

# FRACTAL ANALYSIS OF GROSS DOMESTIC EXPENDITURES ON RESEARCH AND DEVELOPMENT (R&D) WORLDWIDE

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**Abstract**— *This paper aimed to describe the roughness of data on gross domestic expenditures on research and development (R & R&D). From the World Bank statistics, fractal analysis was performed to discover a pattern of self-similarity and ruggedness of gross domestic expenditures on research and development (R&D) of countries worldwide in 2018. The fractal dimension is 1.84710, indicating that 4.7 percent of countries expended a higher percentage of their GDP on research and development (R&D). Hidden fractal dimensions complement this data, which shows that counties with lower rates of gross domestic expenditure on research and development (R&D) have low economic growth and development.*

**Keywords**— *fractal analysis, gross domestic expenditure, research and development*

## I. INTRODUCTION

The data's self-similarity, roughness, or ruggedness is assessed using fractal analysis. It includes numerous methods for assigning a fractal dimension and other fractal features to a dataset, a theoretical dataset, or a pattern or signal collected from phenomena such as natural geometric objects, sound, market fluctuations, and so on (Mulligan, 2004).

Fractal analysis is now widely employed across all disciplines of science. A significant restriction of fractal analysis is that determining an empirically established fractal dimension does not always indicate that a pattern is fractal; instead, other critical criteria must be evaluated (Mandelbrot, 1983).

Gross domestic expenditures on research and development (R&D) are expressed as a percent of the country's Gross Domestic Product (GDP). The gross domestic expenditure on R&D indicator consists of the total expenditure (current and capital) on R&D by all resident companies, research institutes, universities, government laboratories, etc. It excludes R&D expenditures financed by domestic firms but performed abroad.

Research and Development (R&D) has long been seen as one of the essential techniques for ensuring technological potential and thus innovation and economic growth. R&D is defined as a systematic creative activity conducted to grow the store of information, including understanding man, culture, and society, and using this stock of knowledge to invent new applications (Torun & Cicekci, 2007). Thus, R&D investment enhances the likelihood of enterprises and regions obtaining a greater level of technology, allowing them to launch new and superior products and/or processes, resulting in higher levels of income and growth. Pioneers of the endogenous growth model, Romer (1990) and Lichtenberg (1992), demonstrated that the relationship between technological investment and R&D expenditure leads to increased productivity and, hence, growth (Bilbao-Osorio & Rodriguez, 2004).

Wakellin (2001) investigated the links between productivity growth and R&D expenditures in 170 companies listed on the UK stock exchange. The study's findings revealed a remarkable and significant impact on its productivity growth.

Samimi and Alerasoul (2009), on the other hand, evaluated the impact of R&D on economic growth in developing nations. They selected a sample of 30 developing nations for which data was available from 2000 to 2006. According to their findings, emerging countries' low R&D spending has no substantial impact on economic growth.

Furthermore, according to Zachariadis (2003), R&D intensity is related to patenting, patenting is related to technological advancement, and technological progress is related to economic growth. He analyzed annual data on patents, R&D spending, gross output, and productivity growth. Following this, these empirical research findings revealed a favorable relationship between R&D expenditures, patenting, and production.

## II. OBJECTIVES

This paper sought to investigate the ruggedness of the data through fractal analysis of gross domestic expenditures on research and development (R&D) of the countries worldwide in the year 2018 data according to the World Bank. Further, this paper sought to determine the natural (fractal) state of the data, find out if there exist a fractal distribution, and analyse the hidden dimensions and fractality of the data.

## III. METHODOLOGY

This study utilized fractal statistics to measure fractal dimension which is a measure of the roughness of the data. Histograms of the gross domestic expenditures on research and development (R&D) were determined and inspected if it is exponential and fractally distributed to establish a certain pattern or model for the phenomenal trend of expenditure on Research and Development (R&D) of the countries worldwide.

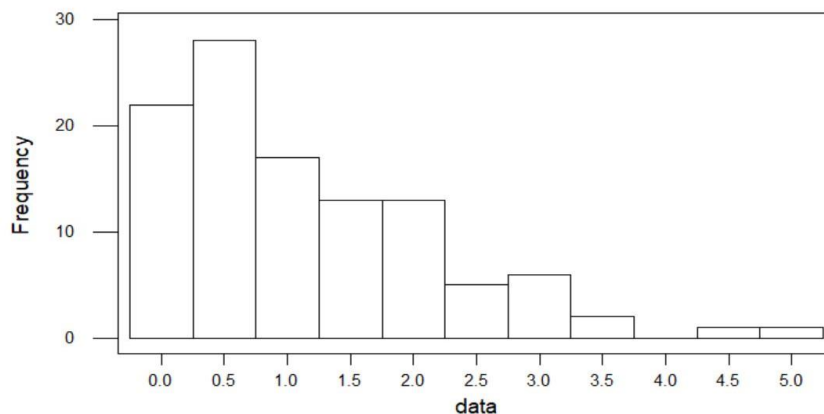
In this study, the researchers employed data from the World Bank. To determine the fractal dimension of the tabulated data set, the researcher first looked at the  $\log x/\theta$ , got the mean of the  $\log x$  then assessed the entire ruggedness index  $\lambda$  of the data. Furthermore, these formulas were used:  $EXP(\text{data}/\theta)$ ,  $\lambda = 1 + 1/x$ .

