Research and Innovation Expenditure: A Key to Global Competitiveness, a Fractal Validation

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Abstract

Despite the clear impact of innovation through research on the national economy, expenditures (percentage from GDP allotted to each quality researcher) for supporting scientific investigations are observed to be highly erratic. This study analyzes the impact of this erratic and irregular pattern of expenditures to research on one's country's productivity and global competitiveness. It is shown that the high fractal dimension in expenditures smoothens the irregularity of both productivity and global competitiveness such that the governments' large amount of investment from GDP to research and development investments together with the alliance of the private units and high quality scientific research institutions collectively contribute to maximizing the economy's potentials to be productive and be globally competitive.

Keywords: research expenditure, productivity, global competitiveness, fractal correlational analysis

1.0 Introduction

One of the components of Global Competitiveness Index (GCI) is innovation. (Global Competitiveness Report, 2013) Innovations are outputs of researches translated into technologies. Thus, the pool of active researchers in a national economy plays an important role in its bid to be globally- competitive. Despite this clear impact of researchers on the national economy, expenditures (percentage from GDP allotted to each quality researcher) for supporting scientific investigations are observed to be highly erratic. This study attempts to analyze the impact of the erratic and irregular expenditures to research on both pool of qualified researchers and technology production (patents) through innovation, as these ultimately accrue to the country's bid to be globally competitive.

The 2013 World Economic Forum formulates three phases where countries are classified accordingly in terms of its competitiveness and the country's expenditure allocation. Factor-driven economies like Bangladesh, India, Venezuela and other countries tend to concentrate on appropriating more budget to institutions, building infrastructure, promoting the wellness of the macroeconomic environment, promoting health and primary education. Efficiency-driven categorized economies as Jamaica, Egypt, Peru and neighboring countries put their thrusts to higher quality education and conducting efficient training; goods market competence, labor market effectiveness, financial market advancement, technological keenness, and taking good care of the market. And there are innovation-driven economies which highlight business sophistication and innovation. The North American and European cities are among the world's most aggressive

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nations today and are likely to retain their advantage until 2025, in spite of issues over aging populations and infrastructure concerns. Asia's (Japan, China, Taiwan, Hong Kong, Singapore) economic climb is reflected in the competitiveness of its cities in 2025. (Economist Intelligence Unit, 2013)

To this effect, the conventional division between countries being "developed" or "developing" will become less relevant and will instead differentiate among countries based on whether they are "innovation-rich" or "innovation-poor". For economies that desire to improve beyond the usual production, quality in higher education, training and innovation are very vital. (Global Competitiveness Report, 2013)

Patents are, in very basic terms, the right to appropriate returns from research (Reitzig, 2004). Prior to application for patents, years of research and research manpower have been expended thus justifying exclusion of other firms from practicing or producing the same processes and products. Research, therefore, forms the core from which technological productivity as measured by the number of patents applied and granted is made feasible. In most instances, the national research productivity is accounted for by research emanating from the academe with a significant portion likewise contributed by the research units of private industries. Interestingly, the amount of expenditure (% from GDP) to patents of countries follows an erratic pattern. While many of these nations allocate much to innovation, their global competitiveness indices are still relatively low with that of the others which allocate less for innovations. In the case of Finland, it leads all countries in terms of its expenditures to innovation by allocating 3.8% from its GDP and is one of the leading in the GCIs. However, Monaco and Bosnia and Herzegovina allocate 0% of its budget to research and development yet they have higher GCI than those countries allocating much more. It is to this extent that the researchers feel the expedience to quantify and analyze these irregularities through fractal analysis (fractogram) and are hopeful to recommend some measures on policy making relating to expenditure appropriation to innovation and patents.

2.0 Basic Concepts in Fractal Statistics

Fractal statistical analysis applies to situations where the mean or first moment does not exist due to the presence of outliers. It also applies to situations where smaller fluctuations dominate the larger ones. Padua (2012) suggested using a power law distribution similar to Pareto's distribution given by:

$$1....f(x) = \frac{\lambda-1}{\theta} \left(\frac{x}{\theta}\right)^{-\lambda} \quad , \lambda > 0, \theta > 0, x \geq \theta$$

where λ is defined as the fractal dimension of X and θ is the smallest (positive) value of the random variable.

