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Innovation and Regional Economic Growth in China

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Abstract: Based on historical data and facts, China have long been a rich country to the global extent, China's economic growth has been remarkable during the last few decades; during which, from what I see, the innovation boom after its opening to the world (ever since the end of 20th century) had played significant role during the process. In this paper, I will test my hypothesis in a quantitative way to see if the innovation in China in a regional level is significant for my target cities' economic growth in the last two decades, based on the model I build up (based on Solow Growth model) with the data from National Bureau Statistics of China, I will run regression for the model so I can see the results to see if the measurement I use for innovation is significant for the regional economic growth, apart from this, I will compare the results among cities to see if that cities with higher innovation resulted in a higher economic growth and also see if I can find out which specific innovation field contributed most to the economy. The aim of this article is to explore if there is a specific relationship between innovation and economic growth and what the relationship is in the target cities I choose in China.

Key words: Regional Economic Growth, GRP, Innovation, Regression, Model

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Contents

1. Introduction and background review

1.1 China's Economy historical background review and understandings of Economic Growth:

In the above abstract, where I have briefly introduced the aim of the paper, you would probably know that I want to explore the relationship between innovation and economic growth in a regional level; and in this introduction section, I would like to introduce the basic-structure of this paper; give a background review on the economic-innovation topic, and explain the basic thought and logic behind this idea. I will start from China's historical economy background, the importance of innovation, and China's effort on innovation both in national level and regional level, to connect innovation and economy with a tight logical bridge, so as to extend to further work.

China's economic growth has been outstanding and remarkable to the global extent ever since 1978 to the current year, over these more than three decades of reforming period in Chinese economy, the annual growth of output per capita averaged 8.7% over the country (Knight, 2012), such is similar to knowledge of the power of compound interest that this means output per capita had increased more than twelve times during these periods, and the effect of economic growth on poverty in Chinese citizen was dramatic: over 250 million people were no longer suffer the dollar−a−day poverty any more (Knight, 2012). According to Adam Smith, who wrote in his book: *Inquiry into the Nature and Causes of The Wealth of Nations* that: *China has long been one of the richest, that is, one of the most fertile, best cultivated, most industrious, and most populous countries in the world. It seems, however, to have been long stationary*. (Smith, 1776, p73), all kinds of evidence showed that China had long time been a rich and fertile land even in the global standard, next I will briefly show China's economic growth with statistical prove.

As shown in the following table about annual average percentage rates of growth in real GDP of the selected countries, we can clearly see that China had achieved significantly high output growth of more than 10% annually in each decade by comparing with the other selected countries over the period since 1980; while the world economy in general grew consistently at around 3% per period. For the developed economies, such as the United States, Japan, and the United Kingdom, grew at a modest pace by averaged annum rate not exceeding 4%. On the other hand, after Russian's overnight economic transition, their economy collapsed dramatically down to 4.7% per annum from the second decade, and recovered respectably after 2000; India's economy grew by almost 6% per annum in the first two decades, and the growth increased to almost 8% per annum after 2000 with its economic reforming and acceleration of its marketization: quite similar to China’s developing steps, evidence showed that India might come to rival China's dynamism in the coming decade. Both South Korea (9% per annum) and Taiwan (8% per annum) grew rapidly since the early 1980s but their growth declined as their economies getting matured and become stable. The city states of Hong Kong and Singapore also grew at over 6% annually in the first decade of the table but their growth similarly slowed down afterwards. Vietnam, which started reforming later than China, managed to almost 8% per annum in the decades after 1990 and increased with a high speed to almost 10% in the 21st century. Another small resource but rich economy case, Botswana, achieved over 10% per annum growth in the 1980s, however they cannot sustain the high economic growth and the growth rate kept decline in the following two decades, in 21st century its growth rate dropped to 5.3% per annum, which almost shrink half than the rate in 1980s (Knight, 2012).

