Research on the Relationship Between Income Inequality and Innovation

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Abstract: Since the reform and opening up, China has made world-renowned achievements in the economic field, but at the same time, the problems of unbalanced regional economic development and widening income disparity have also plagued the further development and transformation of China's economy. The study of the relationship between the increase of income distribution inequality and the demand for innovative products of enterprises has become a subject of increasing attention of scholars. In this paper, we analyse the linear and nonlinear relationship between income inequality and innovation by constructing a multiple regression model, and the research results show that in different ranges of Gini Index, innovation varies in different trends. A non-linear regression model may be used to account for the relation between innovation and income inequality. This research points out viable directions to generate more precise predictions of how innovation will vary in the future in certain regions given current Gini Index.

1. Introduction

1.1 Research Background and Significance

Innovation has been a more important factor regarding the fast-developing economy in 21st century. Innovation means both the invention of a new product and the way in which the firm earns money from it. Innovation could be impacted by multiple factors, including the GDP of an economy, the R&D budget firms are willing and able to spend, and the technology level of a country. However, the inequality of the population and its influence on innovation have been topics that are seldom discussed. Indeed, under the general large scale of development, the development of individuals is unbalanced. Innovation cannot be only carried out by large firms and the government. To encourage individuals and small firms to start innovation, the relationship between innovation and income inequality needs to be carried out. The value for this research is that it develops a linkage between innovation and income inequality, which was a topic seldom recognized previously. Categorizing countries to different groups based on their Gini Index and the performance of innovation through the variation of Gini Index. The regression model also fits the data to some extent, indicating some kind of regression model may be used to calculate the future innovation based on current income inequality data.

1.2 Research Contents and Framework

This research focuses on how income inequality affects innovation in both positive and negative way. Linear and non-linear regression models are built with an evaluation based on the distribution of innovation and income inequality. Income inequality is quantified as Gini Index, which makes the calculation of the data easier. Innovation is quantified as patents filed by countries, making the abstract concept visual. There are four parts of the main research, including the categorization of countries through their Gini Index, the result of the linear regression model, the result of the non-linear regression model, and the evaluation of other factors affecting income inequality and innovation. The next part of this paper is organized as follows; the second part is a literature review to sort out the research results about the topics related to income inequality and innovation; the third part is an empirical analysis to explore the linear and nonlinear relationship between income inequality and innovation by constructing a multiple regression model; the fourth part is the results and discussion, and finally, the conclusion.

2. Literature Review

21 years after entering the 21st century, the global economy has developed in a large scale. Under structural reforms and new policies, some developing countries have been pacing up, trying to catch the economic growth of the developed ones. The research shows that the empirical results indicate that total patents granted that measures the quality of innovation is a statistically significant determinant of economic performance, which implies that quality innovation is more vital compared to quantity innovation [1]. John E. Tookey (2011) pointed out that the net effect of such renewal or improvement is a novelty of process, technology or technique which allows stakeholders to make new choices [2]. Salih Yesil and Inci Fatma Doğan (2019) indicates that innovation capability had a significant positive influence on innovation [3]. Therefore, what defines innovation capability then? Innovation capability refers to the potential of individuals or organizations to carry out innovation. Siong Hook Law, Tamat Sarmidi and Lim Thye Goh (2020) claims" Any move towards promoting innovation should be a priority" [4]. In their research, it is found out that the innovation activities of upper-middle-income countries are catching up with the high-income countries where these two income levels converge to a similar point. Income inequality has been a negative result of some kind of developments globally, John Wildman (2003) argued that any policy that aimed at equalizing health but does not account for income inequality, will lead to unequal distribution of health [5]. Income inequality affects the population's life expectancy, and the negative effects of income inequality are stronger in high-income countries [6]. This is linked to innovation given that countries with generally high income do not always perform as countries with high innovative ability. Thus, the relationship between innovation and income inequality is analyzed.

3. Methodology

This research tries to develop a model showing the linear of non-linear relationship between the income inequality and the innovative production of a country. The fundamental concept of this research is to use the RStudio to analyze the Gini Index and patents filed in the country. Gini Index can used to measure a heterogeneity of income [7]. The research chooses this coefficient to represent the income inequality level of a country because the Gini index can be deduced from the Lorenz Curve which is a highly quantitative curve measuring the diversion of the highest income and the average income of a country. Innovation is an abstract concept. It is hard to evaluate precisely the innovation an organization has each year. Patents have been always linked with innovation [8]. Therefore, the research tries to quantify innovation by taking patents being filed each year in countries as the measure of innovation. Data in the research is downloaded from THE WORLD BANK. Data from 1967 to 2019 is provided on the website. Number of patents filed each year is given by WIPO.

