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Investigating Zipf's Law for the Firm Size Distribution: The Case of Australia

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by

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Declaration Statement

I declare that the work presented in this Thesis is, to the best of my knowledge and belief, original and my own work, except as acknowledged in the text, and that material has not been submitted, either in whole or in part, for a degree at this or any other university.

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Abstract

This thesis examines the presence of Zipf's law in the firm size distribution of Australia. In this thesis, firm sizes are measured by sales and total assets. Firms refer to the public limited companies in Australia. After executing the regression analysis it is found that the upper tail of Australian firm sizes displays a Zipf's law. Specifically, top 100 firms in Australia follow a power law with exponent approximately equal to 1. This result suggests that various government regulations and industrial policies influence over the operations of firms which leads to a particular pattern of firm size distribution.

Key words: Zipf's law, firm size distribution, sales, total assets.

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Acronyms and Abbreviations

CDF	Cumulative Distributive Function
GDP	Gross Domestic Product
HHI	Herfindahl-Hirschman Index
OLS	Ordinary Least Squares
PL	Power Law
R & D	Research and Development
SMEs	Small and medium-sized enterprises

Chapter 1: Introduction

Zipf's law is well recognized in the field of natural languages centering on the distribution of word frequency. Different fields of study have taken the theme of Zipf's law and applied it into their studies such as web access statistics and internet traffic; open source software package in-degree connectivity etc. Hence, the span of Zipf's law is widespread. The upper tail of a cross-sectional distribution of numerous economic variables such as income, wealth, city size distribution, firm size distribution shows a power law. Power law in the upper tail of a distribution can be observed when the distribution has a skew distribution. The skew distribution refers that the out of total number of firms in the economy, number of large firms are small compared to the small firms. This characteristic of firm size distribution is captured by the theory of Zipf's law. When the number of firms with sizes greater than s is negatively related to s, then it can be defined by the Zipf's law. Bottazzi, Pirino and Tamagni (2015) argued that upper tail of firm size distribution often follows power law. They also argued that Zipf's law is a good fit for the upper tail of firm size distribution.

It is evident that firms play a vital role in boosting economic activity. Firms utilize different factors of production in an economy and produce goods and services. Therefore, firms hold a key position in an economy in determining what to produce and how to produce. Entrepreneurs can acquire profit by establishing new companies or firms which is the fundamental force for economic growth of a country (Da Rin, Di Giacomo & Sembenelli 2011). Governments of every countries focus on increasing entrepreneurship by promoting new firms so that the mechanism of innovation, competition, employment and economic growth sustain in the long run (Da Rin, Sembenelli & Di Giacomo 2010).

Firm size distribution varies across different countries. Firm size can be measured by revenue, asset, sales, employee, and profit and so on. In this thesis, I will focus on the firm size distribution of Australia for the year 2018. There has been hardly any recent study on Zipf's law for Australian firm size distribution except for di Giovanni and Levchenko (2013). Their study found the Zipf's law for the large firms of Australia. However, they did not provide any policy implications behind their findings of Australian firm size distribution. Moreover, their paper was based on only one variable sales. In this thesis, I will work with sales data for the firm size distribution of Australia. In addition, I will also employ the total assets data to show the robustness of my analysis.

This thesis experiments to find out how many large firms in Australia can display the Zipf's law. In this regard, I tried to conduct the regression analysis for top 1000, 500 and 100 industrial corporations of Australia. After the analysis it was found that only top 100 large industrial corporations of Australia exhibits the Zipf's law. Even though there might have been various policy implications regarding these particular results, I also tried to include a discussion on the Australian industrial policy as it may have an effect on this specific type of firm size distribution.

In this introductory chapter, I will discuss the motivation of my thesis; then I will explain the objectives of my study. After that, a brief outline of the thesis will be presented.

1.1 Motivation, Aim and Objectives

Firm size distribution is immensely discussed in the field of Economics. It has a crucial impact on the market structure as well as the degree of industrial concentration. According to Evans (1987), firm size distribution analysis can provide a signal regarding the degree of industrial concentration. In this context, the dynamics of firm growth and their implications for the firm size distribution is a very important issue. The study of Zipf's law in the distribution of firm size is essential for analyzing the concentration of large firms in an economy as well as the policies behind it.

A market can be a combination of large firms as well as small firms. The upper tail of a firm size distribution is mostly characterized by the large enterprises. Thus, identifying the features of upper tail of the firm size distributions is essential as it will facilitate to comprehend the market structure.

The aim of thesis is to explore the Zipf's law for the firm size distribution of Australia for the year 2018. To achieve this aim two objectives are defined which are as follows:

a) Identifying the number of firms for which Zipf's law can be observed;

b) Exploring the policy implications behind the findings.

To achieve these objectives, following steps will be employed in this thesis:

i) Collecting the data on sales and total assets for Australians firms;

ii) Analyzing the dataset with the help of adequate econometric techniques to determine the existence of Zipf's law for firm size distribution;

iii) Explaining the results by means of the relevant literature and industrial policy of Australia.

1.2 Outline of the Thesis

This thesis is divided into several chapters and is organized in the following way. Chapter 2 will cover the literature review related to Zipf's law. In this regard, this chapter will first give an overview of the theoretical background of Zipf's law. Then, the literature on Zipf's law related with city size distribution will be presented. After that,the relevant literature on Zipf's law associated with firm size distribution will be provided. In this chapter, I will try to demonstrate some the gaps in the literature.

In Chapter 3, I will focus on the methodology of the thesis. This chapter will elaborately provide the description of data and then discuss the limitations of data. The econometric model used in the methodology will be explained in this chapter. Selecting a cutoff level of firm size is very important in the analysis of Zipf's distribution. Therefore, at the end of the methodology chapter a discussion on cutoff level selection will also be provided.

In chapter 4, I will present the findings of the econometric analysis based on two variables sales and total assets. Result of total assets is employed in this chapter to check the robustness. If the results of total assets are aligned with the results of sales then robustness will be achieved. Adequate amount of tables and figures will also be provided to show the results of the regression analysis.

Chapter 5 will offer an interpretation of the results. Moreover, it will explain the policy implications behind the findings of the thesis. In this regards, critical analysis of the relevant literatures will be presented. Moreover, various government regulations as well as industrial policies of Australia will be discussed.

Finally, chapter 6 will present the conclusions of the thesis. The concluding chapter will explain few shortcomings of the thesis and also provide recommendations for further study.

Chapter 2: Literature Review

Zipf's law is famously documented in the field of economics such as city size distribution and firm size distribution. This chapter will discuss the theoretical explanation of Zipf's law. It will also discuss the various literatures on city size distribution as well as firm size distribution. As the thesis focuses on the firm size distribution in Australia, the literature review chapter will more emphasize on the firm size distribution. At the end of this chapter, I will provide a brief summary of my discussion.

2.1 Theoretical Background

Zipf's law is a universal law and it is widely accepted. This law is very much relevant in the fields of social sciences and economics. According to Saichev, Malevergne and Sornette (2010), Zipf's law is acquired by this probability equation $P(s) = Pr\{S > s\}$. Here, S is some random or stochastic variable and it is often defined by the size or frequency. S is larger than s meaning the size or frequency is above a minimum threshold s. In Zipf's law, $P(s)$ decreases with the continuous rise of s. Mathematically, this relationship can be shown as $P(s) \sim s^{-1}$.

Zipf's law is named after George Kingsley Zipf who was as American linguist. He examined the statistical occurrences of word frequencies in different languages. This could symbolize a common empirical regularity which could justify some universal principle. Even though he did not develop the theory, he documented the empirical regularity and made it very popular. Zipf (1949) showed this law for the word frequency distribution in natural language by proposing an algebraic function illustrating the probability distribution. Initially, Zipf (1949) presented Zipf's law as a relationship between rank and frequency referring to the commonality of vocabulary in natural languages. A set of text in any language shows a pattern in the use of words. Few words are used regularly in a text. Conversely, other words are not used that often. The top most used word will appear in the text approximately twice as much as the second most used word. Thereafter, compared to the third most used word it will emerge around thrice as much in the literature and this pattern goes on. There is an opposite relationship between the rank and frequency of word. Zipf's law is applicable to various fields of social sciences. Gabaix (1999) described the Zipf's law for the city size distribution. The distribution of income was assessed by Pareto (1896) whereas the distribution of firms was evaluated by Gibrat (1931). After that a variety of studies were conducted centering on the Zipf's law.

Zipf's Law is regarded as a special case of the distributional power law (Gabaix 2009). Power law (PL) shows a functional relationship[1] between two variables. In this case, a relative change of a variable causes proportional relative change in the other variable. Power law is also known as scaling law. According to Gabaix (2009 p.256), the formal definition of Power Law (PL) can be represented by the equation

$$Y = kX^{\alpha} \qquad (1)$$

Here, X and Y are defined as the variables of interest. k is a constant and α is the PL exponent. For example, if X is multiplied by factor of 10, then Y is multiplied by scale 10^{α}. Alternatively, it can be stated that Y scales as X to the power α. If the PL distribution shows $\alpha = 1$ approximately, then it is called Zipf's distribution.

Gabaix (2009) in his paper stated that, research established that PL can explain the distribution of firm size. This implies variations can be observed for very small firms and extremely large firms in general. Even with these deviations empirical sustainability of the Zipf's law does not fall short. Gabaix (2009) discussed when two variables are proportionally related, then the log of one

[1] For example, if a functional relationship between two variables x and y is represented by $y = x^2$. Thus, when $x = 1$, y is also 1; however when x increases to 2, y increases to 4. This proportional change is also called scaling law.

variable plotted against the log of other variable will generate a slope equal to 1 to comply with the Zipf's law. If the PL exponent (α) is low, the distribution becomes fat-tailed (Gabaix 2001). A probability distribution is called fat-tailed distribution when it displays large skewness or kurtosis.

2.2 Literature on city size distribution

Zipf's law is well documented in the distribution of city sizes. The basic explanation of Zipf's law for cities was presented by Zipf (1949) through the rank size distribution. Afterwards, Zipf's work was taken further in the case of city size distribution.

According to Zipf (1949), elementary version of Zipf's law for cities is presented by

$$R_i S_i = K_o \text{ where, } i = 1, 2. \ldots\ldots\ldots, n \qquad (2)$$

Here, R_i is presented by the rank of the city i, S_i denotes its size and K_o is a constant value.