Country	1980–90	1990–2000	2000–7
World	3.1	2.9	3.2
China	10.2	10.6	10.3
United States	3.0	3.5	2.6
Japan	4.0	1.1	1.7
United Kingdom	3.2	2.7	2.6
Russia	1.9	−4.7	6.6
India	5.8	5.9	7.8
South Korea	9.4	5.8	4.7
Taiwan	7.9	6.4	3.8
Singapore	6.4	7.6	5.8
Hong Kong	6.9	3.6	5.2
Vietnam	.	7.9	9.8

Country	1980–90	1990–2000	2000–7
Botswana	10.3	6.0	5.3

(Sources: World Bank, World Economic Indicators; Taiwan, Taiwan Statistical Yearbook.)

By looking at the data we can see that China's growth rate in economy ever since the last three decades had been outstandingly significant, and this was achieved through various of reasons over the country from official government to its citizens, for example, the governmental policy within and outside the country, including its increasing interaction with foreign innovative enterprises, promotions on research institutions and universities, and internal innovation booming from national companies, research and educational institutions, and some innovation from private subject also contribute to the economic growth. In this paper, I want to discuss about and dig into the relationship between economic growths and, an important economic factor, innovation; I would try to find the relationship between innovation and economic growth in regional level through a quantitative way by running regression for a economic model I build and see if this innovation factor to economic growth could be significant. Apart from this, I also want to find out the most contributive field to the economy and solve some other questions relevant to this topic.

1.11 Structure of the article:

The structure of the research will be presented as follows: in this introduction section above which I have stated the China's economic situation in the last few decades compare with other countries, I will also talk about the significance of innovation and highlight the national innovation progress as well as regional innovation promotion with Beijing as an example, also some relevant backgrounds had be introduced , for example the economic growth background, the reason I choose my target city from the same level (which is discussed through these cities and come up with an answer that within the same level of city they are comparable, while not comparable with different levels of cities), followed I will discuss importance of China's policy on innovation, the measurement of the variables of my study research, innovation, education (probably will be measured by investment on education or the number of higher educational institutions which have direct contributions to the local economy), population of the city (measured by population size), economic growth rate (measured by Gross Regional Product growth rate), etc. then in the research method section I will discuss model I will build up which includes all the mentioned variables with a econometric equation, then I talk about my data base, which I get from the National bureau statistics of China and some other resources, then is the running econometric test to see if there is any relationship between the innovation and GRP, and finally based on my test result combined with literature I will come up with my conclusion. (GRP stands for Gross Regional Product, which is used for regional level, since GDP is for national domestic)

About the generalizability of my research, due to the limit of the data and city sample I think I cannot generalize my study result to other regions but just limits my conclusion to the cities I choose, I will discuss this later in the limitation section and I also expect that in future studies this problem could be fixed, but for the contribution to the literature review of the interactions on China’s regional policy and innovation, I expect that the government enrollment in these cities are rather significant.

1.12 Understandings of Economic Growth:

In order to explore the relationship between innovation and economic growth, first we need to understand what is the economic growth and theories about it. One of the most influential and well-known economic growth models is the so-called neo-classical or Solow, model of growth (Solow, 1956). The Solow model of growth derived strong conclusions based on traditional production function and also the assumption that each factor of production had diminishing returns. With savings and investments, though starts from a low level of output per capita, the capital-labor ratio and output-labor ratio will rise, based on the assumption of diminishing returns to capital of the economy, marginal growth of capital and the market-determined rate of profit on capital will decline, and finally the economy will reach a long-run equilibrium level of output per capita. According to Solow, this equilibrium level could be achieved only as a result of technical development, assumed to be determined exogenously (Knight, 2012). This growth model predicts that economy will reach a long-run equilibrium status of output per labor through exogenous technical development, and the further away from this status, the faster the econmy will grow because of diminishing returns.

Based on Solow’s growth model, The economy can be described with the following function:

$$\mathbf{Y = AK^{\alpha}L^{\beta}, \text{ where } \beta=1-\alpha.}$$

A is the technology factor for the combination of K (capital) and L (labor). And The elasticity coefficients for K and L are presumed to be equal to the shares of capital (a) and labour (b) in value added (factors paid according to their marginal productivity). This gives the following estimate:

$$\mathbf{dY/Y= a*dK/K + b*dL/L + dA/A.}$$

Where dA/A could be considered as Total Factor Productivity (TFP) (Lennart Schön, 2013). In this sense, the growth of economy consists of the value added in captial and labor, plus productivity from other factors. The economic model I build is based on this basic equation and logic which consists of labor, capital and other factors' input that I choose (I will discuss the model later in model and regression section).