The research focuses on data from 2000 to 2020 since the global economy has developed in an astonishing fast pace in these 20 years. The growing economy has caused much imbalance in the distribution of wealth. First, the global Gini Index of 30 countries is plotted in a scatter graph in RStudio. Due to numerous external factors, though a best fit line is drawn, the dispersion of the data points is relatively large. Evaluation of external factors playing the role in determining the income inequality is needed. The process of plotting the scatter graph of patents as an innovation process is generally the same as that of Gini Index. After both innovation and patent are plotted, they are integrated to show how innovation varies with income inequality. After that, a graph of Gini Index as X-axis and Patents filed as Y-axis is plotted. How the patents filed with Gini Index is observed, though it does not seem to be a regulatory one. In numerous cases, patents filed in countries are not related to Gini Index in a typical way that the research expects. The coefficient between Gini Index and the Patents filed, respectively referring to income inequality and innovation is calculated. The research first extract the data of Gini Index and Patents filed in 30 countries from 2000 to 2019 to an excel.

Then the data is imported and processed in RStudio through the linear regression model in order to calculate the coefficient and related data of this relationship. The 30 sets of data are imported and processed. Each is drawn as a scatter graph. The research first analyzes the data in a linear regression model with a formula:

$$\mathrm{P} = \mathrm{b} + \mathrm{IG} + \mathcal{E} \tag{1}$$

where: P refers to patents filed. b refers to the intercept. I refers to the coefficient. $\mathcal{E}$ refers to standard errors. After that, a non-linear regression model is built with formula:

$$\mathrm{P} = \mathrm{b} + \mathrm{I}_1\mathrm{G} + \mathrm{I}_2\mathrm{G}^2 + \mathrm{I}_3\mathrm{G}^3 + \mathcal{E} \tag{2}$$

where: P refers to patents filed. b refers to the intercept. I_1, I_2, I_3 refer to the coefficients. $\mathcal{E}$ refer to standard errors. The research than predicts that there might be external factors affect patents filed instead of Gini Index alone. In following research, external factors are evaluated after categorizing the countries to different group.

4. Results and Discussion

4.1 Classification of Countries

Less income inequality between people may, as a result, raise people's competitiveness in innovative areas. If income is highly inclined to one part of the society, there could, to a large extent, be people feeling that the relative cost of them doing innovative researches is less acceptable than that towards people of higher income in society. The research examined countries' different Gini Index and patents filed, covering developed countries, developing countries and less developed countries. The research found out that there are no one-size-fit-all trends of the wealth inequality and innovation while countries of different Gini Index levels have different trends of distribution. Among the countries examined, there are several countries that have a generally linear relationship between Gini Index and number of patents filed in the country. The similarity of them is that they all have either relatively high Gini Index or relatively low Gini Index. This finding suggests that the Gini Index in a special range is demanded if a country wants to achieve a sustainable development. In the case of Brazil, the patents filed each year form a linear and decreasing relationship with the local Gini Index. In the year in which Brazil had a 52.8 Gini Index, the country filed 4959 patents. But in the year in which Brazil had a 58.4 Gini index, the country filed only 3439 new patents. The Brazil case is not special. In Colombia, when it had a Gini Index of 49.7, 595 new patents were filed. When its Gini Index increased to 58.7, only 75 new patents were filed. What's more, the increasing trend of the Gini Index and the decreasing trend of patents filed form a best-fit line with small standard deviation, so does the Brazil example. After constructing models for 50 countries with high wealth inequality, the research suggests that there could be a negative correlation between Gini Index and patents filed when the Gini Index exceeds a level of 40. The coefficient between the patents filed and Gini Index is deduced to be also changing with the countries' different levels of Gini Index. For countries which initially have a low Gini Index, there is also a linear relationship between the patents filed and the Gini Index. Finland, Austria, Canada all have an increasing trend between patents and Gini Index. In the Finland case, when the country has a Gini Index of 26.8, the patents filed that year were 1419. When the country has a Gini Index of 28.3, the country has patents filed 1804. For Canada, when the country has a Gini Index of 32.7, the patents filed were 4078. When the country has a Gini Index of 33.8, the patents increase to become 4998. For Austria, the rate at which the patents filed grow with the growth of Gini Index is steadier, but also with a linear relationship. The similarity of those three countries is that they all have a Gini Index around 30 but lower than 35.

