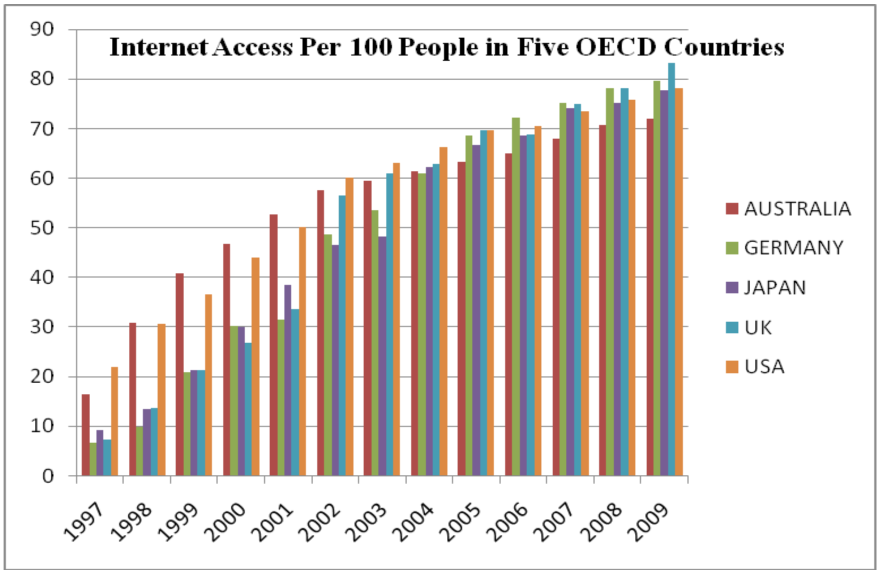
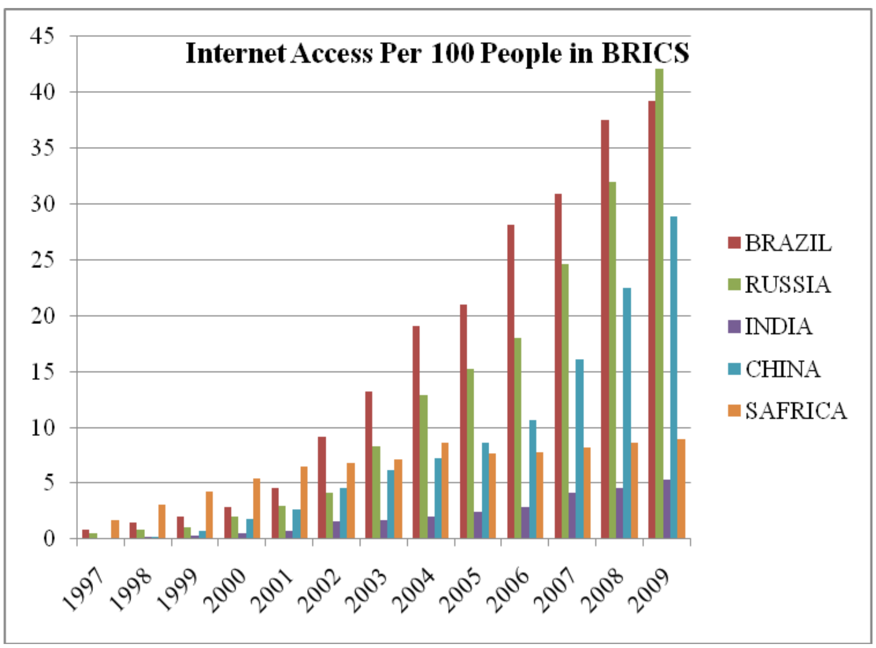
DOI: 10.7885/1946-651X.1037

CHART 5A



Source: Authors' creation using data from the World Bank database.