The maximum likelihood estimator of λ is:

$$2.... \hat{\lambda} = 1 + \frac{1}{\log\left(\frac{x}{\theta}\right)}$$

so that each observation contributes to the fragmentation of the support X. Padua (2013) demonstrated that the distribution of the maximum likelihood estimators obey an exponential type of distribution so that both the mean and variance of the fractal dimensions exist.

A device called fractal spectrum or λ(s) spectrum was suggested by Padua et al.(2013) to identify locations on the support X where high data roughness or fragmentation occur and where smoothness appear to dominate. The spectrum is defined as:

$$3..... \lambda(s) = 1 - \frac{\log(1-\alpha)}{\log\left(\frac{X\alpha}{\theta}\right)} = 1 - s\log(1-\alpha)$$

where, X_α is the α^{th} quantile of X and $s = \log\left(\frac{x}{\theta}\right)$.

3.0 Research Designs and Methods

The study is descriptive in nature and aims to validate a new procedure for assessing relationships between two variables that do not behave as realizations from a normal distribution but from a power law or fractal distribution. Data for the variables are based from the Global Competitiveness Report 2013, for global competitiveness index which compositions are based from the following diagram:

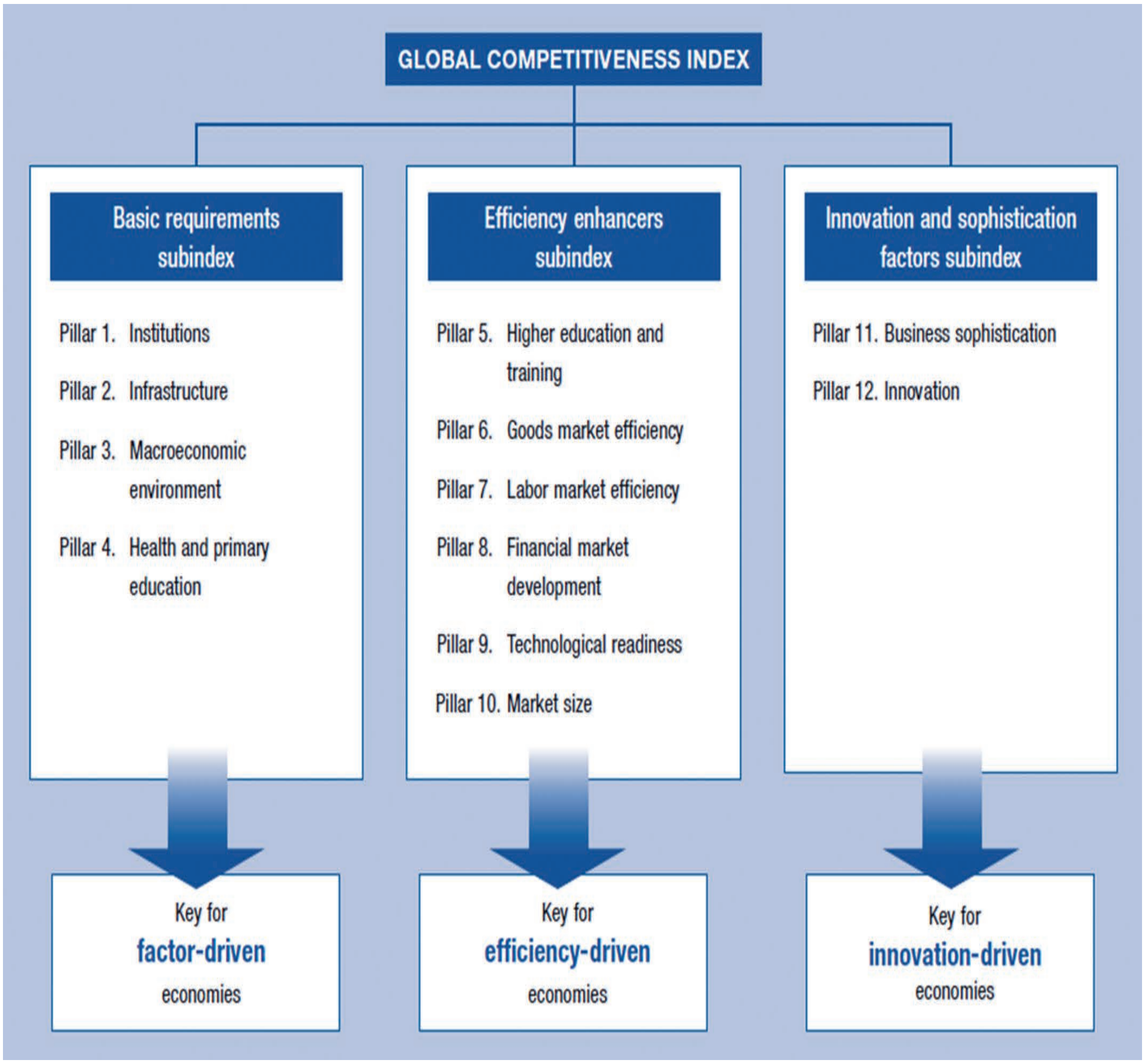

Figure 1. Global Competitiveness Index Indicators

and Human Development Report 2013 research and innovation figures respectively.

The data obtained are analyzed first by utilizing statistical software to determine the one-dimensional representations of the expenditure, productivity index (expressed as patent per researcher) and the country's global competitive index. This one-dimensional