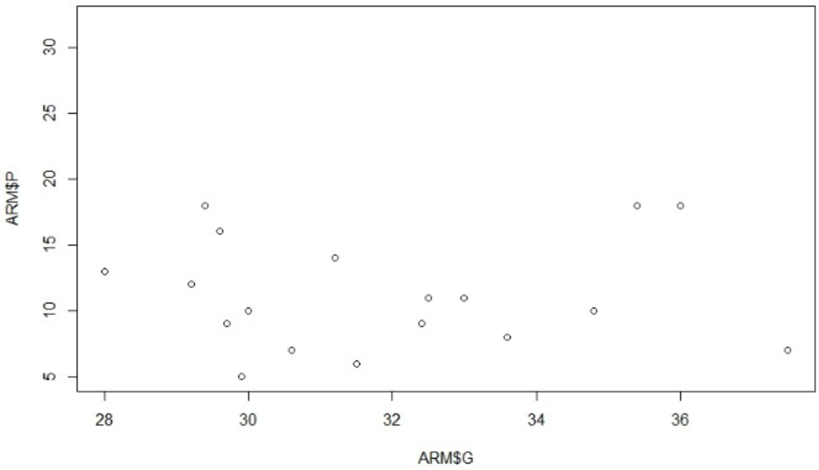

Figure 1 The variation of patents filed with Gini Index in Armenia

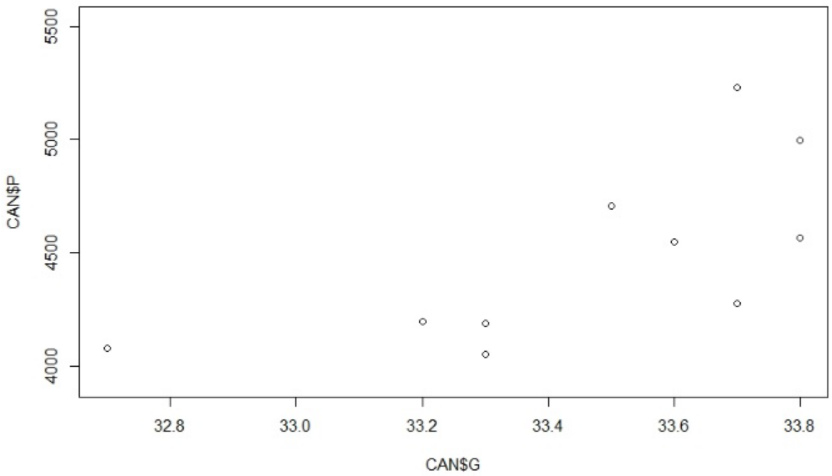

Figure 2 the variation of patents with Gini Index in Canada

For those with Gini Index between 35 and 40 or below 30 in figure 1 and 2, the distribution of patents filed and Gini Index is random. The research suggests that in the cases of those countries, the innovation is more affected by other factors instead of Gini Index. Thus, the motivation of wealth inequality towards innovation in different levels of Gini Index should be evaluated. For countries with high Gini Index which means the wealth gap is large, the negative correlation between Gini Index and patents filed suggests the wealth should be distributed more equally. Indeed, the distribution of wealth is partially related to a country's science and innovation. Though it seems gathering the wealth to the top organizations may proliferate a country's innovation, the research has proven that to distribute the wealth evenly may provide normal people with enough financial ability to continue carrying out researches and assist society to develop as a whole. There should be an innovation optimum point which occurs usually between a Gini Index of 35 and a Gini Index of 40. In this optimum point, the wealth is distributed reasonably, creating an ideal environment for the maximum amount of innovation to take place. People of all classes in the society get the right amount of wealth and they are willing to carry out innovation.

When the Gini Index of a country is higher than the range of 35-40, the income inequality of this country is large. People whose income is not fairly distributed may suffer to live. They thus have little motivation to carry out innovation. As the number continues to increase, the wealthy people are owned increasing more resources that they act like oligopolies, having no incentive for innovation. When the Gini Index of a country is lower than the optimum range, the consequence of this could also be harmful to the economy and innovation. An extreme condition of this could be all the people at the society are owning the same amounts of resources. The extreme equity, when achieved, may also cause the society to lose the impulse to invent, and to innovate. By inputting 30 sets of data of countries into RStudio and using multiple regression models to calculate the coefficient, the research suggests there could be some indirect relationship between income inequality and innovation.