1.2 Interactions between economy and innovation in China

So far I have discussed about China's economic growth and understandings of economic growth, next I want to discuss the interactions between economic growth and innovation in China in order to understand the China's propensity in innovation. In 2009 there was a speech where given to an academic audience at Cambridge University by Chinese previous premier Jiabao Wen, who agreed and recognized the unprecedented nature of "once in a century crisis" at that time affecting the global economies, which also included China, UK and other member countries of the EU. As part of China's coordinated macroeconomic response, Premier Wen highly reiterated the important government's determination, which was to achieve economic recovery through technological innovation in order to make energetic efforts towards progress, strengthening and maintaining that science and technology were the basic policy issues of 'fundamental importance in overcoming the financial crisis and recovering economy'. To some extent, Premier Wen's statement presciently captures the transitions and reforming taking place in China today, as the country tries to promote and upgrade its productive capabilities from low-value added manufactures industries into high-technology, knowledge-led based sectors industries through technology development and innovation boom. Enhancing China's capacity to innovate is, therefore, being considered as an ongoing priority among other reforming strategies (Crookes, 2009).

1.3 Government's effort in policies and promotions of innovation in China:

In 1976, Deng Xiaoping became the new Chinese leader after the death of previous Chairman Mao Zedong. Deng promoted fundamental reforms in the Chinese economy and argued that 'science and technology are the chief productive forces'; he also said that China needed to learn from Western nations. As a result, the government began reforming the old systems and began creating a market oriented economy, launching the "Open Door Policy", decentralizing fiscal and managerial control, redefining public and private ownership, and encouraging new linkages between research and production (Kun Chen, 2007). Nationally, recognizing the significance of innovation, the Chinese Government has been putting efforts in leading the country towards being a knowledge based market economy; the policies initialized by Chinese government include National High-technology Research and Development Plan (863 Plan), the National Basic Sciences Initiative (973 Plan) and the Torch program that specifically aims at facilitating commercialization of scientific research outcomes (Peilei Fan, 2012). Apart from these plans and programs, government in China also sets up national high-tech parks (53) to attract foreign developed companies to stimulate domestic high-tech firms; these efforts undoubtedly highly promoted innovative activities in China. Based on Fan and Watanabe's research in 2006, from 1981 to 2000, more than 40 percent of the economic growth was contributed by technological progress. The World Bank and OECD also had quite similar figures and highlight the promotions in innovation activities and their contributions to China's economic growth (OECD, 2008, 2009; Zhang *et al*., 2009).

Regionally, local government also devoted focused effort on promoting innovation and technical development; here I use the capital of the People's Republic of China, Beijing, who had achieved outstanding economic growth in the last few decades, as an example to clarify Chinese government's effort in promoting innovation. Beijing is the educational, political, science and technology center in China, after the "open door" policy, the economy was allowed to diversify from the previous old social systems as for the establishment and legitimization of private ownership started; small businesses and private companies had gradually become the mainstays in the market economy; at the same time, many foreign direct investments were attracted to serve the domestic market due to the new "open door" policy, not only building factories for producing products, but also they had built up specific research institutions and official department for further research in China, from local enterprises' perspective, there are policies promoting them to innovate and make connections to the foreign companies so they were able to absorb the newly advanced technology from foreign companies, these companies gradually became the later high-tech or advancing companies that contributed a lot to the local economy (Cohen & Levin, 1990). On the other hand, local Universities and research institutions (URIs) were also promoted a lot due to the government policy. In the early 1980s, the Beijing government decided to lower governmental cost of support on URIs, in this case the URIs has to look for funds by themselves alternatively, the foreign investment and foreign-owned companies became their hot source so they had to look for opportunities of cooperation; in order to strengthen the connections between URIs and foreign investment and enterprises, Beijing Government have established policies for further promotions, such as establishing fiscal, professional and legal services, and provide funds for student, newly start-ups, and small technology-base firms; emphasizing patent laws and building up technology zones and innovation industry base near URI (Kun Chen, 2007). And the promoted high-tech programs included fields in biotechnology, new materials, lasers, energy, information, robotics and space (Segal, 2003). In this way, up till 2003 there were 71 universities and 371 research institutions in Beijing (Beijing Statistical Information Net, 2005). After the governmental policies in 1980s, the high-tech firms had taking the place of traditional manufacturing industries and become the most important source for the economic growth in Beijing, based on the statistics from Beijing Statistics Information, the percentage of high-tech firms accounted for total industrial valued added increased from 25.4% to 39.3% in 5 years from 1999 to 2004. Beijing had become the top city in China in terms of science and technology capacity in 2004. In 2000, 25% of government S&T funds were allocated to Beijing institutions, and 18% of all R&D funds were expended in Beijing and 18% of all patents were granted to entities located in Beijing (Kun Chen, 2007). Up to 2003, total R&D spending in Beijing reached RMB25.63 billion, of which government funding accounted for RMB13.67 billion. From the above description and data prove, we can see that government have put a lot of focus on policies in promoting innovation after 1980s such as building up connections between universities, high-tech firms and some industries programs; promote small to medium companies to new technology and build linkages to foreign companies for new technology absorption, etc. for other cities, quite similar in the first level of cities, the high-tech enterprises' output in the last few years had contributed a lot to the economic growth (Xu, 2013/5/5).