graphical representation was then exported to a fractal software available for free in the net. The fractal software outputs the fractal dimensions of the variables in question. In turn, these fractal dimensions represent the degree to which the variables fragment a smooth straight line.

The two-dimensional scatterplot of the amount of expenditures allocated to innovation versus the productivity index and the allocated expenditures versus the global competitiveness indices of the countries were plotted using the same statistical software. Once again, the plots were exported to the fractal software to obtain the resulting fractal dimension of the two-dimensional graphical representation. This fractal dimension now represents the effect of the ruggedness or roughness of the data on expenditures to the irregularity of productivity indices and GCI. The extent which the roughness of expenditures influences the roughness of the global competitiveness index is given by

$$R^2 = 1 - (\lambda_{xy} - 1)^{\sqrt{\lambda x \, \lambda y}}$$

where:

$\lambda_{xy} = two - dimensional\ fractal\ dimension$

$\lambda_x = fractal\ dimension\ of\ x$

$\lambda_y = fractal\ dimension\ of\ y$

4.0 Results

Figures 2, 3 and 4 show the one-dimensional plots of the expenditure, productivity index (expressed as patent per researcher) and the country's global competitive index. Following is figure 5, the fractal spectrum displaying a graphical view of the multifractality of the data while Figures 6 and 7 show the two-dimensional plots of expenditures allocated to innovation versus the productivity index and the allocated expenditures versus the global competitiveness indices of the countries.