4.2 Linear Regression

Simple linear regression is first used to process this data and to derive a coefficient between Gini Index and patents filed. The research supposes there is a linear function of this relationship with an intercept and an error term. The proposed function is (1) shown in the part 3. Using this formula, the research examines several sets of data.

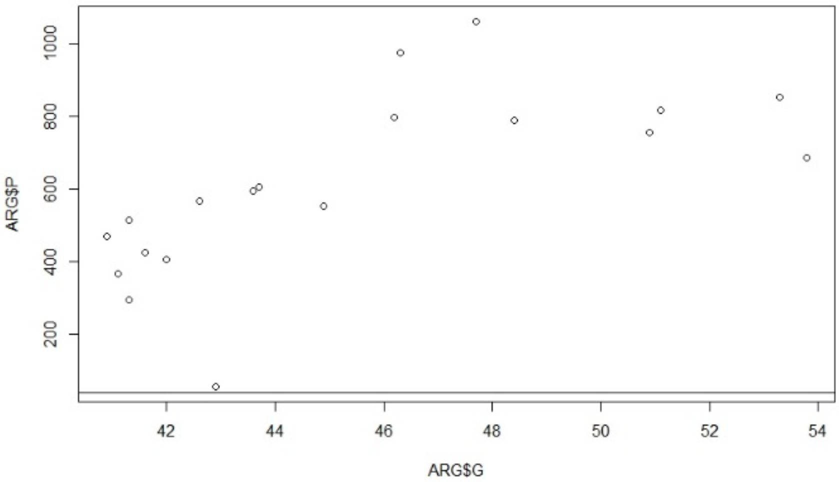

Figure 3 The variation of patents with Gini Index in Argentina

Figure 3 shows the variation of patents filed in Argentina as a result, or spontaneously, of the variation of Gini Index. The Gini Index varies in a range from 40 to 54, indicating that the country has been with a generally large income inequality. The range of P, indicating patents filed by the country, is from 0 to 1000. The estimated coefficient between P and G has been 39.20 with an intercept of -1171.90. The multiple R-square, which shows the reliability of this linear regression for this data set, is small, indicating that the deviation of the data from the calculated linear regression model is large. The standard error of the intercept is 474.18, and that for the coefficient is 10.39. the P value that also indicating the reliability of this model, with the smaller value it is, the more reliable the model, is 0.001515. From the analysis above about the data in Argentina, the research concludes that the relationship between Gini Index and patents filed in Argentina may be affected by multiple factors, resulting in a random relationship. The data left does confirm this hypothesis. All 30 graphs are drawn and shown. G in the graphs indicates Gini Index. P indicates patents filed.

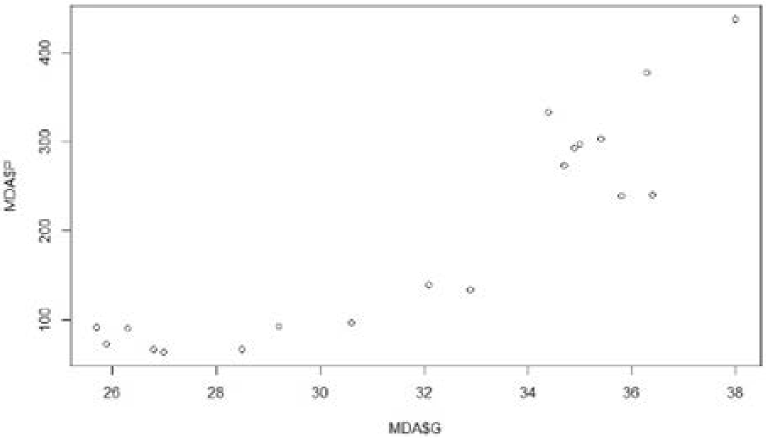

Figure 4 the variation of patents filed with Gini Index in Moldova

In Moldova, Colombia, Brazil and Denmark, however, the results show some traits of a linear relationship. In generating linear regression models, the research finds that the coefficient for MDA is 26.135 with an intercept of -638.128. The multiple R-squared for this data is relatively high with a value of 0.8086. Though not high enough to deduce that the data for Moldova will be varying along the estimated line, this coefficient for 20 years of data is capable of showing the possible relationship between Gini Index and Patents filed in this country. The standard errors for the coefficient and intercept between Gini Index and patents filed are respectively 3.084 and 99.133, two smaller numbers than those for Argentina. The minimum for the residuals is -87.621. The 1st quarter is -49.019. The median is 4.802. The 3rd quarter is 38.097. The maximum is 82.091.