This basic version can be generalized by equation

$$R_i^g S_i = K_o \qquad (3)$$

In this equation, the exponent g is a constant which takes positive values.

Brakman et al. (1999) discussed the various interpretation of the Zipf's law exponent. They denoted equation (2) as Zipf's law. Moreover, equation (3) is characterized by the rank-size distribution. Hence, Zipf's law is considered to be a special case of rank-size distribution. Equation (3) has a parameter which is g. Here, g is very important as it needs to be equal to one to show the existence of Zipf's law in a distribution. In the empirical analysis of cities, equation (3) in log version becomes

$$log(S_i) = log(K_o) - g\, log(R_i) \qquad (4)$$

Brakman et al. (1999) argued that if the distribution follows Zipf's law, then p is equal to one. They provided explanations for different values of g. For example, if g yields a value between 0 and 1 then the slope of the curve will be flatter and city sizes will be more evenly distributed. However, if $g > 1$, number of large cities are huge contradicting Zipf's law which will distribute the city sizes in wider dispersion (Brakman et al. 1999). According to Brakman et al. (1999), the negative relationship between the log size and log rank is the result of rank variable transformed from the size variable. More precisely, the city sizes are arranged according to a descending order. For example, the largest city was ranked number 1, the second largest city was ranked number 2, the third largest city was ranked number 3 and so on. Thus, the ranking of the city sizes are derived from the sizes of city based on population. Brakman et al. (1999), furthermore, argued that when extremely small cities are not included in the sample then the predicted outcome can be acquired. When the size of the city falls below a particular threshold then it is very hard to maintain the inverse relationship between size and rank for the small cities. When the size of a city becomes very small it cannot be that easily separated from the rural areas. Therefore, small cities are needed to be excluded from the sample for city size. This explanation indicates that there is a threshold value for urbanization (Roehner 1995) and there are many methods for determining the threshold level (Parr 1985). Brakman et al. (1999) excluded small cities to estimate the exact results for their study. In this thesis, small firms were also ruled out to acquire a precise outcome regarding Zipf's law. Nevertheless, the actual cutoff level value was not clarified in the paper of Brakman et al. (1999). On the contrary, in this thesis I tried to present the threshold value for the firm size distribution analysis.

In the paper of Gabaix (1999), he argued that empirically Zipf's law in terms of city size distribution is an evident fact in the field of economics. According to Gabaix (1999), the primary model for the Zipf's law is expressed as $P(\tilde{S} > S) = \alpha S^{-\zeta}$. In this equation, α is a constant value and S is the large number of cities based on population. If ζ is equal to 1 then the Zipf's law is present in the city size distribution implying that ζ is the Zipf's exponent. In the basic model

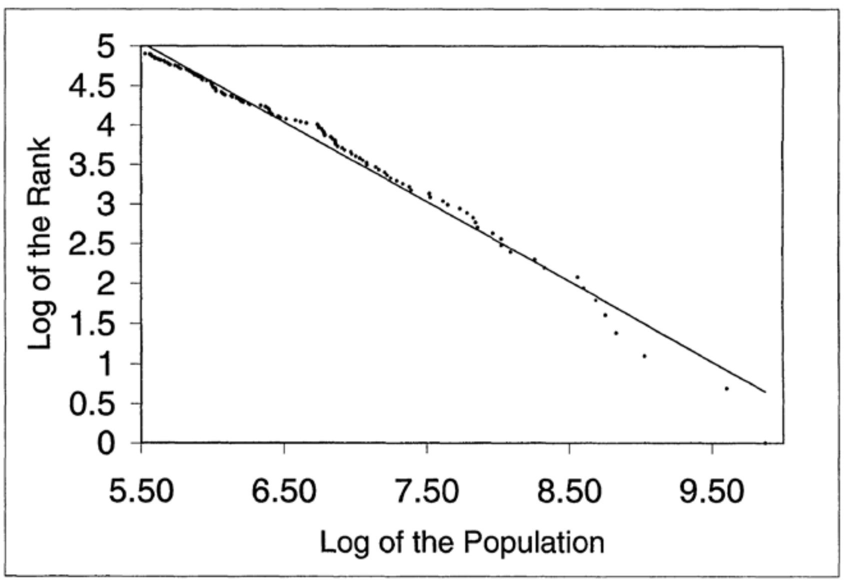
Gabaix (1999) used a fixed number of cities denoted by *N*. Gabaix (1999) defined the size of cities in terms of population. He argued that size distribution of cities fits the power law in most countries of the world.

In the case of city size distribution, Gabaix (1999) argued that most countries in the world show power law. If the city size is defined by population greater than a value *S* then the city size is proportional to *1/S*. He further stated that, empirically all cities in the world have a tendency to follow some proportional growth process in the upper tail of the city size distribution. This pattern naturally leads to the Zipf's law. Above a certain city size, most of the shocks such as regional shocks or municipal policy shocks decline as the size of cities increase. The shocks are defined by an unexpected events for example, taste shock to the climate or shocks to the local activity. There are also municipal policy shocks described by effective education or efficient police or higher education. The big cities are more capable of tackling those shocks compared to the small cities. At the upper tail, the city growth reaches a positive stage where these various shocks cannot have any negative effect on the city size distribution.

Gabaix (1999) explained the "rank-size rule" which illustrates that the probability that a city takes a size higher than *S* falls at the rate 1*/S*. According to the rank size rule, a country's largest city will be twice the size of the second largest city and thrice the size of the third largest city and so on. Alternatively, the ratio of second biggest city to the first biggest city will be $1/2$; the ratio of third ranked city to the first ranked city will be 1/3 and so on. These size ratios are often used as an essential tool for comparing the actual city size distribution with Zipf's law. Gabaix (1999) argued that if Zipf's law is proven accurately, the rank-size rule will be proven only approximately conditional upon the proper probabilistic explanation of Zipf's law.

Gabaix (1999) conducted an experiment on Zipf's law for the 135 large metropolitan cities of the U.S.A. in 1991. The size of the city was defined by the number of population. The cities were arranged in a descending order based on the population size. The city with the highest population was ranked number one, the second highest was ranked number two and so on. Then, log of the city rank and log of the corresponding population were calculated. After that, plotting log of the rank on the y-axis and log of the population on the x-axis generated a straight line with slope close to -1 which is shown in the figure-1 (Gabaix 1999).

Figure 1: City size distribution in U.S. metropolitan areas



Source: Gabaix (1999 p. 740)

Afterwards, running the regression estimates Gabaix (1999 p. 740) found the following results:

$$\ln \text{rank} = 10.53 - \underset{(0.010)}{1.005} \ln \text{size} \qquad (5)$$

The slope coefficient is -1.005 with R-squared (R^2)[2] equal to 0.986. In this regression analysis, 98.6% variation in the log rank in explained by log population. The data are very close to the fitted regression line with slope equal to -1 approximately. The standard deviation[3] is very low (0.010) which is a good indicator of the estimation. In terms of distribution, the result implies that the probability of city size higher than a certain size *S* is inversely related to *S* which is given by $P(Size > S) = \alpha S^{-\zeta}$ with α is a constant value. When ζ approximately equals 1 it shows presence of Zipf's law in the distribution. In Gabaix (1999) work, Zipf's law was visible for only 135 largest metropolitan cities in the USA. Similarly, in my thesis Zipf's law is present only for the 100 top large firms in Australia which will be discussed later. Yet, the author did not explained how to select the cutoff level of city size. In terms of methodology, Gabaix (1999) utilized the rank-size rule to capture the presence of the Zipf's law. However, in this thesis, this method was not utilized to find out the Zipf's law for the firm size distribution. I only used the log-rank and log-size plot to observe the linear relationship between the variables. This technique of plotting the log values of data is as same as with the log-rank and log-population plot of Gabaix (1999).

2.3 Literature on Firm Size Distribution

Gibrat (1931) presented a model of random growth in the context of distribution of firms. He argued that the distribution of firm size shows lognormal pattern. He showed that firm size can be measured by the number of employees or sales. However, total assets can also measure the size of firms which is utilized in this thesis. Gibrat (1931) argued that, most of the time firm size follows a lognormal distribution (Axtell 2001). Robert Gibrat established that the distribution of firms in the U.S.A. in terms of employees follows a normal distribution of the log values of the

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[2] R^2 computes how close the data are to the fitted regression line.
[3] The standard deviation defines how spread out the dataset is located from the average value. The low standard deviation means the most of the values are close to the average value.

variables which is known as simple Gibrat phenomenon (Kalecki 1945). According to the theory of probability, a lognormal distribution is a continuous probability distribution of a random variable where the logarithms of the variables are normally distributed. For example, if we assume X is a random variable which is log normally distributed then $Y=\ln(X)$ shows normal distribution. Similarly, exponent function of Y that is $X=\exp(Y)$ demonstrates lognormal distribution if Y has a normal distribution. When a random variable is log normally distributed it only obtains positive real values. In contrast, Stanley et al. (1995) argued that log-normal distribution fits the data accurately except for the upper tail of the distribution. It should be noted that very few values can be observed in the upper tail of the distribution and Zipf's law analyzes the upper tail of a distribution. Thus, Stanley et al. (1995) stated that with the help of Zipf's plot the variables in the upper tail can be analyzed. In their study the Zipf's plot shows the log of the rank against the log of the variable.

Ijri and Simon (1967) explained the skewed distributions of business firms using Gibrat's law. They argued that growth of firms can be defined by two components. First one is the industry wide component and the second one is an individual component. A firm may produce more speedily than rest of the firms in the industry for various factors. For example, if a firm could innovate in the production or marketing procedure and if the firm could acquire new management team or performance (Ijri & Simon 1967). The authors furthermore added that when a firm grows at a certain ratio for example 10% in one year, carry-over effects may lead to the growth of more than 10% in the next for that firm. Study of Ijri and Simon (1967) reflected on the characteristics of firms' growth with the sample of large business firms of the USA.

Ijri and Simon (1967) analyzed the firm growth mainly concentrating on a single industry. However, they also stated that the single industry analysis could be applicable to all the firms in a country. Therefore, in this thesis I could discuss the growth of firms applying the explanation of Ijri and Simon (1967). In Australia, there are different sizes of firms. The growth of different categories of firms may have an effect on the Zipf's distribution of the large firms.