2. Research Questions:

My study research is about the relationship between innovation development and China's economic development on city's level, my research questions are listed as follows:

1. Did innovation really play positive and significant roles for the city's economic growth independently? If so, what contributions the innovations in China from different cities have contributed to the China's city economy since the end of last century?
2. Which innovation application field (Invention; Utility models; Designs) contributed most in the innovation?
3. Is that true that with more innovation the city's economy will grow faster? Does each city have different input for their economic growth?

3. Previous research and theoretical foundation

In this section I will briefly discuss previous research to the similar topic including the theory of innovation, economy growth in China, innovation growth, and also the theory foundation for the model that I build. There are a lot of previous research on the innovation, innovation and China's economic growth based on my literature review.

Innovation has become an increasingly important determinant of economic growth (Fargerberg, 1994). I find Fagerberg, Godinho, and Gershinkrona's literature are rather helpful to support the significance of innovation and linkage between innovation and economy, in which they also discussed the measurement of innovation (as will be discussed later in the innovation measurement), the importance of relevant policy on innovation and its effects, etc (this discussion on regional policy is showed in the introduction section, the government policies of China in the 1990s and their effects on economic growth). Fagerberg and Godinho's literature about innovation and catch up can contribute to the national innovation process and innovation system in China, its capabilities and its influence, which, in later data discussion in Beijing's economic growth in relation with innovation will be shown as an example and focused on. Apart from this, some relevant research about China's innovation and influences between innovation and economy are reviewed and studied as well, for example the *China's embrace of the market economy: understanding its innovation strategy* by Irwin Crookes Paul, there is one research mainly conducted by Tao qu, Jun-Cai Chen about China's economy and innovation, on the contrary to my study to explore the impact of innovation on economy, it exams the causes of innovation in the context of inward foreign direct investment in China, they find that local absorptive capacity critically affects creative power, Economies transfer techniques using various approaches, impacting local innovation in diversity (Tao Qu, 2013); apart from this, they also find that China benefits substantially from technical spillovers of imported parts mostly from Asian economies, and conclusions such as Governments should support research and develop machinery and equipment industries to accumulate know-how. China should proportionately import parts from European countries and USA to realize trade balance thus to reduce trade conflicts (Tao Qu, 2013). The involvement of government, foreign and national enterprises, research institutions and universities are rather important. There are studies on different innovation policies in China cities Beijing and Guangzhou, since they have all experienced an economic boom through innovation policy. I do not deny that the relationship between economy and innovation is kind of mutual to both sides since innovation can accelerate the economy while the economic booming can stimulate the innovation promotion in reverse. In my research, through these previous theoretical or experimental bases, I will test the relationship between economic growth and innovation in a single direct, which is the impact of innovation in economic growth, through a quantitative way to see that if there is an effect of innovation could lead to a city's economic growth (Xu, 2013)