## IV. RESULTS AND DISCUSSIONS

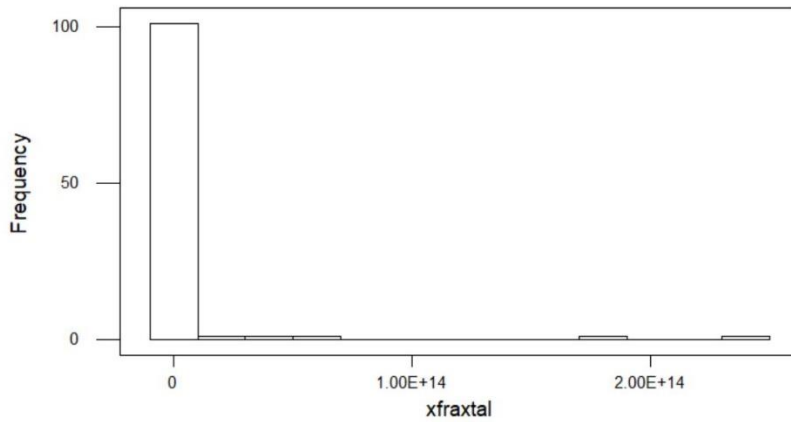
The data presented in this section depicts the exponential and fractal distributions of R&D expenditures as a percentage of GDP of the countries globally. Figure 1 depicts a histogram or exponential distribution of research and development (R&D) expenditures as a percentage of GDP per country in 2018.

Figure 1 depicts the Expenditures on Research and Development (R&D) as a percentage of GDP of the countries worldwide, which appear most frequently between 0.01 and 0.08 indicating that these countries have lower gross domestic spending on R&D. The data implies that these countries with lower expenditures on research and development will likely to have low economic growth. This is based on the study of Tiryakioglu (2016), that research and development (R&D) expenditure has predicted a significant influence to the economic growth in developing countries.

As depicted in Figure 2, the exponential distribution has one-stroke features, hence the xfractal dataset confirms that the distribution is definitely fractal.



**Figure 1:** Exponential Distributions of Gross Domestic Expenditure on Research and Development (R&D)



**Figure 2:** Histogram or Fractality of the data in the Year 2018

According to table 1, the gross domestic expenditure on research and development (R&D) of countries worldwide in 2018 was 1.18, with a minimum observation ( $\theta$ ) of 0.01. Furthermore, the fractal dimension is 1.84710, implying that 4.7 percent of countries obtained a higher percentage of gross domestic expenditure on research and development (R&D).

**Table 1: Fractal Distribution of Data (n=108)**

Variable	Mean	Minimum Observation ( $\theta$ )	Lambda ( $\lambda$ )
Gross Domestic Expenditure on Research and Development (R&D)	1.18	0.01	1.84710

As shown in Table 2, the values ranged from 0.01 to 0.07 where Mauritania attained the lowest rate while the Gambia has the highest rate of 0.07. The data implies that these countries have lower rate of gross domestic expenditure on research and development (R&D). From World Data Atlas (2018), these five countries showed very low expenditure on research and development (R&D) at 0.1% from their GDP.

**Table 2:** Countries with Lower Rate of Gross Domestic Expenditure on Research and Development (R&D)

Country	Percentage
Mauritania	0.01
Guatemala	0.03
Iraq	0.04
Kuwait	0.06
Gambia	0.07

Table 3 shows the list of countries with a high percentage of GDP expenditures on research and development (R&D). As indicated in Table 3, there are 5 countries or 4.7 percent among 108 countries which expended higher percentages from the GDP for research and development (R&D). The data shows that Israel were identified as the country with highest rate of GDP expenditure on research and development (R&D).

**Table 3:** Countries with High Rate of Gross Domestic Expenditure on Research and Development (R&D)

Country	Percentage
Israel	4.94
Korea, Rep.	4.53
Sweden	3.31
Japan	3.28
Austria	3.17

## V. CONCLUSION

This paper sought to investigate the ruggedness of the data through fractal analysis of gross domestic expenditures on research and development of the countries worldwide in the year 2018 data according to the World Bank. Further, this paper sought to determine the natural (fractal) state of the data, find out if there exist a fractal distribution, and analyze the hidden dimensions and fractality of the data. Research and Development (R&D) is one of the most important variables influencing the country's economic growth and development through enhancing technological capabilities, expanding the resource base, and promoting resource use capability. Countries that innovate through R&D activities always have strong economic growth, and various studies have shown the importance of R&D in economic growth. As presented in the results of this study the countries with higher rate of expenditure from the GDP for research and development (R&D), had a good economic growth and development, and those with low rate of expenditure for research and development (R&D) from the GDP has low economic growth and development. Furthermore, fractal analysis is by far the best tool for assessing data roughness.

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