In terms of firm size, industrial economies show presence of large number of small firms and low quantity of big firms simultaneously over time (Axtell 2001). In this case, the probability is rightly skewed indicating that the median firm size is higher than the modal firm size (Axtell 2001). Axtell (2001) further argued that this feature of firm size has been robust for a long time as it does not get influenced by the transformation of political environment and regulatory setting; mergers and acquisitions of firms. Firm size distribution is also resistant to large quantity of demographic changeover within employment of human resources. For example, entry of a great number of female workers in the labor market of the U.S. (Axtell 2001). In terms of firm size distribution, the upper tail is frequently explained by the Pareto distributions (Axtell 2001). According to Axtell (2001 p. 1818), tail cumulative distributive function (CDF) for a discrete Pareto-distributed random variable, *S*, is given by the following equation:

$$\Pr[S \geq s_i] = \left(\frac{s_0}{s_i}\right)^{\alpha} \qquad (6)$$

Where, $s_i \geq s_0, \alpha > 0$

In this equation, s_0 is the minimum size of firm and the exponent α is estimate of the equation. Axtell (2001) explained the Zipf's Law using the employees' data of largest 500 U.S. firms from 1988 to 1997 which showed the result of $\alpha \sim 1$. However, between the period 1992 and 1997, there was a significant change in all U.S. firms' revenue and work force which changed the α value. There was an up and down movement of the α values. Even though the value of α was different, it remained close to one.

Evans (1987) argued that small firms face more proportional risks than the large firms. The risks involve credit risk, liquidity risk, market risk and operational risk. In this context survival rate of small firms become very low. Therefore, most of the market share could be occupied by large firms. From the firm size distribution analysis degree of industrial concentration can be evaluated. Number of small firms contributing to the production process in the market is defined by the industrial concentration. If the concentration is very low that implies large firms do not have influence in the market. Therefore, dynamics of firm growth as well as the implications for the firm size distribution are very important in the field of economics. Riskiness could have an effect on the distribution of firm size in Australia. This could also give an indication of industrial concentration of Australia. It might give an idea about the influence of large firms in the industry.

There is an association between firm size distribution and the development of a country (Poschke 2014). Thus, firm size distribution is strongly related to the income per capita. Firm size distribution is different in every country according to the structure of the economy. Developed countries have fewer small firms. In richer countries exhibit the higher level of average, dispersion and skewness of firm sizes (Poschke 2014). Therefore, firm size distribution in developed countries is different from the firm size distribution of developing countries. Poschke (2014) furthermore stated that governments have different economic policy based on different firm sizes. In many countries in the world government spends resources to patronize the small firms. At the same time, government can also promote large firms implicitly. According to World Bank (2019), in 2018 Australia was the 13th largest country in the world based on Gross Domestic Product (nominal). Its gross domestic product per capita is 56,420.201 U.S. Dollar (International Monetary Fund 2019). Thus, according to the study of (Poschke 2014) there might be a relation between the firm size distribution and the development of Australia. It can also be added that government's economic policies might have shaped the firm size distribution in Australia.

Size distribution of firms in an industry or in an entire economy is approximately highly skewed where the upper tail often exhibits a Pareto distribution (Simon & Bonini 1958). Pareto distribution is a power law probability distribution. As Pareto (1896) discussed distribution of income which stated that large proportion of wealth in a society is captured by small fraction of population. Pareto distribution is related with continuous probability distribution whereas the Zipf's law is associated with a discrete distribution. But both law exhibit power law with negative exponent.

Simon and Bonini (1958) argued that the upper tail of the firm size distribution follows the Pareto distribution and no economic theory was explained regarding this resemblance. Therefore, they described that the reason behind this industrial concentration was the shape of long-run average cost curve. In the long run, all the inputs of firms are not fixed; they become variable. The cost of producing per unit output in the long run is considered to be long-run average cost. Long-run average cost is influenced by the returns to scale and scale economies. Returns to scale is defined as a change or variation in output from a proportionate change or variation in all inputs. Scale economies can be classified by the cost advantage of a firm when it produces its outputs. When a firm increases its productivity, cost per unit of output may get reduced. Simon and Bonini (1958) described that minimum costs associated with production may need not be similar for all the firms. In other words, if the firms have same minimum costs their output level will be different. Simon and Bonini (1958) found that Pareto distribution fits better than the log-normal distribution at the upper tail of firm size distribution. In Australia, firms may enjoy cost advantage which may have impact on the firm size distribution. Returns to scale are very important in the production which might be applicable in Australia's firm size distribution.

Simon and Bonini (1958) stated that single firm in an industry may expand or contract based on profit, new investment, dividend policy and mergers. However, these factors may also rely on the efficiency of the firm, exclusive use of particular factors of production, brand preference by customers, growth of product in which an industry specializes and so on (Simon & Bonini 1958). Moreover, Simon and Bonini (1958) argued that the Pareto distribution approaches to the Yule distribution at the upper tail of firm size distribution. Yule distribution is also called Yule-Simon distribution which is a discrete probability distribution. The tail of Yule-Simon distribution is recognized as Zipf's law.

According to Luttmer (2007), Zipf's law can be explained by the high entry costs or difficulty of imitations by firms. Both these factors can affect the derivation of the Zipf's distribution. Entry cost is one kind of obstacle which makes it difficult for firms to enter a market. Entry cost may emerge due to government regulation and patents, start-up costs, technological challenges, education and licensing requirements. However, this entry costs or barriers to entry may be different based on different market structure. For example, in perfect competition there are zero barriers to entry. The reason behind this condition is that in perfect completion market firms can freely enter and exit the market. The products are homogenous and there is no need for government regulation or patent right. In a monopolistic market, there is a medium barrier to entry as the products are differentiated. On the contrary, an oligopoly market displays very high barriers to entry as there are few firms that operate in the market. This indicates a highly concentrated market. Moreover, oligopolists can collude to earn maximum profits which will make even harder to enter the market for new rivals. Monopoly market structure shows very high to absolute barriers to entry. In monopoly there is only one producer in the market and it has all the market power which restricts the entrance of new firms. From this discussion it can be apprehended that if Australia's large firms show Zipf's law then there might be an existence of high entry costs for the small firms. Moreover, small firms may face difficulty of imitations if Zipf's law prevails.

Furthermore, Lieberman and Asaba (2006) stated that imitation appears to be a widespread practice in every category of business. One firm may imitate another firm if it wants to introduce new products and processes firms tend to imitate each other. Moreover, imitation takes place concerning the implementation of managerial techniques and organizational structures. Imitation can be regarding market entry and the proper investment decision. To survive in the competition, firms may imitate. However, imitation can have both positive and negative effects. Similar activities from rivals through imitations can strengthen competition. On the contrary, identical actions among firms may create collusion.

New firms entering in a market are constrained by uncertainty and risk (Gentry, Dalziel & Jamison 2013). Firms might face a range of uncertainties and risks for example, labor strikes; emergence of new technology; breakdown of machine; damage from fire; theft incident; natural disasters like flood or earthquake and many more. Moreover, theses adverse situations are related not only to the new firms but also to the existing old firms. These risks and uncertainties can create a massive adverse effect on the firm size distribution.

Government deregulations, tax incentives, developing new technology or scientific breakthrough can lead the pathway for new industry to emerge (Sine, Haveman & Tolbert 2005). In addition, these actions might also have an impact on the existing firms. These observations can be utilized while discussing the firm size distribution in Australia.

Luttmer (2007) analyzed a model specifying growth which is the outcome of specific firm selection, technology shock, imitation by new firms and sustainability of successful enterprises. The model specified by Luttmer (2007) showed balanced growth and unique characteristics of firm size distribution.

According to Gibrat (1931), the progress of a firm is not dependent on the size of firm. However, since the study of Gibrat (1931), researchers had established an association between the observed size distribution of firms and theories of firm entry, random growth and exit. The study of Luttmer (2007) focused on the balanced growth of firms which was mainly related with the observed firm size distribution. In addition to that, Luttmer (2007) discussed about the ability of firms' to imitate; the entry of firms and the fixed costs associated with firms' production. The author explained these topics based on a general equilibrium model which analyses the interaction among demand, supply and prices of many markets in the entire economy.

Luttmer (2007) argued that the size distribution of firms is related with entry of firms in the market; random growth of firms and random exit of firms. However, firms in his studies are mainly monopolistic competitors. Monopolistic competitors are those who produce differentiated goods. Therefore, characteristics of monopolistic firms may not capture the behavior of all firms in an economy. In case of monopolistic firms, there are entry costs for new firms which could create barriers to entry. If the entry costs are very high then it is difficult for new firms to enter the market frequently. Therefore, firm distribution can show a thick tail (Luttmer 2007). If barriers to entry are low then firm growth will be rapid. However, the growth depends on the performance of new firms. If the new firms can imitate the incumbent firms and increase their productivity then they can stay in the market for a long time. When entry is difficult, firm size distribution nearly exhibits the Zipf's law (Luttmer 2007). In this case, a huge proportion of market share is captured by the existing large firms. If barriers to entry are high in the market then the welfare impact will be small (di Giovanni & Lechenko 2013). Few large firms will capture the large proportionate share of economic activity. When firm size distribution captures the Zipf's law, then the outcome of welfare derived from the extensive margin of trade is very negligible (di Giovanni & Lechenko 2013). This indicates that the number of exporting firms is very small. Hence, large firms mostly account for higher volume of exports.

On the contrary, Luttmer (2007) argued that lower entry costs make it easy for more variety of firms to access the market; it sometimes also creates a discrepancy as many inefficient firms may enter and survive. Moreover, lower entry costs have negative impression on the average size of firms and profitability of firms as it is dependent on the size. Large number of firms in the market also eliminates the possibility of gaining excessive profit. When the potential entrant tries to imitate a random number of incumbents, the earning from the entry is allied with the average size of the incumbents. Luttmer (2007) further argued that at the equilibrium level of entry, high expected gains from entry should compensate high entry costs.

According to Luttmer (2007), if the new firms are able to imitate the incumbents barriers to entry are low and growth accelerates. Here, selection of industry is also very crucial as some industries have more barriers compared to others. When firms cannot perform well in the market, they are replaced by new firms. A negative relationship can be observed between the barriers to entry and the growth rate of economy. The fat tail occurs when entry is challenging. When entry is not easy the predicted firm size distribution approximately follows Zipf's law. However, Luttmer (2007) also illustrated that if entry is flexible in some industries Zipf's law can also appear for the firm size distribution.