3.1 The crucial role, basic features and measurement of innovation

Next I will discuss an important element of my thesis, innovation. Since this study is to explore the relationship between the great economic progress in China and in the field of innovation (patent activity), accordingly, I will discuss the innovation issue as an important indicator of economic growth, in the following and specific areas, the concept and characteristics of the innovation and what is used as the main indicator for innovation. Innovation, by definition, is the first attempt to carry out a new idea for a new product or process into practical use (Jan Fagerberg, 2007), or it could be briefly summarized as the commercialization of new products or processes. And the capability of a country to innovate is usually considered as one of the main drivers for economic prosperity. As it is well known to the public that innovation plays an important and key factor for a country's economic development; as mentioned above, the purpose of this paper is to test the relationship between innovation and economic development regionally in China from a quantitative perspective, and find out which innovation field contributed most to the Chinese economy in the research region. In order to test the relationship between innovation and economic situation, innovation element needs to be quantified so as to run regression with a model, so I will need to find the indicator for innovation, economically it is quite important to measure innovation to be used as indicators or statistics for analysis, and this is also very important for my study.

The first measurement is patent, which is a conventional simple indicator for measuring innovations, nowadays as a country's policies and protective laws in innovation are becoming more and more complete and perfect, patent registering and protecting the innovators' benefits are highly emphasized by policy makers and innovators themselves. Patent systems usually keep records of detailed information for a new-to-market invention goods, people apply for patents registration for their innovations and therefore they could use their innovation commercially without worrying others copying or cheating on results, the well-kept and tracked patents documents allow innovators to put their innovation into commercial use. Due to its simplicity, efficiency and effectiveness, this patent measurement is widely used by many places around the world; at the same time, there are some drawbacks of using patents as measurement for innovation, for example, technology invention based on previous technology is not considered as innovation, but this kind of improvement would no doubt contribute to industry output; another flaw is that not all registered patents are put into commercial use, therefore as a measurement it will lead to some bias in missing data. The second traditional measurement is the expenditure on research and design, a country's effort put into R&D is directly linked into its innovation level, comparing to patents, the measurement of expenditure R&D can offer more detailed classification on the various kinds of innovation since there are different divisions of concepts of Research and Development, however, practically it is often limited to use expenditure on R&D and an indicator due to the limited access to R&D data, on the other hand, we cannot definitely say that once there are R&D input in a company there will be output as innovation, thus this single-sided input measurement is not often used for innovation (Xu, 2013)

As society develops very fast, the more and more knowledge and recognizes on innovation, there are more measurements for innovation today, some are even complicated as using multi-factors, but also there will be unavoidable drawbacks for these different kinds of measurements. In China, the main generator for economic growth is innovation, with large numbers of patents. In fact, in a very short period with historical background, Chinese government decided to change its economic policy, which helps the process that transferred from traditional agriculture and traditional production to innovation business, the patents registration is a general summarize of all the technological invention for commercial use. In my study, take all factors in to consideration, such as limits, availability of data, the validity and reliability of data I will use patents registration as the indicator for innovation, the patents registration includes all the registered patents within the current year and have a official document in the China’s patent office, as the advantages and disadvantages are as discussed above, there will be some bias existed use this measurement, however, since it is the most effective and efficient way accepted by the public, and I can have access to the necessary data since the end of 20th century from the National Bureau of statistics of China, which will be my main data resources for this study. (Xu, 2013)

3.2 China’s city division

The China’s city division, in some way, matters to how the statistical result will be compared and why this could be done. In China, the division is based on competitive factors including financial power, political status, geographical influence and also city geographical size, etc (translated from National Bureau). Based on this standard, China’s cities are divided into five levels; as it is well known to the public there are five cities in the first level which includes famous cities such as Beijing, Shanghai and Shenzhen, the second level includes some cities that have lower influence within China comparing with the first level but still politically or economically important such as Nanjing, Wuhan, Xian, Tianjin, Chongqing, etc; there are also third, fourth and fifth level of cities, but I do not include them in my study, cities within the same level have similar political power, financial power and some other equal development resources and environment so they are comparable; comparing Beijing and, let’s say, a second or lower level of cities, would be meaningless since they are not politically or financially equal, and that’s the reason why I only choose cities within the same level to do the comparison, and only in this way the results are meaningful, thus for the conclusion I will summarize as two different levels of regions. For this study, first level of cities: Beijing, Shanghai, and Guangzhou; Second level of cities: Tianjin, Wuhan, and Chongqing.