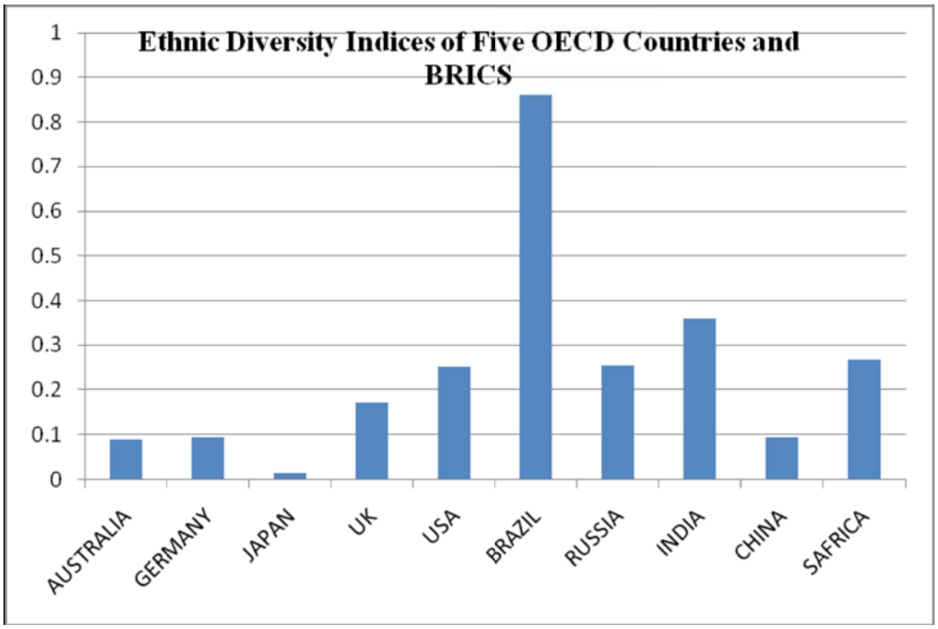
CHART 5B



Source: Authors' creation using data from the World Bank database.

Ethnic Diversity. Among the five OECD countries, the U.S. is the most ethnically diverse country with a diversity index of 0.25. The other countries rank as follows: the U.K. (0.17), Germany (0.09), Australia (0.09), and Japan (0.02). Among BRICS, Brazil is most ethnically diverse country with an index value of 0.86. The others rank as follows: India (0.36), South Africa (0.27), Russia (0.25), and China (0.09). After Parrotta et al. (2011), we expect to see statistically significant positive correlation between ethnic diversity and innovation activities. See Chart 6.

CHART 6



Source: Authors' creation using data from the CIA's World Factbook database.

REGRESSION RESULTS

We run both random effect and fixed effect regression models and summarize the results in the Table 3. In columns 2 and 3 of Table 3, we report the results of the baseline regression model, and in column 4 and 5, we report the results of a variant model after incorporating some fiscal variables. We have reported robust standard errors to correct for the heteroskedasticity. We have reported both the random effect and fixed effect models for further robustness check.

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DOI: 10.7885/1946-651X.1037

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TABLE 3

DETERMINANT MODEL REGRESSIONS OF PATENT COUNT

	Baseline Model		Variant Model	
	Random Effect	Fixed Effect	Random Effect	Fixed Effect
Internet Access (InNet)	0.063	0.092	0.110**	0.094
	(0.049)	(0.084)	(0.051)	(0.103)
InNet × BRICS	0.082	-0.105	-0.090	-0.116
	(0.071)	(0.138)	(0.085)	(0.157)
Ethnic Diversity Index (Div)	0.365***	0.001	0.862**	0.001
	(0.047)	(0.001)	(0.345)	(0.001)
Div × BRICS	0.002	0.001	-0.012	0.001
	(0.004)	(0.001)	(0.010)	(0.001)
Per Capita Power Use (Power)	0.054	0.931	0.496	0.909
	(0.225)	(1.127)	(0.349)	(1.713)
Power × BRICS	0.832***	0.340	0.345	0.226
	(0.219)	(1.351)	(0.327)	(1.904)
Enrollment in Tertiary Education (TertiaryEd)	-0.322	-0.352	-0.172	-0.352
	(0.272)	(0.482)	(0.406)	(0.520)
TertiaryEd × BRICS	0.555*	1.169	1.122**	1.249
	(0.337)	(0.949)	(0.531)	(1.042)
R&D Expenditure as Percent of GDP (R&D)	2.834***	1.276***	3.313***	1.275***
	(0.174)	(0.284)	(0.424)	(0.243)
R&D × BRICS	-4.009***	-1.915**	-4.300***	-1.878**
	(0.283)	(0.616)	(0.404)	(0.659)
Trade Openness	0.940	0.809*	-0.410	0.781
	(0.576)	(0.391)	(0.968)	(0.460)
Trade Openness × BRICS	2.456	12.438***	10.259**	12.778***
	(3.584)	(3.143)	(4.274)	(3.283)
Maximum Corporate Income Tax Rate (CIT)			1.117***	0.025
			(0.419)	(0.252)
CIT × BRICS			-0.967	-0.363
			(1.392)	(0.831)
Maximum Personal Income Tax Rate (PIT)			2.338	-0.169
			(1.799)	(3.108)
PIT × BRICS			-1.172	0.001
			(1.575)	(0.001)
	(2.961)	(4.697)	(3.557)	(4.974)
Observations	120	120	120	120
R-squared	0.994	0.609	0.995	0.627

Note: We report robust standard errors in parentheses and emphasize statistical significance of the estimated coefficients at the conventional 10% (*), 5% (**), and 1% (***) levels. InNet = percent of people with access to Internet. The binary variable BRICS takes on a value of 1 for BRICS countries and 0 otherwise. Trade openness is measured as ratio of value of export plus import to GDP.