In addition, Luttmer (2012) conducted a study on the US Census data on firms' employment compiled by Small Business Administration (SBA). Here, number of employees above 20 was included in the dataset. Luttmer (2012) argued that firm size distribution approximately follows Zipf's law if the entrants can achieve very little progress depending on the technologies that is utilized by the least productive incumbents. This activity leads to higher rates of entry and exit which was observed from the dataset. The small improvements of entrants are associated with the limited capability to imitate and the small size of the entrants.

2.4 Summary

Even though Zipf's law was initiated to explore the frequency pattern of words in any natural languages it has a wide range of applications in the field of economics. From the ample studies on Zipf's law it can be stated that city size distribution and firm size distribution show Zipf's law. In addition, there are many policy implications regarding firm size following Zipf's law. Government regulations, barriers to entry, various risks and uncertainties etc. have impact on firm size distribution which can reveal the existence of Zipf's law.

Chapter 3: Methodology

In this chapter, the methodology regarding detection of Zipf's law will be discussed. Here, I will present and explain a regression model. The source and explanation of data will also be analyzed and discussed. Moreover, comparing various literatures, I will try to provide an overview on how to obtain a cutoff level of observations.

3.1 The model

In this thesis, an ordinary least squares (OLS) will be utilized to investigate the Zipf's law. It is one type of linear least squares methods where one unknown parameter deriving the shape of the distribution will be estimated by the help of a linear regression model. In this thesis the unknown parameter will define whether Zipf's law exists in the firm size distribution of Australia.

Inspired by the work of di Giovanni and Levchenko (2013) I will explain the Zipf's law with the help of power law equation. In this regard, I will not only utilize the variable sales but also use the variable total assets. Thus, I will use sales and total assets to define the firm size distribution. Moreover, the data of total assets will be utilized in the regression analysis to check the robustness. The cumulative distributive function (CDF) is given by

$$\Pr(z > s) = cs^{-\alpha} \qquad (7)$$

Here, z can be defined by both sales and total assets. Here, z is the number of sales and total assets which is greater than a particular value s and c is the constant. The independent variables in this model is s where, Pr$(x>s)$ is the dependent variable. According to the definition of Zipf's law, if the absolute value of the exponent α is close to 1, then the distribution will follow Zipf's law.

The CDF is used to find out the probability that a random observation which is taken from the population will be less than or greater than or equal to a specific value. It is also useful in determining the probability that an observation will be equal to or in between two values. One benefit of using the CDF is that it can be defined for any kind of variable such as discrete, continuous and mixed. In this thesis, the CDF calculates the cumulative probability for a given z-value. In this thesis the given z-value is sales and total assets. CDF of a real-valued random variable z is the probability that z will take a value less than, greater than or equal to s.

To find the estimates first we take the natural log of the CDF (Axtell 2001) which becomes:

$$\log\Pr(z > s) = \log(cs^{-\alpha}) \qquad (8)$$

$$\log(\Pr(z > s)) = \log(c) - \alpha\log(s) \qquad (9)$$

Following the methodology of di Giovanni and Levchenko (2013), estimated probability $\Pr(z > s)$ is derived by the number of firms higher than s divided by the value of total number of firms for a fixed set of sales values and total assets values. After that, natural log of this probability and s are taken. Then, $\log(\Pr(z > s))$ is regressed on $\log(s)$ which will acquire the estimate of α which is also the slope of this regression model. In the regression analysis, a distribution can be well represented when logs are applied. It lessens the extrema in the data and limits the effects of outliers. Extrema is the collection of maximum and minimum values of a function. Outlier is a data point which significantly differs from the other observations of a dataset. It can cause serious problems in statistics. It can skew the dataset. It can also have a significant effect on the mean and standard deviation of the dataset. As a result, outliers can alter the result of data analysis.

Logarithmic scales have advantages in visualizing charts and graphs as well. If the graph represents skewness towards large values, for example few values may be higher than the bulk of the data; logarithmic scale can well capture the larger values. The logarithmic scales can also be useful to present percentage change of data. For finding out estimate of the CDF, Stata[4] software will be used. After regressing the log of probability and log(s) in Stata, estimate of α will be derived. If α is equal to 1 or close to 1 then the distribution will be called Zipf's distribution.

3.2 Source and description of data

The firm size can be measured in different ways such as total assets, sales or number of employees. According to Ijri and Simon (1967), firm size is measured by the total assets or sales volumes of the firms. Friend and Lang (1988) used total assets as a firm size indicator. Di Giovanni and Levchenko (2013) conducted a study on the Zipf's law with the sales database of companies collected from Osiris. Therefore, in order to represent the firm size of Australia, data of total assets and sales have been used in this thesis. Availability of data was the reason behind selecting total assets and sales for describing Australia's firm size distribution. For the analytical study of Zipf's law, a large number of observations are needed. However, obtaining data regarding number of employees for every firm in Australia is not available. As the methodology discussed in this thesis is following the one with di Giovanni and Levchenko (2013), data on total assets and sales were collected from the "Osiris" database. This database is provided by Bureau van Dijk Electronic Publishing, which was established in 1991. It is also known as Bureau van Dijk or BvD. Osiris is a database of public limited companies including banks and insurance companies around the world. However, the limitation of this database is that it only covers publicly listed companies.

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[4] Stata is a statistical software which is used for data analysis and data management. It is also utilized for producing graphical representation of data. Stata will be used to find out the log values and run the OLS regression.

Osiris provides the income statement, balance sheet, cash flow and ratios along with news ownership, ratings, earning estimates and stock data of listed corporate over 130 countries. Including only the listed companies' information in the dataset has some advantages. First of all, information about listed companies is publicly available and therefore, their statistics will be very reliable.

As this thesis analyzes the firm size distribution, it uses the total assets and sales data of industrial corporations located in Australia. Data availability is a very important factor in this thesis to show the pattern of firm size distribution. As a result, total assets owned by business and sales value have been chosen as it is available in the Osiris database. A total 2031 industrial corporations' data on total assets for the years 2018 is available in the database. Likewise, a total 1182 industrial corporations' sales value for the year 2018 was available in the database. As Axtell (2001) did not counted firms with 0 number of employee as firm size, in this thesis 0 value of total assets or sales is not treated as a firm size indicator. In the Osiris database total assets and sales are expressed in the value of thousand U.S. Dollars[5].

The total assets in the data base are defined by the combination of fixed assets and current assets. In the balance sheet, asset is a very important part which shows companies earnings and worth. Fixed assets are purchased by firms for long-term use. These fixed assets cannot be converted into cash quickly. In the Osiris database, fixed assets comprise tangible fixed assets, intangible fixed assets and other fixed assets. Tangible fixed assets have physical values and it can be measured as well. These types of assets are used in the operational activities of firms. Examples of tangible fixed assets are land, buildings, plant and machinery, manufacturing equipment, office equipment, furniture, computers, motor vehicles, fixtures and fittings etc. Intangible fixed assets

[5] U.S. Dollar is regarded as a global currency and it is universally accepted in international transactions. Thus, the value of the total asset in this data analysis will be presented in U.S. Dollars.

are nonphysical assets. It is very difficult to put a value on it. Examples of intangible fixed assets are brand recognition, goodwill and intellectual properties, for example patents, copyrights and trademarks.

On the other hand, current assets are defined as short-term assets which can be converted into cash within a year. Current assets are more liquid than fixed assets. In the Osiris database, current assets are the mixture of stock, debtors and other current assets which includes cash and equivalent, prepaid expenses and advances, deferred charges, short-term investments.

Sales are regarded as a component of income statement of a company. Here, sales are defined by net sales which are derived from gross sales after the adjustments or excise tax. Gross sales are the value of total sales derived from all the transactions during a period. Excise tax is imposed on the production of goods which should be paid by the business.

3.3 Selecting the Cutoff Level

It is crucial to select a cutoff level of observations to run the regression for Zipf's law. It is observed that above a specific minimum size threshold power laws are considered to be a good fit of the data (Axtell 2001; Luttmer 2007). Thus, according to di Giovanni, Levchenko and Rancière (2011), there is a possibility that power law may not well describe the size distribution of small firms. As a result, to eliminate the small firms from the dataset, a lower cutoff level may be selected based on graphical representation (Gabaix 2009). Graphical plots of statistical data are very powerful tools as visual inspection can detect a pattern or irregularities in the dataset. Visual tests are very easy to comprehend and they can sometimes notice patterns or anomalies in the data. It is very much likely that when a dataset passes the visual tests it also passes the quantitative statistical test. On the contrary, visual tests are subjective which is based on personal opinions and intuitions. They cannot even quantify how well or poorly a model fits the data.

However, selecting a cutoff is very complicated as there is no single agreement on deciding the optimal cutoff level (Beirlant et al. 2004). Gabaix (2009) argued that any applied researchers select the cutoff based on visual goodness of fit. They may even utilize a very simple rule to choose the cutoff level, for example, selecting top 5% observations from the distribution (Gabaix 2009).

In the context of city size distribution, there are many methods to select a lower cutoff level in urban system. For example, Lasuen et al. (1967) utilized 10,000 population size as the cutoff level in city size distribution. Rosen and Resnick (1980) chose the first 50 largest cities from the ranking of the cities in a descending order. Wheaton and Shishido (1981) used a given share of larger population such as metropolitan areas which captured 70% of the total urban population were selected. According to Wheaton and Shishido (1981), the cutoff ratio between developed countries and developing countries should be different. In developed countries, the number of cities with large population would be higher than in developing countries. Thus, if the similar cutoff rate is used between developed and developing countries then developing countries could have small number of cities for the empirical analysis. Thus, precautions should be taken when choosing the ratio for cut-off level. Sakashita (1979) used a central value of size class of frequency for which the frequency was at maximum.

Di Giovanni and Levchenko (2013) chose the top 44 countries in the world in terms of Gross Domestic Product (GDP) for their study on the power law and Zipf's law. 44 countries that were selected had at least 1000 sales data for firms. Sales data from 2006 to 2008 were extracted. Australia was also included in that list as one of the top countries in the world. In this thesis, total assets and sales figure from Australia's firms are chosen as more than 1000 data are available for total sales and sales. It should be noted that the power law is only good fit for the firm size distribution when a certain minimum threshold is selected. This is the limitation of the database as all the 1000 firms' size distribution will not show the power law. If the log sales are plotted against log rank in the graph then the curve may not show the linear relationship. For this reason, only those values of sales should be chosen where the plot shows linear association among the variables (di Giovanni & Levchenko 2013). However, the authors did not mention what was the cutoff level of observations they used for every county to conduct the regression analysis.