3.3 Different regions have different Capabilities for innovation

Of course, difference regions or cities will have different innovation capabilities; and that is the reason why some city or provinces develops faster than the rest. Generally speaking, based on previous research, China’s economic inequality at the provincial level declined in the early 1980s, but had increased ever since the mid-1980s (Chen and Fleisher, 1996; Tsui, 1996; Bao *et al.*, 2002; Wan *et al.*, 2007), and this economic inequality might caused by factors such as locations, labor density, infrastructure, and some political factors (e.g. booming capital investment in coastal provinces, decentralization, agglomerations, improved factor mobility, openness and capital input). (Peilei Fan, 2012). In Peilei's paper, where they have tested the inequality of innovation in different regions in China through econometric models, had statistically proved that different regions in China had different capabilities to innovate; specifically the east-central-west regional inequality increased over time, whereas the interprovincial inequality exhibited a V-pattern; both oscillated from 2004 to 2006; and especially determining elements that cause the inequality of innovation are population, economic development level, R&D, location and openness (Peilei Fan, 2012). This research article make me realize that compare cities within different levels is meaningless because every year the government input in political effort, financial investment, openness and R&D target are quite different in different level of cities, while within the same level, though slightly different, would be more comparable, therefore this is the reason why I compare the cities within the same level in China to see whether they are significant and how the relationship will be. Further, their study result shows that different cities have different capacities in innovation, and somehow can explain the difference in regression result if not all are significant nor have a positive relationship, because different cities have different focus in economic input, labor or capital, while running the regression, it can be possible that the target city's focus is on labor or other capital variables I choose, therefore the statistical result can be explained.

3.4 Innovation proximity

Another important aspect in this theory section is innovation proximity, which matters the importance of regional and global knowledge flows, and can help me explain the growth in innovation for second level of cities; next I will briefly explain this theory, aiming for the link of economic growth between the different levels of cities. According to Boschma in 2005, the proximity in innovation system means more than just geography, it covers the following dimensions: cognitive, organizational, social, institutional and geographical, and geographical proximity refers to spatial distance between actors, both in its absolute and relative meaning, and geographical proximity may facilitate inter-organizational learning, but it is neither a necessary nor a sufficient condition (Boschma, 2005), "neighborhood effects"…will always, in an almost automatic way, tend to create a degree of overlap between spatial and other forms of proximity", (Malmberg and Maskell, 2006, p. 11), but spatial proximity has an impact on processes of interactive learning, because it leads to more or less automatic processes of observation, monitoring, benchmarking, and informal information exchange such as buzz, this theory is developed by Malmberg and Maskell, on the benefits of spatial proximity where it can be analyzed and this is the social dimension, though Boschma thought geographical proximity could be replaced by other proximity forms, Malmberg and Maskell's opinion refers that the spatial proximity strengthens cognitive proximity by developing a common institutional, social and cultural setting, and I prefer to think that the latter's theory and thinking more punctual to my case.

Since my study is to explore the relationship between innovation and economic growth in regional level, there is a possibility that the regression result of my model might not explain the actual fact that innovation cause the economic growth, for example, second level cities, and that's where I might use spatial proximity to big cities (first level city or big developed regions) to explain their innovation growth since they take advantage of the geography that their information might be the most instant from big cities. In my case, the second level of cities in China which are geographically preponderant close or near to big cities, they have faster and fresher information, transferred technology than other lower level cities, thus their boom in innovation might get caused by those innovations from big cities and regions.

The relationship between innovation and economy, however, is a complicated problem, because possible situations could be that innovation dose not motivate the economy immediately but with several years lag, or one regions' innovation activity cause economic growth in another region, due to the data limit, I can just solve the previous problem with lagged regression model, for the latter problem of regional innovation mutual impact, which more complex data is required, I would not be able to solve in this study, and this becomes the limits of the study, or causing the regression bias, in respect to say.