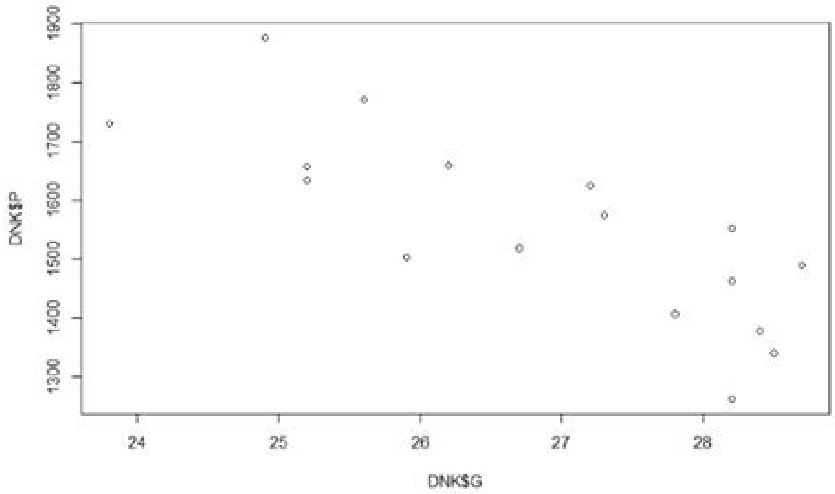

Figure 5 the variation of patents filed with Gini Index in Denmark

For Denmark, the coefficient is -0.0075 with an intercept of 38.49. The standard errors respectively are 0.0014 and 2.2725. The multiple R-squared is 0.6396. For the residuals, the minimum is -1.7140 with 1st quarter being -0.8242, median being 0.1609, the 3rd quarter being 0.6159 and the maximum being 1.3859.

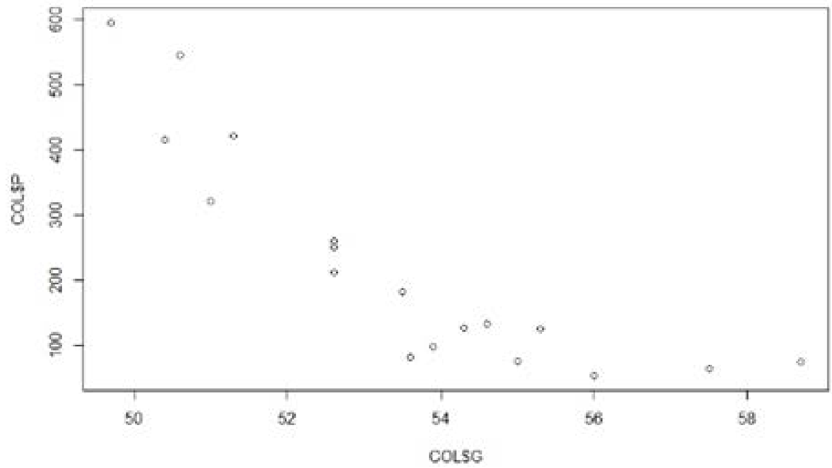

Figure 6 the variation of patents filed with Gini Index in Colombia

For the data set of Colombia, the coefficient estimated is -0.0124 with an intercept of 56.32. The standard errors are 0.0018 and 0.5086. The residuals are -1.6933, -0.6942, -0.3934, 0.5066, 3.3192. This sample has also a high multiple R-squared with a value of 0.7457. After processing the all 28 data sets with linear regression model, the research result shows there could be no, or little, linear relationship between Gini Index and patents filed in country. This, in other words, indicates that there is no obvious linear relationship between income inequality and innovation. Innovation does not increase or decrease in a linear way as income inequality increases or decreases. The following table shows all multiple R-squared, which shows the deviation of single data from the proposed formula, for 28 data sets.