Figure 2: Relationship between log rank and log sales

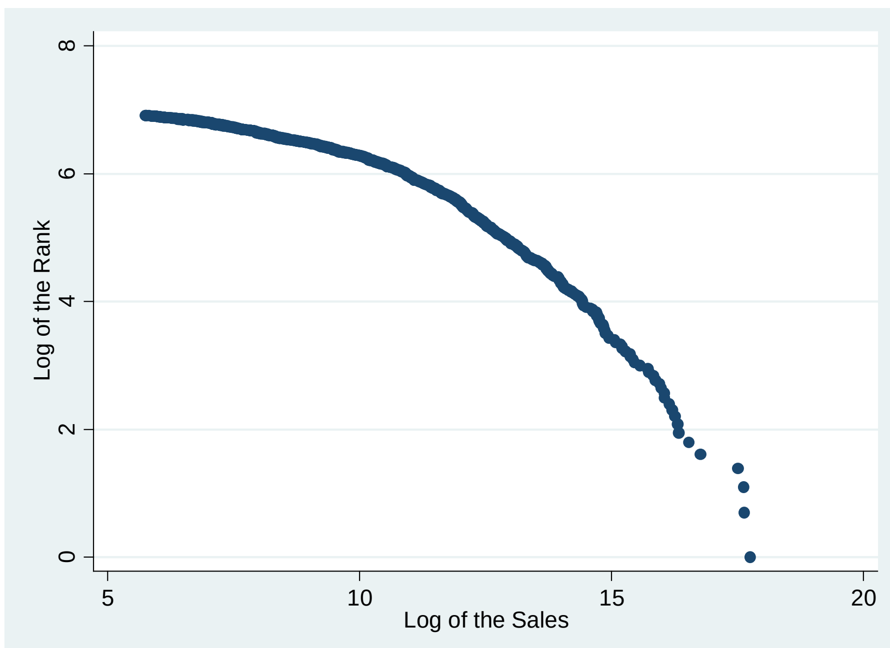
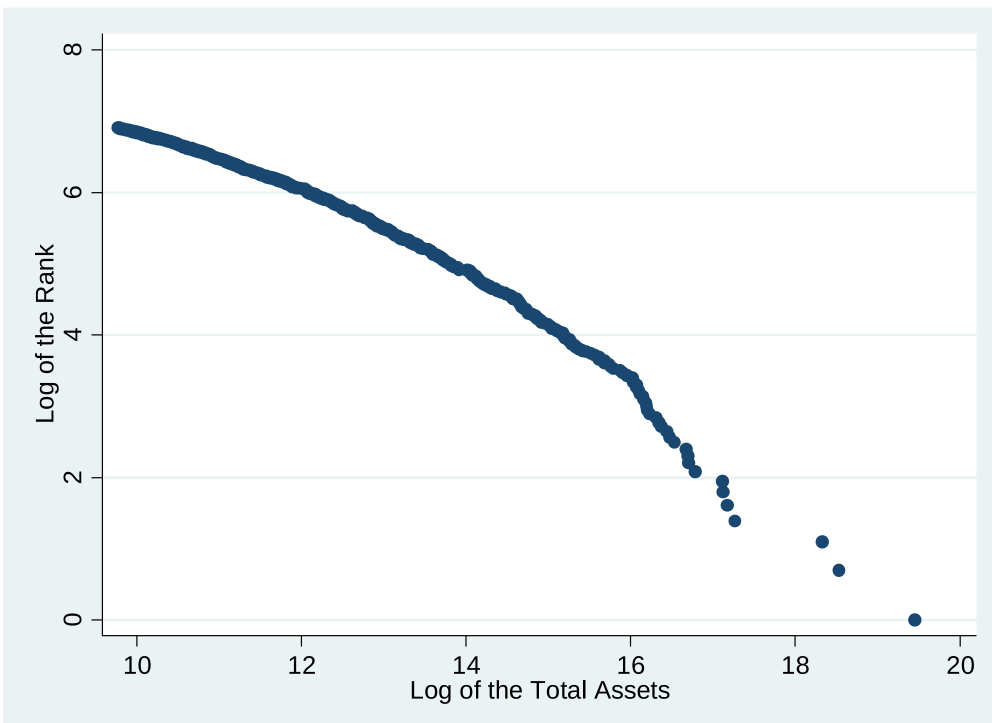


Figure 2 shows the relationship between log rank (lr) and log sales (ls). 1000 firms' sales data are plotted in this log-log coordinates and the graph does not show linear relationship between the log rank and log sales variables. The concavity nature of firm size distribution may indicate that small firms are expanding at a faster rate than the large firms. Thus, to achieve the approximate linear relationship between the variables, the first 100 sales data of Australia's industrial corporations are selected to acquire the estimate of α.

Similarly, at the same time, to check the robustness, if the log values of total assets are plotted against log rank in the graph then the curve does not show the linear relationship as well. For this reason, only those values of total assets should be chosen where the plot shows a linear association among the variables.

Figure 3: Relationship between log rank and log assets



In Figure 3, the vertical axis is measured by log of the rank (lr) and horizontal axis is determined by the log of total assets (ls). Plotting log rank (lr) against log assets (ls) of the top 1000 Australian firms illustrate that there is a negative relationship between these two variables.

However, this curve is also slightly concave rather than linear. Thus, it can be stated that for the top 1000 firms in Australia Zipf's law cannot be observable.

Consequently, to achieve the approximate linear relationship between the variables first 100, 500 and 1000 sales and assets data of Australia's industrial corporations will be selected to acquire the estimate of α. Afterwards, if the regression analysis delivers value of α equal to 1 in absolute term for any of these numbers of observations for sales and assets then it can be concluded that for this top (100 or 500 or 1000) largest firms of Australia portray the Zipf's law.

To sum up, for conducting the regression analysis there will be three sets of data with 100, 500 and 1000 observations for both sales and total assets. If one of the datasets shows the value of the estimator equal to or close to 1, then for that particular dataset Zipf's law holds for the industrial corporations in Australia.

Chapter 4: Results

In this chapter, findings from the regression analysis based on sales will be presented with the help of tables and graphs. Moreover, robustness will also be checked though the regression analysis of total assets.

4.1 Model Estimation for Sales

To obtain the result, α is estimated using ordinary least squares (OLS) in the log-log coordinates. Table 1 provides the results of regression analysis based on sales for top 100, 500 and 1000 industrial corporations in Australia for the year 2018.

Table 1: Regression Result (Sales)

Firm size based on Sales				
Model : $\log(\Pr(x > s)) = \log(c) - \alpha \log(s)$				
Number of Observations	Coefficient (α)	Standard Error	P value	R-squared
100	- 0.9221094	0.0132247	0.000	0.9805
500	-0.6256351	0.0054973	0.000	0.9630
1000	-0.3655306	0.004635	0.00	0.8617

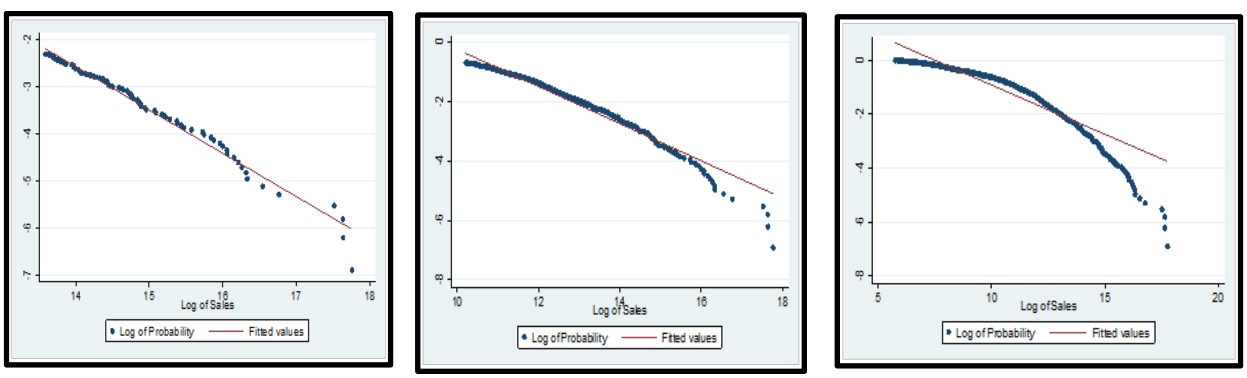
Table 1 shows that in the case of 100 observations the firm size in Australia follow the Zipf's distribution as absolute value of α is approximately equal to 1. This result is highly significant with probability 0.00(<0.05). The standard error is also very low which shows the estimate calculation is precise. The coefficient of determination (R-squared) is 0.9805 which is very high.

In the studies of Gabaix (1999) as well as di Giovanni and Levchenko (2013), R-squared values were found to be very high as well. R-squared shows how well the data fit the regression model. Here, R-squared represents that almost 98% variance in the dependent variable is explained by the independent variable.

On the contrary, with 500 observations, firm size in Australia does not follow the Zipf distribution as absolute value of α is not close to 1. However, the results are highly significant and R-squared value is very high.

Likewise, the top 1000 firms of Australia do not follow the Zipf distribution. Here, α is approximately 0.37 in absolute value. Still, the results are highly significant along with high R-squared value.

Figure 4: Firm size distributions based on Sales



(a) 100 observations

(b) 500 observations

(c) 1000 observations

Figure-4 shows three log-log plots of the firm size distribution in Australia for the year 2018. Here, log of probability is denoted by log ($\Pr(x > s)$) and it is plotted against the log of sales ($\log(s)$). Log of probability is plotted in the y-axis whereas log of sales is plotted in the x-axis. In Zipf distribution, α is regarded as the slope of the model.

In case of 100 observations, Figure 4(a) shows that the firm size distribution follows the Zipf's law as the plot of the variables approximately depicts a straight line. Here, most of the values are on the straight line except few observations.

On the contrary, for 500 observations, Figure 4(b) does not show the Zipf's distribution as log-log plots of the observations do not represent linear line. Many observations are far away from the straight line. This implies the actual values differ with the estimated values.