Apart from innovation, some other elements are also very important for city's economic growth; in my study, I consider population of the city (labor input), educational level and high-tech enterprises' output (capital input) also contributive to the economic growth, therefore, in order to exclude these variables' influence, we will need to include them in my model to run the regression thus I can say that the result is from innovation. This will be further explained in the hypothesis and model section.

4. Research Method

This study will be a quantitative study, and the mainly research method will be stated as follows: start from China's economic rapid development in the last decade from 1995, I will pick some representative cities from the first two levels of cities, look for the patents registration and GRP (measurement for economic situation) in these cities and comparing them within the same level to see whether the cities that have higher innovation could have a result of higher GRP per capita growth by building up a regression model. Furthermore, I will also look for the data in these cities that which innovation field contributed most to the economy, probably by looking at the percentage and summarize them, the role of government, based on literature review, is rather important during this rapid developing process, from the early 19^{th} century China's fall behind the western Europe and its catch-up in the end of the last century, China's policy on introducing foreign innovation, interaction among research institutions, universities, internal and external enterprises.

Here I cite some basic figures from the National Bureau of Statistics to see the economic growth in different first-level cities, by looking at the GRP growth, in 2012 the GRP for Beijing, Shanghai, and Guangzhou have reached their peak value separately 1.78 trillion RMB, 2.01trillion RMB and 0.57 trillion RMB (National statistics, 2012), and the trend of the growth in GRP during the last twenty years are obviously increasing by looking at the growth trend. Here I use Beijing's GRP growth trend from 2004 to 2012 as an example. The data for innovation, which is the patent registration, from 1990 to 2003, all the national patents registration had increased from 22588 to 182226, in 2003, Beijing had registered patents 8248 cases, and Guangdong had 29235 registered patents cases, which was far more than Beijing's registered cases, however, its GRP is lower than that of Beijing, which is interesting to me, and I want to compare these to cities to see their relationship between economic situation and innovation situation. The cities that I am thinking about are: in the first city level: Beijing, Shanghai and Guangzhou; in the second city level: Chongqing, Wuhan and Tianjin. These cities are quite representative in their GRP and official registered patents. And in order to exclude the effect of my other variables' influence on economy, I need to include these variables in my model to run the regression so the regression result will show the purely effect of innovation in my model on economy.

After listing economic situation and innovation for each of my target cities, I look for the measurement of other variables in my model, which are Economy, Population, education and high-tech enterprises' output, the economy situation will be measured by GRP of the city in the current year, and the education will be measured by the basic statistics on Educational Funds for each city of the current year, which include Government appropriation for education, funds of social organizations, donations and funds-raising, income from teaching research and other Auxiliary activities, and other kinds of educations funds (because these different varies of educational funds can contribute directly to the city's economy, in China, before high level education all education are free or only cost a little, and also part of credit are from these high-level educational activities such as talent trainee, and also consider the availability of data, in this case I statistics on Educational Funds to represent the contribution from education to economy), and the output from registered high-tech enterprises the current year will be used for measuring high-tech enterprises' output of the city which contribute to the local economy.

5. Hypothesis and Variables of the tested model

The aim of this article is to explore the relationship between innovation and economy, and my hypothesis is that innovation plays positive and significant role for the economic growth. Next what I will do is to test my hypothesis with a econometric model, In this regression model, where I have included innovation, population, educational expenditure and high-tech enterprises output based on the thought of labor input and capital input, population is considered as labor input and the rest variables are considered as capital input. Apart from economy and innovation these two major elements, other variables include education, population, and the high-tech enterprises' output of the city for the current year. The education will be measured by the statistics on Educational Funds, and the research situation will be represented by purely amount of high-tech enterprises' output for the current year which also contributes directly to the economic growth. Followed up with my econometric equation:

Y (GRP) =αX (Innovation) + Education + Population + High-Tech Enterprises' output+ C

My hypothesis is that in the regional level the city does have a relationship between innovation and economic growth and with higher innovation (more registered patents), there will be a higher economic growth (GRP growth rate), by running regression and testing the significance of the result I can test my hypothesis for my research through quantitative way. And further by looking at the percentage of patents emphasis I could tell in my target cities which innovation field contributed most to the economic growth. The above part I explained the mainly methodology for my research to see the relationship between innovation and economic, a positive α would reject my null-hypothesis and thereby I accept testify my hypothesis.