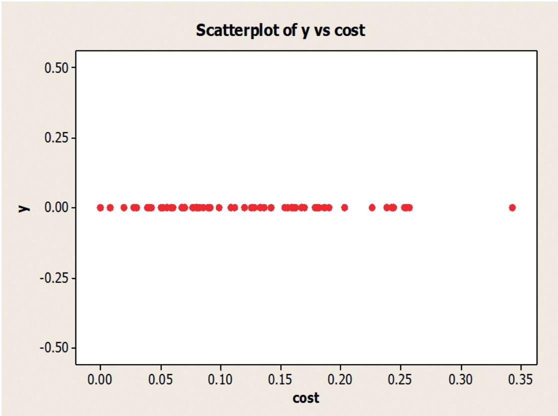

Figure 2. One-dimensional plot of the expenditure

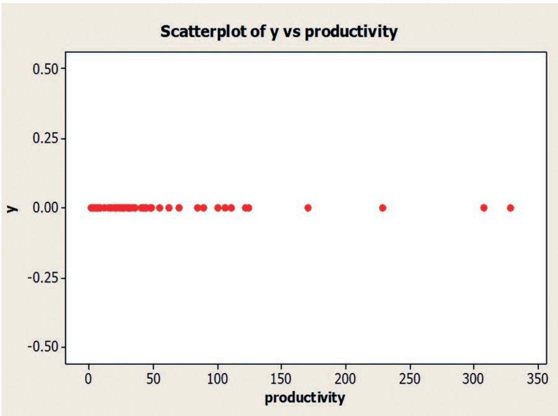

Figure 3. One-dimensional plot of productivity

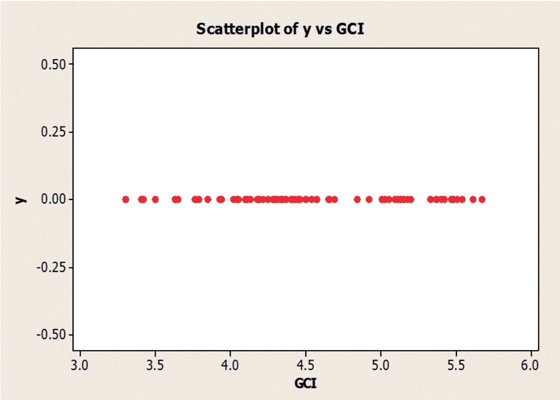

Figure 4. One-dimensional plot of the GCI

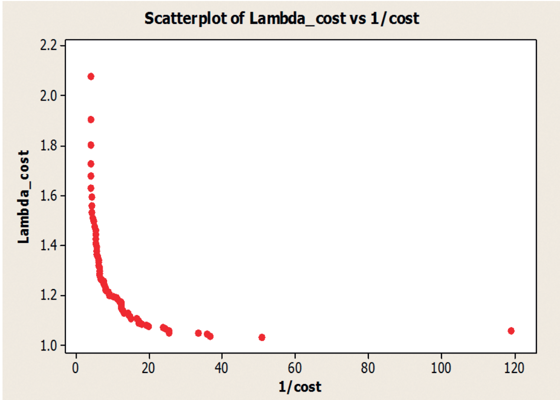

Figure 5. Fractal Spectrum of Data on Expenditure

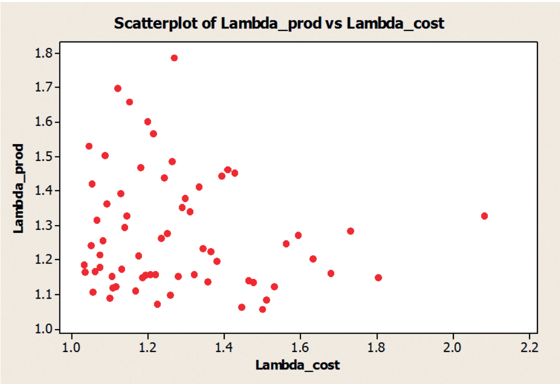

Figure 6. Two-dimensional plot of cost vs productivity

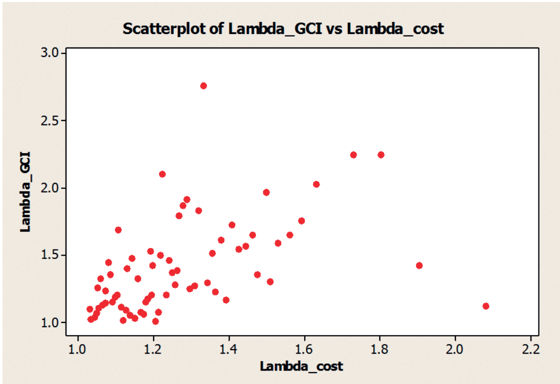

Figure 7. Two-dimensional plot of cost vs GCI

Table 1. Summary of Fractal Dimensions

Variable	Fractal Dimension
X: expenditure	1.68
Y: productivity	1.57
Z: Global Competitiveness Index	1.56
XY: scatterplot	1.20
XZ: scatterplot	1.18

Table 2. Comparison of Correlations

Classical Correlational Statistics	Fractal Correlation Statistics
$R_{xy} = -0.144$ (p-value=0.230)	$R^{\lambda}_{xy} = -0.130$
$R_{xz} = 0.682$ (p-value=0.000)	$R^{\lambda}_{xz} = -0.472$