Similarly, Figure 4(c) does not show the Zipf's distribution as log-log plots of the observations do not represent a linear relationship for 1000 observations. The curve is concave and most of the observations are not close to the straight line. Therefore, the actual values vary with the estimated values.

4.2. Robustness: Model Estimation for Total Assets

To obtain the results of total assets similar methodology of sales will be applied. This regression analysis can also be applied for checking the robustness of the regression analysis of sales.

Table 2 describes the results of regression analysis based on total assets for top 100, 500 and 1000 industrial corporations in Australia for the year 2018.

Table 2: Regression Result (Total Assets)

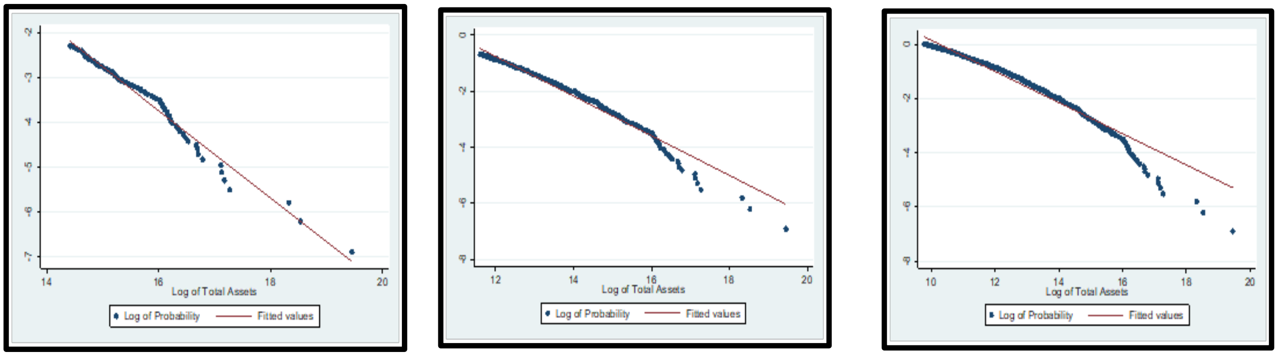
Firm size based of Total Assets				
Model : log (Pr(x > s)) = log(c) – α log (s)				
Number of Observations	Coefficient (α)	Standard Error	P value	R-squared
100	-0.9741452	0.0138827	0.000	0.9805
500	-0.7070999	0.005183	0.000	0.9739
1000	-0.5742585	0.0037193	0.000	0.9598

Table 2 depicts that in the case of 100 observations, the firm size in Australia follows the Zipf's distribution as the absolute value of α is approximately equal to 1 which is nearly 0.97. This result is highly significant with a probability 0.00 which is less than 0.05. The standard error is also very small indicating the accurate computation of the estimate. The coefficient of determination (R-squared) is 0.9805, which is very large. R-squared values were also very high in the regression analysis of Gabaix (1999) as well as di Giovanni and Levchenko (2013).R-squared explains how well the data fit the regression model. Here, R-squared represents that almost 98% variance in the dependent variable is explained by the independent variable.

Conversely, with 500 observations, firm size in Australia does not follow the Zipf's distribution as absolute value of α is not close to 1. However, the results are highly significant and R-squared values are very high.

Correspondingly, for 1000 observations, the firm size in Australia does not follow the Zipf's distribution as absolute value of α is only 0.57 approximately. Nevertheless, R-squared values are very high and the results are highly significant.

Figure-5: Firm size distributions based on Total Assets



(a) 100 observations

(b) 500 observations

(c) 1000 observations

Figure-5 shows three log-log plots of the firm size distribution in Australian for the year 2018. Here, the log of probability is denoted by log (Pr(x > s)). Log of probability is plotted in the y-axis against the log of total assets in x-axis which is depicted by log(s). Here, s shows the values of total assets of firms in Australia. As mentioned before, the parameter α is considered to be the slope of Zipf's distribution.

When the number of observation is 100, Figure 5(a) shows that the firm size distribution follows the Zipf's law as the plot of the variables approximately depicts a straight line. Here, most of the values are on the negative sloping straight line. Only few observations diverge from the straight line.

In contrast with Figure 5(a), Figure 5(b) does not illustrate the Zipf's distribution for the 500 observations. Here, log-log plots of the observations do not show linear line as most of the observations deviate from the straight line. This implies the actual values vary with the estimated values.

Likewise, figure 5(c) does not confirm the Zipf's distribution for the 1000 observations. In this case, log-log plots of the observations do not show a line as it is to some extent concave. Most of the observations diverge from the straight negative line. This indicates that the actual values greatly differ from the estimated values.

In summary, it can be established that for both sales and total assets, Zipf's law exists for top 100 firms of Australia.

Chapter 5: Discussion

In this chapter, I will explain why only top 100 large firms in Australia show Zipf's law. In order to that I will first describe the industrial concentration in Australia. Afterwards, I will provide a firm size comparison between Australia and the U.S.A. In addition to that, I will also provide a section describing the policy implications behind my findings. In this section, I will give a brief overview of the previous industrial policy of Australia followed by recent industrial programs along with government regulations which might be associated with the firm size distribution.

5.1 Analysis of Results

One question arises from the outcome of the regression analysis. "Why Zipf's law is visible for top 100 firms in Australia?" To answer this question I have presented two explanations. First explanation is based on the industrial concentration in Australia. The second clarification is the median firm size comparison between Australia and the United States of America (U.S.A).

5.1.1 Industrial Concentration

From the literature review of Evans (1987), it was conceived that firm size distribution analysis shows some degree of industrial concentration. When concentration is very high, large firms can show more dominance in the market. Zipf exponent α can also measure the degree of concentration. Degree of concentration in this context represents the frequencies of large firms relative to small firms in an economy. If the absolute value of α becomes larger then it indicates that relative size of large firms will be higher compared to the small firms. In other words, if the value of α is high it provides an indication of inequality in firm sizes. This implies that a high proportion of large firms can influence the production or services provided by the market. On the other hand, if the absolute value of α becomes smaller over time then it means size of firms is distributed more evenly. Thus, the top firms in the economy cannot entirely influence the market and the market will be highly competitive.

Likewise, Gabaix (2011) suggested that firm size distribution provides an indication of the degree of industrial concentration. Industrial concentration demonstrates the market share of a particular firm in an industry. This industrial concentration can be useful to analyze the business cycle of an economy and therefore to execute antitrust policy. In the case of Australia, the market is not so much concentrated as from the 1000 observations we can see that Zipf's exponent is very low. This indicates that out of top 1000 firms, large firms do not have a large influence over the market. The same examination goes for top 500 firms as the Zipf's component is also lower. Even within 500 firms the large firms do not have much control over the market. However, in the top 100 observations, the Zipf's law exists. Therefore, within the top 100 firms, if large firms have more market power it would not be able to have much influence over the all the firms in industry.

According to Bakhtiari (2019) market concentration is rising in Australia on average. However, this increase is observed in those industries where concentration is already present. Particularly, the export oriented firms show high concentration in the industry. Before, 2007 market concentration was falling however since 2017 the concentration began to increase. Size of the domestic market is very small in Australia. Bakhtiari (2019) conducted a study by using the Hirschman-Herfindahl Index (HHI) to investigate the dominance of large firms in different Australian industries between 2002 and 2016. The Herfindahl-Hirschman Index (HHI) is a useful method to measure market concentration. It also determines market competition. The HHI can be in range between close to zero and 10,000. HHI approaches to zero in a perfectly competitive market. On the other hand, if HHI moves towards the value 10,000, the market is considered as monopoly.

The study of Bakhtiari (2019) found that few large firms dominate a small number of industries. Telecommunication services, printing and support services, iron and steel services as well as electricity transmission industries are the most concentrated industries in Australia. By definition, it is well-known that most concentrated industries are comprised with few firms.

5.1.2 Comparison of Firm Sizes between Australia and the USA

Based on sales and total assets data, top 100 industrial corporations in Australia showed the Zipf's law for the year 2018. However, Axtell (2001) studied that 500 U.S. large firms showed the existence of Zipf's law. Number of firms in the U.S. following the Zipf's law is five times higher than the number of Australian firms. It is a recognized fact that Australia is a small developed country whereas the U.S. is a large developed economy. As a result, number large firms in Australia are supposed to be lower than the number of large firms in the U.S.

By using the industrial corporations' data from the Osiris database, I have tried to provide a comparison between the U.S. firms size and Australian firm size. Median value is used here to show the difference between Australia and the USA. Median is chosen as a measure of comparison as it can actually deliver an overall view of the dataset. USA is chosen as it is one of the top largest and open economies in the world. Both dataset are from the year 2018 on the variables sales and total assets. We have divided the dataset into three sets of observations, such as 100, 500 and 1000. However, it should be noted that for the number of employees only 94 observations were available for Australia. Thus, it was not possible to compare the median value of the number of employees between the two countries.

To obtain the median values for each of the observations, the data is arranged according to the decreasing order and then the median values are identified. Here, median is chosen as it can be a representative of the dataset. Median is a measurement of the centre of a dataset as it separates the higher half from the lower half values.

Table 3: Median observations (100, 500 and 1000) between USA and Australia

	Top 100 firms		Top 500 firms		Top 1000 firms	
	USA	Australia	USA	Australia	USA	Australia
Sales (Thousand US Dollar)	44,489,500	2,073,752	10,095,950	166,465.5	4,253,579	27,888
Total Assets (Thousand US dollar)	149,175,500	4,279,933	31,777,051	434,241	12,206,502	113,266

Source: Osiris Database

For each of the observations, median values of the U.S. are almost more than twenty times higher than Australia. This reestablished the fact that firm sizes of Australia based on sales and total assets are much smaller compared to the firm sizes of the U.S. Consequently, the number of large firms in Australia is also lower than that of the U.S.

To sum up, due to small size of the large firms compared to the US firm size, it can be established that Australia has few large firms. This could indicate the reason behind the finding that only the top 100 large firms showing the Zipf's law.