Table 1. The multiple R-squared of linear regression for 28 countries

Country	Multiple R-squared
ARG	0.4558
AUT	0.0283
BEL	0.2663
BLR	0.139
BRA	0.6643
CAN	0.4693
CHE	0.0484
CHL	6284
COL	0.7457
CRL	0.0419
DEU	0.1686
DNK	0.6396
DOM	0.1039
NOR	0.028
ECU	0.3692
ESP	0.0021
EST	0.1298
FIN	0.1449
GBR	0.5363
GRC	0.1858
HND	0.0057
IDN	0.2938
ISL	0.1349
ITA	0.2995
KAZ	0.0974
KGZ	0.0227
LVA	0.0048
MDA	0.3391

4.3 Non-linear regression

Since dozens of data have shown the non-linear behavior of patents varying with Gini Index, non-linear regression model is introduced with formula (2) in part 3. In order to compare this novel model with the previous linear one, the research processes the data of Colombia with non-linear model again. As a result, this model receives its highest multiple R-squared of 0.9286 with a P-value of $2.868*10^{-8}$, both indicating that for this data set, the non-linear model fits the distribution of data better than the linear model does. The non-linear model behaves more effectively when evaluating such data with little correlation in linear model. b, the intercept, is $1.02 * 10^5$. I_1, the coefficient for the first item of G, is -4.978e+03 with a standard error of 7.052e_03. I_2, the coefficient for the second item of G, is 8.048e+01 with a standard error of 1.303e+02. I3, the coefficient for the third item of G is -4.306e_01 with a standard error of 8.018e_01.The intercept of this function is 1.020e+05 with a standard error of 1.270e+05. The residuals for this data are -78.75, -16.20, 2.68, 25.81, 91.43. Thus, the non-linear model function for the relationship of Gini Index and patents filed in Colombia is given by the following formula:

$$P = 1.02 * 10^5 - 4.978 * 10^3 G + 80.48 G^2 - 4.306 * 10^{-1} G^3 + \mathcal{E} \qquad (3)$$

Though the non-linear function of the data in Colombia is deduced, the research has not found the general trend of the relationship between Gini Index and patents. Thus, more data is processed.

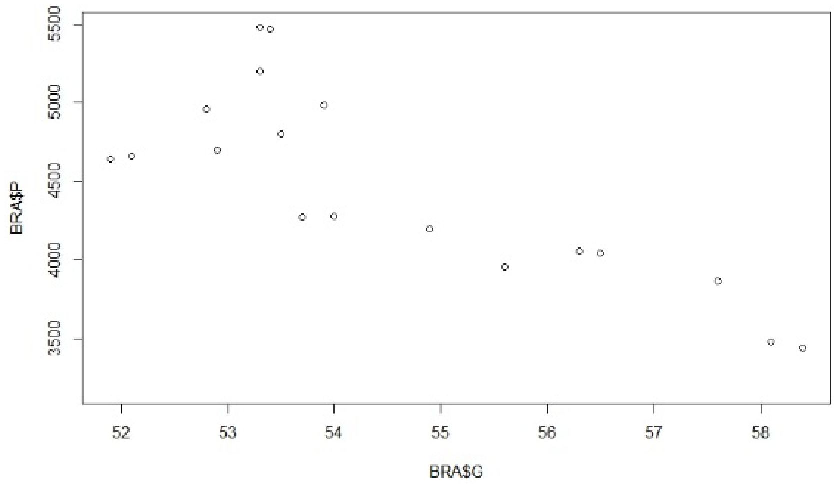

Figure 7 The variation of patents filed with Gini Index in Brazil

For Brazil, when using the simple linear regression to process the data, the coefficient is -0.0027 with an intercept of 66.63. Both are respectively with standard errors 0.0005 and 2.163. Residuals of this data set are -2.2053, -0.9064, 0.2144, 0.8438, 1.5159. This linear regression model is also not reliable and effective. The multiple R-squared is 0.6643, showing the large deviation of scatter points from the model. Introducing the non-linear model for the data in Brazil, the multiple R-squared becomes 0.7321. The function for the data in Brazil is shown:

$$P = -3.454 * 10^6 + 1.878 * 10^6 G - 3.391 * 10^3 G - 20.37G^3 + \mathcal{E} \quad (4)$$

The standard errors for the intercept, the first coefficient, the second coefficient, the third coefficient, are $2.183*10^6$, $1.191*10^5$, $2.164*10^3$, 13.1, respectively. After deducing the two functions of the non-linear model, the research finds that a general function for all the data cannot be deduced. Thus, the research starts to focus on how well equation (2) can fit into all the data sets, instead of deducing the certain function. The following table shows the samples and their multiple R-squared.