Despite popular presumption that the Internet has leveled the innovation playing field by making distance communication and knowledge sharing faster and cheaper, in our regression results, we hardly find statistical evidence supporting the popular contention. In our baseline specification, the correlation coefficient for *Internet access* is positive for both the random effect and fixed effect models, but neither of them is statistically significant. However, in the alternative specification, the correlation coefficient is statistically significant for the random effect model and not for the fixed effect model. When we multiply the *Internet* variable with the binary *BRICS* variable, the coefficient of the interaction variable shows mixed signs, and none of them are statistically significant. Thus, we contend that the Internet is yet to emerge as a major driver of innovative activities in emerging countries.

Both in the baseline and variant random effect models, the D*iversity* variable is found to be positive and statistically significant at conventional levels. However, in the fixed effect models, this variable is positive but statistically insignificant. The ethnic diversity variable, when interacted with the *BRICS* binary variable, turns out to be positive but statistically insignificant for the baseline model. For the variant model, the correlation coefficients displayed mixed signs, and none of them were statistically significant. We contend that the BRICS countries are yet to capitalize on their ethnic diversity as a driving force of innovation.

The estimated coefficient of the variable *Energy* is positive but statistically insignificant. However, the coefficient of the power interaction variable is positive and statistically significant at the conventional levels in the baseline (random effect) model and positive but statistically insignificant in other models. From this result, we contend that emerging economies can improve their innovation performance by improving the generation and distribution of electricity so that per capita power consumption may rise.

The coefficients of the variable *TertiaryEd* turn out to be statistically significant when it is interacted with the variable BRICS for random effect models. We contend that investment in higher education in BRICS economies will earn positive dividends in the form of increased patented innovation.

Correlation coefficients of the variable *R&D expenditure* are positive and statistically significant across model specifications, and the coefficient is negative and significant in the BRICS interaction variables. This suggests that productivity of R&D expenditures in terms of increased innovation activities is significantly lower in BRICS compared to that in five OECD countries.

The correlation coefficient of the variable trade *Openness* is positive and statistically significant in the baseline specification (fixed effect model), but when we interact the variable with binary variable BRICS, the coefficient is positive and statistically significant for both the baseline (fixed effect) model, and alternative specification (both random effect and fixed effect models). From this result, we contend that the new wave of trade

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DOI: 10.7885/1946-651X.1037

liberalization will foster innovation activities more in emerging economies relative to that in OECD economies.

In the variant model, we control for some fiscal variables such as corporate income tax (CIT) and personal income tax (PIT). The coefficient for the CIT variable is positive and significant in the random effect model, and the coefficient for the PIT is ambiguous in signs across random effect and fixed effect models. None of them are statistically significant. The positive association between CIT rate and innovation needs to be interpreted with caution. According to the rent-seeking model of public economics, when an economic agent (firm or individual) earns economic profit or 'rent,' the government may take away a portion of that economic rent through levying taxes at higher (confiscatory) rates, which may result in the positive correlation between innovation and higher tax rates in the data.[4]

Conclusions

This paper, to the best of our knowledge, is the first study of the impact of macro-variables on innovative activities in BRICS. In the reported regression results, the estimated coefficients of some of the determinants did not conform to our hypothesis. Perhaps regressions using a longer panel dataset containing data from more OECD countries and more emerging economies (beside BRICS) would produce more intuitive results. Another limitation can be our model specification. We may have omitted some important variables. For example, differences in agglomeration economies or public policy priorities across BRICS and the OECD countries may also be contributing to the observed differences in terms of productivity of innovation activities in these two groups of countries. Also, other structural factors such as differences in legal environments related to intellectual property rights enforcement and differences in prospects of commercialization of patented knowledge due to variations in market sizes may lead to varied rates of innovation productivity as measured by patent counts. We could not test the impact of these above mentioned variables in this paper due to data constraints. With availability of more comprehensive time series data, future research efforts will be well spent in testing the impact of these variables on productivity of innovative activities using more comprehensive models.

[4] We contend the underlying intuition to be as follows: innovation, through commercialization thereof, may increase economic attractiveness of a region or country; allowing generation of economic rent for producers, and thus enabling fiscal authorities to collect part of it via taxation.

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DOI: 10.7885/1946-651X.1037