5.2 Policy Implications

The outcomes of this thesis can be associated with findings of several literatures. Guner, Ventura and Xu (2008) argued that various government policies have an impact on the size distribution of firms. Government may promote the small firms all over the country or enforce restrictions on the large firms which may affect the size distribution of large firms. By imposing taxes, government can limit the operations of large firms. In different countries governments may take initiative to subsidize the small firms which will encourage new establishments of small firms. Otherwise, a government can also restrict the operational activities of large firms. At the same time governments in some countries may take some policies to enhance the activities of small firms. According to Guner, Ventura and Xu (2008), policy distortions depending on the firm size are called size-dependent policies. These size-dependent polices can have a considerable effect on quantity of output, level of productivity etc. The paper of Guner, Ventura and Xu (2008) showed an example of Italy where firms having more than 15 employees, have to go through employment protection legislations. These legislations are different than that of small firms. In Italy five types of regulation were associated with the firms' size. The regulations were regarding employment protection; common dismissal system; compulsory quotas on hiring, firms' safety standards; and exercising firms' rights in the formation of union related activities. Guner, Ventura and Xu (2008) also argued that policies regarding small and medium enterprises (SMEs) have influenced on the firm size distribution in a country. There are two types of policies that can have an effect on the SMEs. First, endorsing entrepreneurship and shrinking the cost of entry. The second policy is related to the size-dependent policies that offer special facilities to the SMEs. In Korea SMEs attain the benefits of subsidies; obtain credit guarantees from the Korean Credit Guarantee Fund (KCGF) and the Korea Technology Credit Guarantee Fund (KOTEC). SMEs in Korea can also obtain the essential funding from local and foreign banks as they are obliged to lend a specific percentage of their total loans to the SMEs. Furthermore, SMEs also benefit from special tax treatments in the category of income and property tax as well as registration and transaction taxes. Even though, the study of Guner, Ventura and Xu (2008) focuses only on the developed countries, the size-dependent policies can be experienced all over the world. In line with their study there might be a possibility that the government of Australia regulates the large firms by imposing tax. If tax is imposed the operational activities of large firms get restricted which may have effect on the number of large firms in the economy. At the same time government of Australia might have taken various initiatives to promote the small firms of the country such as subsidizing them. This might promote new establishments of small firms. Australian governments might also take policies to regulate the large firms. As a result, government regulations might have reduced the productivity and output growth of large firms.

Similarly, Garicano, Lelarge and Van Reenen (2016) emphasized that the size-dependent regulations have an impact on the firm size distribution. They conducted a study based on the firm size distribution of France between 1995 and 2007. In France when a firm employs 50 or more workers it has to go through various labor laws. These regulations have a significant effect on the distribution of firm size. Even if the firm is an efficient one due to the labor laws it can employ fewer workers and therefore produce little output which will eventually affect the aggregate productivity. Here, regulations raise the labor costs when firms have 50 employees or more. If the number of employees is 50 or more, firms have to obey many rules. Some of the rules specify that firms will have to establish a works council, appoint a representative for the union; provide comprehensive information on every employee to the Labor Ministry set up a health and safety committee etc. Therefore, some productive firms may choose to remain below the legal threshold because if they cross the threshold they have to pay high price for that. This indicates that certain regulations make the firm size smaller than the unregulated economy. This labor law creates welfare loss for firms as the firm size gets smaller. In connection with the paper of Garicano, Lelarge and Van Reenen (2016), there might be a possibility that government of Australia enforce some labor law on the large firms. Based on the number of employment, if the large firms have to follow some regulations that increase their operational costs, then it might restrict the activities of large firms. If the employment level over a certain threshold causes firms to pay high price under the regulations, then there might be a potential decrease in the size of firms. The large firms in Australia might not get encouraged to expand their establishments under the regulations. Thus, labor law in Australia might have some impact on the firm size distribution.

By using the database of European firms, Klapper, Laeven and Rajan (2006) found that high entry cost hampers the creation of new firms. In their study they argued that the main reason for high cost of entry is complying with the regulatory requirements in order to establish a limited liability company. In this thesis, database of public limited companies of Australia are utilized to capture the existence of Zipf's law. Thus, it is obvious that to set up a public limited company in Australia some regulatory requirements have to be fulfilled. This would usually generate some costs for the firms. However, as described in the paper of Klapper, Laeven and Rajan (2006), the cost of satisfying of these regulatory requirements for Australian firms might not be as high as the European firms. On account of this, there is a possibility that the small firms in Australia face fewer obstacles to enter the market. Therefore, lower entry cost might increase the large number of new firms in the market in Australia.

Da Rin, Di Giacomo and Sembenelli (2011) performed an experiment with 17 European countries to reveal how corporate tax can affect firms' entrants in the market. They found strong evidence that low level of corporate taxation actually increase the entry rates of firms. Tax reduction can increase monetary benefits for firms. If the tax rate is high, then the entry cost will be also high. As a result, only large firms will be motivated to enter the market. In line with this paper of Da Rin, Di Giacomo and Sembenelli (2011), it can be assumed that the corporate tax for the small firms in Australia is lowered which may stimulate more firms to enter the market.

Furthermore, Luttmer (2007) illustrated that high entry cost or complexity in imitation by firms can have effect on the firm size distribution. Zipf's distribution can be derived resulting from one of these factors or even by the combination of these two features. In aligned with this literature, if the entry cost is not high then it becomes easier for the small firms to enter the market. For example, in Australia there might be flexible government regulations, patents and licensing requirements; less start-up expenditures and technological challenges for the small firms. As a result, these facilities may create an uncomplicated access for the small firms. Therefore, there is a possibility that market in Australia cannot be highly concentrated. Luttmer (2007) also argued about the feasibility of imitation by firms. Imitations make easier for firms to expand their activities and establishments. In this regard, if Australian small firms can imitate effortlessly then there might be an opportunity for them to expand their businesses. This could also be reason for the less concentration of large firms in the Australian market. In this case, large firms might not be able to possess high market power.

There are also uncertainty and risks that create problems for new firms to enter the market (Gentry, Dalziel & Jamison 2013). Labor strikes, invention of new technology, machine breakdown, cost from fire, theft incidence, natural disasters such as flood or earthquakes etc. are associated with uncertainty and risks. These factors cause hindrance for the new firms to enter the market. These components can create complexity for the existing firms to carry out their operations as well. If the new small firms in Australia face less uncertainty and risks then it might create an easy access in the market. Moreover, less uncertainty and risks might generate fewer complexities for the small firms to continue their business operations smoothly. Consequently, more small enterprises might be in operations in Australia due to minimal impacts of these factors. Thus, large firms might not have greater market power.

In addition, new industry can be launched by government deregulations, tax incentives, and development of new technology or scientific advancement (Sine, Haveman & Tolbert 2005) etc. If the new firms could access these facilities then it would accelerate the process of market entry by the young firms. Hence, in accordance with the literature of Sine, Haveman and Tolbert (2005), it can be inferred that if there are sufficient assistances provided to the small firms of Australia, then the small firms would become more committed towards their business actions. Accordingly, it could imply that number of smaller firms might be rising more than the large firms in Australia.

5.2.1 Australia’s Industrial Programs and Government Regulations

According to Mitchel (2015), Australia is a small open economy with one of the highest income per capita in the world.

In the past, tariff protection regulation helped the manufacturing sectors of Australia by enabling them to be more competitive in the international market (Mitchel 2015). With this policy, employment was generated and it was also focused to secure the infant-industry in the early twentieth century. However, because of the drawbacks of tariff protection, industrial policy of Australia moved to encourage productivity and competition through incentives for industry (Mitchel 2015). In the early 1970s manufacturing industries in Australia were affected by the high competition from the emerging economies and less protection levels for the industrial sector.

One of the main features of Australia’s economy is the dependence on the exports of primary commodity goods. Despite being heavily protected, manufacturing industries fail to become the major exporter of Australia. Between 1988 and 2012 Australia's exports were greatly dominated by the commodity goods sector. In order to diversify the economy, Australia adopted the policy of tariff protection in the early twentieth century focusing on the physical production in manufacturing and agriculture.

After the establishment of Federation of Australia in 1901, federal government introduced a protectionist policy named Customs Tariff Act 1901 to nurture the local industries. However, the policy was not able to achieve the desired goals of diversified industry as this policy did not provide simultaneous incentives for the innovation by industries. Thus, since the 1980s a new policy concentrating competition and productivity was implemented by reducing tariff. In addition to that, incentives such as financial assistance, infrastructure supports were offered to reform the industrial sector. Tax cut was initiated from the mid-1980's which led to the reduction of protection. As a result of new competitive industrial policy It might be possible to infer that there is less concentration by large firms in the market structure of Australia. Even though there are concentrated firms in Australia however, most of them are export oriented (Mitchel 2015).

According to Karanikolas (2013), Australia's current industry programs mainly focus on the development of small businesses by increasing their competitiveness. In order to achieve this goal government provides incentives to the small firms so that they can invest in innovation and commercialization of latest products. At the same time, government also offers export supports to the small business. A variety of initiatives have been adopted by the government of Australia to foster the growth of small firms. Firstly, one of the largest industry programs was the research and development (R&D) tax offset. Providing tax offsets for the R&D expenditures lead to the reduction of companies' R&D costs. Secondly, there is major funding for SMEs in Australia in order to increase their competitiveness in the market. Information gap is one of the main constraints for the SMEs to survive in the market competition. Therefore, with Enterprise Connect program in Australia, the SMEs receive reliable information and support so that these facilities can increase their competitiveness. Moreover, the SMEs have also access to the knowledge regarding new technologies as well as how to implement them in their production activities. Thirdly, there is another long-term program called Cooperative Research Centers (CRC). It is a collaborative research between industries and universities to lessen the challenges that the industries face. Fourthly, a commercialization program which aims to support businesses so that they can commercialize their goods or services. In this regard, the business gets funding to cover their commercialization costs. Fifthly, a long term program called Export Market Development Grants (EMDF) targets the SMEs. They are given 50% reimbursement for covering their export promotion expenditures. This program is launched so that the small firms can spread their market share in the international market. With the help of these programs and many more Australian government is continuously supporting its business sectors especially the small firm so that they can compete in international markets.

Likewise, Swanepoel and Harrison (2015) stated that a range of policies were implemented by the federal and state government of Australia to promote the business sectors. However, among these policies, expansion of small business is the main target of Australian government. In Australia, firm sizes differentiate in each region. The authors have defined the firm size by employment. In Australia the number of firms based on employment is basically bottom-heavy. That means firm size distribution is dominated by small and medium enterprises.

Swanepoel and Harrison (2015) expressed the most acceptable fact that a larger economy has a great number of enterprises. Of them, high percentage is occupied by the bigger enterprises.