5.0 Discussions

1. The *one-dimensional* plot of the expenditure to research and patenting reveals an extremely rugged pattern higher than any of the fractal variables as depicted by a dimension of **1.68** (showing a 70% deviation from the normal assumptions). Figure 6, the fractal spectrum, supports this high fractality of the available data. Meaning, while most of the countries have low percentage from GDP allotment to research, several countries give higher budget to innovation is also observed (this analysis cannot be realized with the utility of traditional statistics that smooths out these evident disparity). Monaco, Bosnia and Herzegovina, Guatemala, Algeria, Philippines, and Sri Lanka, and Madagascar for instance belong to the scale of countries where only 0% to 0.1% from GDP is allotted to research expenditures while Finland, Sweden, Japan, Korea (Republic of), Denmark, Switzerland, Germany, and the United States appropriated 2.8%-3.8% of their GDP for this purpose.

2. In terms of the *one-dimensional* plots of productivity and global competitiveness, fractal data generated a dimension of **1.57** and **1.56** respectively (showing 57% deviation from the norm). This shows that the irregularities of productivity and global competitiveness across countries are comparable that is, the disparities between countries which are "innovation rich" (number of researchers over patents produced) or "innovation poor" and globally competitive nations to non-competitive ones are quite similar. This is evidenced by data gathered from the 2013 economies pioneered mainly by European countries which include Switzerland, Finland, Germany, Sweden, the Netherlands, and the United Kingdom to be reported as most competitive. Maintaining its spot on the second-most competitive economy is Singapore, with two (2) other Asian countries, Hong Kong and Japan, making it in the top 7th and 9th respectively. The common strengths of these mentioned countries are related to innovation and strong institutional support. (World Economic Forum, 2013)

   Meanwhile, despite this more optimistic global stance, some ambiguity still remains. For instance, falling a further nine place is Pakistan ranking 133th overall. Since the year 2006, Pakistan's ability to economically excel is crippled by concerns related to corruption, and lack of property rights protection. Also, India has consequently reduced its place from the ranking. On the other hand, the Philippines which was once lagged behind, is now in the lead of India, and its ranking is set 29 places only by China, up from just 8 in 2006. Also, the second largest country of South Asia, Pakistan has dropped 28 positions in the rank and considered the biggest decline of all the sampled economies since 2006. With the unpredictable trends attributed to uneven macroeconomic and investment atmosphere, Mongolia recorded a six places drop over the period.

3. Table 2 reveals the relationship (expenditure and productivity AND expenditure and global competitiveness) as viewed from the classical and fractal statistics' perspective. On one hand, classical correlation would suggest that as the expenditure is increased, a country's productivity is lessened while significantly increasing the GCI. This, however, does not convey a practical and reasonable result. The World Economic Forum reports that as a nation develops and as it aims to be competitive; productivity must be improved. Productivity