Table 2. the multiple R-squared of non-linear regression for 28 countries

Country	Multiple R-squared 2
ARG	0.6425
AUT	0.0555
BEL	0.6141
BLR	0.6587
BRA	0.7321
CAN	0.5602
CHE	0.194
CHL	0.9482
COL	0.9286
CRL	0.115
DEU	0.5415
DNK	0.657
DOM	0.1639
NOR	0.1299
ECU	0.6521
ESP	0.0032
EST	0.318

FIN	0.1674
GBR	0.5666
GRC	0.2206
HND	0.0733
IDN	0.4481
ISL	0.3024
ITA	0.3683
KAZ	0.1613
KGZ	0.2109
LVA	0.1368
MDA	0.8888

Comparing table 1 and table 2, it is obvious that the non-linear model fits the data sets better than the linear model does. This research regards the model effective when the multiple R-squared exceeds 0.8000. Three data sets, Colombia, Chile, and Moldova are thus valuable to evaluate.

4.4 Multiple factors connecting income inequality and innovation

4.4.1 How Innovation Plays an Important Role in Society

Though strictly innovation is defined as 'creating new things and earning profit from them', this research mainly focuses on the inventing sector of innovation, instead of the profit sector. Whether the invention, or innovation, in this case can make profit in the future is not taken into account while the research focuses mostly on how much of those innovation is made.

4.4.2 How Innovation and Income Inequality are Linked

Since innovation represents one of the essential characteristics of small businesses, it is then linked to the public, as small businesses are normally run by sole traders, or small enterprises. Asset, as a paramount driver of innovation, largely determine how much innovation is made, as well as the quality of the innovation. Innovation requires assets, both mobile and immobile. Income inequality directly affects the level of financial property, thus impacting money people are willing and able to spend on their personal interest. As income inequality rises, normal people, or the public, own fewer resources, resulting in decreases in innovation generated by them.

4.4.3 How Income Inequality is Affected

Income inequality indicates the distribution of income among a country. The total wealth, assets, including liquid assets and illiquid assets, of a country is fixed, which means the sum of all money does not change. Thus, it is easy to call that as the other individual owns more assets, the assets left for another group of people in society are less. The pattern of the distribution of income has been well presented by Gini Index. But what could be the factors that cause inequality?

4.4.3.1 Education Level

Income inequality is indirectly affected by skilled-based technology changes [9]. High-skilled workers, other than boosting the distribution of income to be fair in a sense that people normally think, adversely increase income inequality. As the adult population that completes college rose from 11 percent in 1970 to 16 percent in 1979 to 21 percent in 1989, the illiteracy among the total population sharply decreases [10]. There seems to be a vicious circle in which the high-skilled workers that earn more money and at the same time, covering more income of the total, are providing their offspring with a better life quality. As for those who lack skills and cover a relatively small area of the whole income, their worse life quality, in turn, provides their offspring with approximately the same life quality. In this way, it seems the unbalanced education level indeed aggravates the inequality in society. Offering education has been a sign that the public regards the government as good from. However, while implementing education, it is essential that the government distributes the education resources evenly, or the income inequality will in the long run be aggravated.

4.4.3.2 Class Solidification

What comes after the unevenly distributed education and the aggravated income inequality is the class solidification. As discussed above, when education is inclined to a group of higher-income people in society, wealthy people get wealthier with poor population getting poor. To a large extent, this increases income inequality. As this process is circulates, class solidification is aggravated. Innovation is discouraged in class solidification. The sense of individuals that they own approximately same resources is paramount in encouraging innovation. These resources include liquid assets and illiquid assets.

4.4.3.3 The Problem with Free-market Economy

It has been controversial all the time in the date of whether free market is a better approach for citizens or command market does better. After developing regression models and classifying data sets, the research concludes how and when certain approach should be implemented. A free-market economy is the economy in which the price of goods and services is determined by the market in its equilibrium point. Neither the consumers nor the producers, as well as the government, has no ability to control the market price. This kind of market has been examined to be efficient in countries with initially low Gini Index, which is under 40. In those countries, income has already been distributed evenly. At this time, letting the market to adjust itself achieves both allocative efficiency and productive efficiency. By contrast, for countries already with a Gini Index higher than 40, if the government lets the market to adjust itself, the market may not adjust in a way that is beneficial to the low-income population. The command approach is needed in this circumstance to artificially adjust the market to one that deprives the wealthy some of their wealth and distribute it to the poor.