However, this perception does not completely comply with the Australian economy. Australia not being a big economy could be the truth behind this concept.

Swanepoel and Harrison (2015) also argued about a payroll tax threshold plays an important role in the size of small firms to medium firm size. Different states and territories have different payroll tax thresholds rates and payroll tax rates. This type of tax is calculated on the wage of employees which is paid by the employer and this tax is paid monthly. When the total wage bill of an employer or firm surpasses the threshold amount, then the employer or firm is obliged to submit the payroll tax. This payroll tax could have huge impact on the firm size distribution across different states in Australia. As large firms have more employees compared to small and medium firms. Therefore, they have to pay more as tax payment. Due to this payroll taxes, there is a possibility that the large firms are reluctant to hire more employees to branch out their operations as the payroll tax may become an additional burden for them. On the contrary, the medium firms may not strive to shift towards the large firm category as to do so they have to employ more workers. Thus, more labor force will generate more payroll taxes. This could imply that the small firms are growing faster than the large firms in Australia. It should be apprized that this is only a general explanation as the threshold and tax rates are different across states in Australia (Swanepoel and Harrison 2015). Therefore, the size of number of large firms may vary across different states based on payroll taxes.

In Australia, the firm transition ratio differs for different firm size (Swanepoel & Harrison 2015). It is easier for a micro firm to transition into a small firm as it needs just more than 4 employees to get in that category. In this regard, small firms in Australia have higher rates of upscaling. Upscaling partly demonstrates the increasing employment range for different sizes of firms. In Australia, the transition ratio of medium firm to large firm is very low compared to other firm structures such as micro to small; small to medium. The low transition rate between medium firms to large firms could be due to the payroll taxes which have been discussed previously. Therefore, in brief summary it can be stated that as a small developed country Australia might have small quantity of large firms which demonstrate the Zipf's law.

There might be a very important factor in determining the firm size distribution in Australia which is the minimum hourly wage. In Australia, national minimum wage is 18.93 AUD per hour (Business 2019) or 12.14 USD per hour (OECD.stat 2018). Conversely, as a big developed country the minimum hourly wage of the U.S. is 7.25 USD (OECD.stat 2018). Minimum wage of Australia is significantly higher than the U.S. Even though the U.S. has large number of big firms compared to Australia (as discussed in previous section), it offers less minimum wage than Australia. Hence, government regulations regarding minimum wage could be an influential factor affecting the firm size distribution of Australia. Large firms in Australia employ more than 200 workers (Swanepoel and Harrison 2015). Thus, there might be a likelihood that large firms may not want to expand their activities with paying out high amount of hourly wages. Expansion of business requires more employment generation. Therefore, to avoid high labor cost the large firms might not be encouraged to enlarge their operational activities. Moreover, the medium firms who might have the prospect of transitioning to the large firm category by employing more labor force might be unwilling to do so due to high minimum wage compared to other countries. Labor is one of the main factors of production. Therefore, if the labor cost is high that means the cost of production gets high. This situation can lead to lower profits for firms. Therefore, by employing fewer labor force a firm can remain small which may have impact on the firm size distribution.

In summary, it can be said that being a small developed country Australia has only 100 large firms that exhibit the Zipf's law. Moreover, various industrial programs supporting the small firms as well as government regulations have impact on the few large firms showing the Zipf's law.

Chapter 6: Conclusion

The thesis has accomplished its main goal of finding the Zipf's law in the firm size distribution of Australia by utilizing the data on sales and total assets from the year 2018. After completing the econometric technique it was found that for top 100 large firms in Australia, Zipf's law is visible. Various government regulation and industrial policies might have an effect on this particular firm size distribution. Therefore, it can be concluded that the thesis has accomplished its aim and objectives. by finding the desired results. Even though the thesis has achieved its desire outcomes, it has some shortcomings which will be presented in the following section. Afterwards, it will also offer some recommendations for future research.

6.1 Shortcomings

It should also be noted that the data used in the regression analysis of this thesis only from the public limited companies of Australia. However, data on private limited companies were missing from the dataset. As Osiris database does not provide the data for Private limited companies, it was not possible to include those data. If both public and private limited companies' data were exploited then the result might have been different. For example, the actual number of large firms could be more than 100 showing Zipf's law. In this sense, this thesis actually does not represent the whole scenario of the firm size distribution of Australia based on Zipf's law. Even though the thesis failed to present the comprehensive result, this does not imply that large firms of Australia do not follow the Zipf's law. Rather, it is worth mentioning that may be the actual figure of large firms showing Zipf's law cannot be obtained.

On the other hand, the regression analysis used in this thesis is based on the technique provided by di Giovanni and Levchenko (2013). However, their study did not mention the actual cutoff level of large firms for regression analysis. As a result, without knowing the actual cutoff level of large firm sizes it difficult of compare and analyse the result of this thesis with the findings of di Giovanni and Levchenko (2013). Selection of cutoff level of firms was based on observing the log-log plot. After that the cutoff level was chosen where in the plot linear relationship was observable. As a result, this conservative approach (Giovanni and Levchenko 2013) might not generate same cutoff level for other countries. In this sense, it might create ambiguity and difficulty in cross sectional comparison with other countries' results.

6.2 Future Research

For further analysis data on number of employees for firms can be discussed to observe whether the firm size distribution follows the Zipf's law in Australia. In addition to that it should be noted that this thesis only used the data of pubic limited companies. Therefore, there is a scope of conducting a study with the data of all the public limited companies and private limited companies all together. In this way, it will be possible to find more precise and comprehensive outcome.

Firm size is not uniformly distributed in Australia (Swanepoel & Harrison 2015). It varies between different states. Therefore, there is a scope for future research to find out firm size distribution in different states in Australia and compare them. For this study ample data of both public limited companies and private limited companies should be available. Moreover, cutoff level should be same for the accurate comparison.

Moreover time-varying analysis could be done if the data are available in abundant. A comparison between two time periods could give a more precise picture on the evolution of firm size distribution and existence of Zipf's law in Australia. However, in this case selecting a common cutoff level will be very crucial.

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Appendix

Table A: Regression output for the variable sales (100 observations)

```
      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  1,    98) = 4936.13
       Model |  83.6070897     1  83.6070897           Prob > F      =  0.0000
    Residual |  1.65990211    98  .016937777           R-squared     =  0.9805
-------------+------------------------------           Adj R-squared =  0.9803
       Total |  85.2669918    99  .861282745           Root MSE      =  .13015

------------------------------------------------------------------------------
lprobability |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lsales |  -.9221094   .0131247   -70.26   0.000    -.9481549   -.8960639
       _cons |     10.341   .1941718    53.26   0.000     9.955677    10.72633
------------------------------------------------------------------------------
```

Table B: Regression output for the variable sales (500 observations)

```
      Source |       SS       df       MS              Number of obs =     500
-------------+------------------------------           F(  1,   498) =12952.31
       Model |  457.687563     1  457.687563           Prob > F      =  0.0000
    Residual |  17.5975052   498  .035336356           R-squared     =  0.9630
-------------+------------------------------           Adj R-squared =  0.9629
       Total |  475.285068   499  .952475086           Root MSE      =  .18798

------------------------------------------------------------------------------
lprobability |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lsales |  -.6256351   .0054973  -113.81   0.000    -.6364358   -.6148344
       _cons |   6.010373   .0681384    88.21   0.000     5.876499    6.144247
------------------------------------------------------------------------------
```

Table C: Regression output for the variable sales (1000 observations)

```
      Source |       SS       df       MS              Number of obs =    1000
-------------+------------------------------           F(  1,   998) = 6219.38
       Model |   836.04836     1   836.04836           Prob > F      =  0.0000
    Residual |   134.15757   998  .134426422           R-squared     =  0.8617
-------------+------------------------------           Adj R-squared =  0.8616
       Total |  970.205929   999  .971177107           Root MSE      =  .36664

------------------------------------------------------------------------------
lprobability |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      lsales |  -.3655306    .004635   -78.86   0.000    -.3746261   -.3564351
       _cons |     2.7398    .048764    56.18   0.000     2.644108    2.835491
------------------------------------------------------------------------------
```

Table D: Regression output for the variable total assets (100 observations)

```
      Source |       SS       df       MS              Number of obs =     100
-------------+------------------------------           F(  1,    98) = 4923.79
       Model |  83.6030116     1  83.6030116           Prob > F      =  0.0000
    Residual |  1.66398015    98  .016979389           R-squared     =  0.9805
-------------+------------------------------           Adj R-squared =  0.9803
       Total |  85.2669918    99  .861282745           Root MSE      =   .1303

------------------------------------------------------------------------------
lprobability |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ltotalassets |  -.9741452   .0138827   -70.17   0.000    -1.001695   -.9465954
       _cons |   11.84353   .2157842    54.89   0.000     11.41532    12.27175
------------------------------------------------------------------------------
```

Table E: Regression output for the variable total assets (500 observations)

```
      Source |       SS       df       MS              Number of obs =     500
-------------+------------------------------           F(  1,   498) =18612.36
       Model |  462.896238     1  462.896238           Prob > F      =  0.0000
    Residual |  12.3854423   498  .024870366           R-squared     =  0.9739
-------------+------------------------------           Adj R-squared =  0.9739
       Total |   475.28168   499  .952468297           Root MSE      =   .1577

------------------------------------------------------------------------------
lprobability |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ltotalassets |  -.7070999    .005183  -136.43   0.000    -.7172831   -.6969167
       _cons |   7.725802   .0693407   111.42   0.000     7.589565    7.862038
------------------------------------------------------------------------------
```

Table F: Regression output for the variable total assets (1000 observations)

```
      Source |       SS       df       MS              Number of obs =    1000
-------------+------------------------------           F(  1,   998) =23839.73
       Model |  931.187805     1  931.187805           Prob > F      =  0.0000
    Residual |  38.9822138   998  .039060334           R-squared     =  0.9598
-------------+------------------------------           Adj R-squared =  0.9598
       Total |  970.170019   999   .97114116           Root MSE      =  .19764

------------------------------------------------------------------------------
lprobability |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
ltotalassets |  -.5742585   .0037193  -154.40   0.000     -.581557     -.56696
       _cons |   5.883904   .0449924   130.78   0.000     5.795613    5.972194
------------------------------------------------------------------------------
```