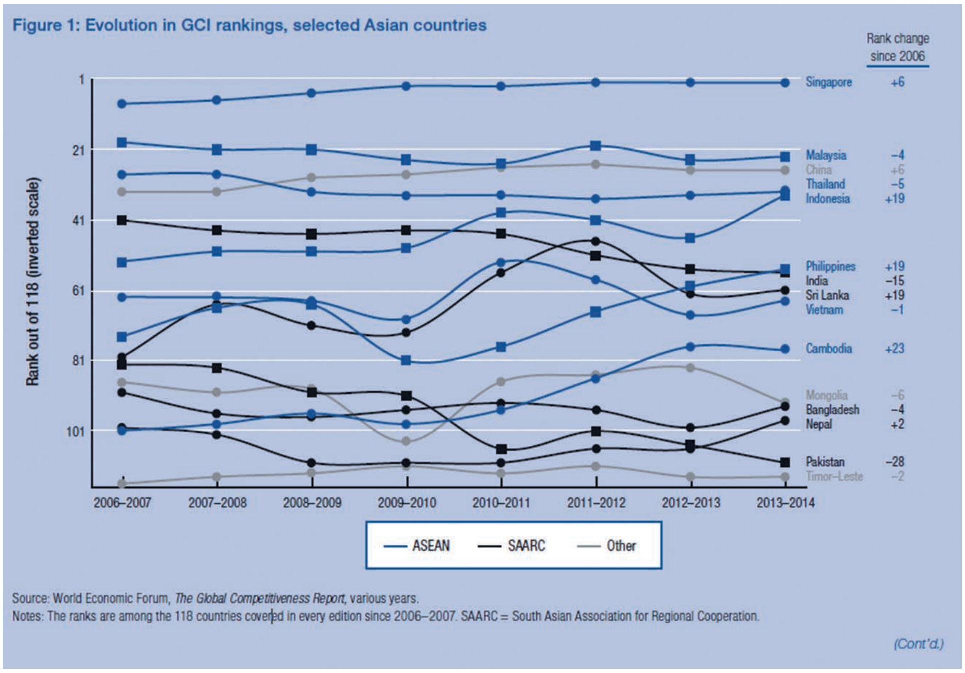

Figure 8. (ASEAN's Competitiveness Landscape, 2013)

performance, weaker than in previous eras, is now the biggest drag on the economy's ability to be competitive. (McKinsey Global Institute, 2012)

On the other hand, fractal correlational statistics (fractogram) reveals that the impact of the variations in the expenditure lowers the roughness of both productivity and global competitiveness, as validated by the negative slopes of the existing relationships. The high variations in research expenditure can be accounted from countries or economies with high amount of allocation to research expenditure (notable economies are Switzerland, Finland, Sweden, Japan, Korea (Republic of), Denmark, Germany, and the United States). Logically then it follows that the nation's capacity to support higher research expenditures can maximize its comparative advantage or even benchmark those of the known leading and globally competitive economies.

Switzerland (spending 3% from her GDP) retains its 1st place position again (Global Competitiveness Report, 2013). The best features of the economy are related to innovation. The country takes pride on the existence of its valuable scientific research institutions making the country a premier innovator. An added feature of the country's great innovation imagery is due to its business sector offering first class on-the-job training opportunities. Its private companies and citizens are proactive in the adaptation of the latest technologies. Another country reported at the top spot is **Finland** (spending 3.8% from GDP), leaped to the third place and ahead of **Sweden** (3.6% of GDP invested to research expenditure). Its strength is noted in both health and primary education and training which can be accounted from the government strong focus on education, technological adoption and innovation. The City of Helsinki Report of 2013 named the country as one of the most innovative countries in Europe. Moreover, Norway (2% of GDP allotted to innovation expenses) features notable improvement in the uptake if Information, and Communications Technology especially regarding the increase of internet bandwidth and increased utility of mobile broadband. A remarkable macroeconomic environment is also observed in the Republic of Korea (9th place, second only to Norway among OECD countries). It boasts best infrastructural and educational systems where enrolment rates at all levels of education are among the highest in the whole word. In total, the country's advanced technological adoption (ranked 22^{nd}) and strong business sophistication (ranked 24^{th}) have caused the country's take on a remarkable capability for innovation (ranked 17^{th})

On the contrary, **Bosnia** and **Herzegovina**, registered a 0% expenditure on research and innovation. Bosnia and Herzegovina, European Union's lowest rated globally competitive country. It made very little efforts towards a functioning economy, promotion of intellectual, industrial and commercial property right to align with EU standards are less advanced (Global Security.org, 2013). Similar economic pattern to Bosnia and Herzegovina is the Monaco government, Having only one university located in Monaco, namely the International University of Monaco (IUM), it is very difficult for the country to generate research outputs and only considers business and private institutions to provide research services but for the sole consumption only of the respective industry. Hence, there is no avenue where national economic agenda are discussed and brainstormed, and policy making formulation is not grounded from an intellectual output, the researches.

6.0 Conclusion and Recommendation

Fractal correlational statistics (fractogram) provides a clearer validation that an economy investing higher amount (% from GDP) on a functional research output (patents and innovations), contributes to maximizing its potentials to productivity and global competitiveness. The analysis of roughness on research expenditure (onto productivity and global competitiveness) of a country justifies that a sufficient investment in research and development (R&D) by the government with an alliance with the private sector and the presence of high-quality scientific research institutions can collectively form a powerhouse of globally competitive economy where generation of the basic knowledge needed to build the new technologies; extensive collaboration in research and technological developments between universities and industry; and the protection of intellectual property rights should be advanced.

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