4.4.4 The Colombia case.

Colombia has been a country with a high poverty rate, while the undernourishment rate of Colombia has been declining, from 11.1% in 2010 to 4.8% in 2017. Colombia's income inequality has increased in 2018 after a decade of gradual decrease. The top 10% of the country's earners received almost 40%percent of the country's income, which is 10 times of what the bottom 20% earned. While whole Latin America has seen a steady decrease if Gini Index, Colombia has seen an increase in Gini Index in 2017 and has had some fluctuation in its Gini Index. From figure 6, it is obvious that an increase in Gini Index causes the innovation process, which is patent here, to decrease. The reason has been the class solidification caused by the incline of education and infrastructure resources discussed above. From the Colombia case, the research also concludes that for countries with a higher range of Gini Index, in Colombia's case, from 50 to 58, the downward sloping innovation variation with income inequality is more obvious.

4.4.5 the Moldova case

Moldova had a Gini Index of 33.7 in 2018. This wasn't a high measure compared to Colombia. However, the service and education sector in Moldova presents large spatial gaps. Moldova registered the second highest gap in PISA test scores between urban and rural areas, with firms in the North and South of Moldova facing a higher waiting time to electricity and water than those in the capital, Chisinau [11]. Figure 4 indicates that for countries with a neutral range of Gini Index, the variation could also be upward-sloping because the threshold value of Gini Index in which there is a downward-sloping variation after the value has not been met. In cases like this, when liquid and illiquid assets are accumulated in wealthy people in a reasonable way, innovation can be improved.

4.4.6 the Chile case

Chile has been one of the fastest-growing the most thriving countries in South America. The poverty rate of Chile has been successfully reduced from 7.4% of people living on less than $3.20 a day in 2006 to 1.8% in 2017. The free-market economy of Chile increases the general living quality, but aggravating poverty to some extent [12].

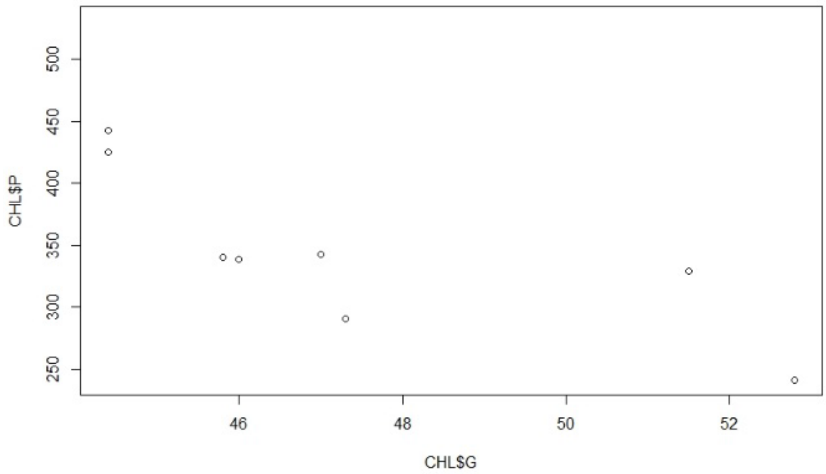

Figure 8 the variation of patents filed and Gini Index in Chile

The free-market economy aggravates income inequality in Chile, which later decreases patents filed. The Chile case fits the assumption that for countries with high Gini Index, to implement free-market policy will enlarge the income gap between the rich and the poor. Thus, the imbalanced liquid and illiquid assets among the wealthy and the poor discourage innovation.

5. Conclusion

The value for this research has been it categorizes and classifies the relationship between innovation and income inequality which has been a topic that has been seldom investigated. In results and discussion, the research first overlooks the pattern of patents and Gini Index in the graphs and concludes a general trend of them. Second, the research implements the classical linear regression model in R language to the 29 data sets. Though there are a few data sets that match with the proposed linear regression model, the research concludes that the innovation and income inequality do not vary through a linear regression model. Third, the non-linear regression model is implemented. This time the all 29 data sets see a drastic increase in the multiple R-squared, which is the value that measures the reliability of the results. The research then concludes that compared to the linear regression model, the relationship between innovation and income inequality fits better in a non-linear regression model. At the end, the research discusses multiple external factors including education, technology, and the type of economy that may impact innovation directly from income inequality.

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