The model I will use is a multi-variant Least square lag model because there are more than one variables that have impact to my Y value and I need to include time lag in my model to detect the time effect of innovation, in order to test the effect of innovation on economy; due to the fact and previous analysis that population, education and high-tech enterprises' output are all influential to economy, I need to include these variables exclude their impact on economy, so the regression result, the α effect is from innovation; furthermore, in order to test if there is any lag effect, for example, the innovation in the previous year doesn't cause economic growth immediately for the current year, but lead the economic booming in the coming year, this is the reason for testing the time-lag effect. In my case, based on two aspects of considerations I include lag with 1 year to test this kind of situation. My first concern is that innovation effect could rarely be lagged for two or more years and have an effect in China, due to the production efficiency and business efficiency people ought to put innovation into business goods as soon as possible, one year lag would be more reasonable and logical; second concern is that the data limit for my data resource, also the data limit situation in China, the time length of the data is not long enough to run regression with more lags, thereafter the length would be even shorter and cause insignificance in the regression result.

6. Data and Regression

The main data resource I may have access to is the National Bureau of Statistics of China or the so-called *China Statistical Yearbook on Science and Technology*, which is an officially systematically organized national province, city and self-owned states including economy, social and all other national and regional statistical data, it is a comprehensive data base that can reflect the economy and social development situation for the people's republic of China and the only complete data resource I can get access to for this research. Other data resources I might also use are from official website of China's statistic such as CNKI (National Knowledge Infrastructure, which is raised by World Bank in 1998 aiming at organizing, transmitting and sharing national informatics knowledge for information construction.), National Statistics Index, etc, but since these data resources are not official, I just use them to fix missing data and for corrections of data.

For the database which include the data I need from 1995 to 2011, I check the National Bureau of Statistics of China for each year and comply the data I need to put into a new excel file, as they are shown in the appendix for each regions, some missing data I get from other resources such as the local Bureau of Statistics, news and other website information, for other parts of the missing data that I cannot find replace resource, I use interpolation or calculating the growth rate to fix the missing data point (few points).

About the validity and reliability of data source: the National Bureau of Statistics of China is the official data resources calculated and open to the public by Statistics Office, we cannot avoid the fact that the statistical system in China is quite new and many data details is not that complete or comprehensive compared to developed countries, there is one article that I come to which mentioned big flaws of the China's data system, mainly about its reliability (sometimes exaggerating data too much show to public), transparency and efficiency; while in my study, I cannot say that I can avoid these problems, I try my best to keep the data real by looking up additional resources (CNKI, World Bank data), and I think Chinese government really need to put more effort in completing the data system with more details, opening and transparency.

For all the data resource in my database, theoretically I should smooth the data before I run the regression in order to erase bias and make the result more precise, however, since the time series of my data is not very long, there will be unexpected result such as insignificance, in practical I deal my data with the method of interpolation and calculating growth rate (fixing miss data), and then take logarithm and calculate the growth rate for each variable. Before running regression, I have some expectations on the result that the relationship in regional level in different cities would be positively significant, and within the same level of cities, higher innovation growth result in a higher economic growth.

The software for running regression is E-views. Here I simply introduce the steps for running regression: smoothing the original data as I mentioned above, check the stationary of for each variable in the model and then run the regression, finally I will analyze and compare the regression result. In the following part I will use Beijing's data as an example to show the process: Beijing's original data:

	Economy (GRP: 100 million RMB）	innovation(case）	Population(10000 persons）	Education expenditure(100 million RMB）	High-tech zone enterprises output(100 million RMB）
1995	1829.42	4025	1070	84.2556143	101
1996	2022.26	3295	1078	94	198
1997	2134.85	3327	1217	117	272
1998	1371.81	3800	1223.39	117	370
1999	2537	5829	1249.9	151	643.42
2000	2565.3	5905	1107.53	193	910.37
2001	2845.65	6246	1122.3	250.3	1986.49
2002	3212.71	6345	1136.3	319	1477
2003	3663	8248	1148.82	354	1607.75
2004	4283.31	9005	1163	393	1873.8
2005	6886.31	10100	1180.7	449	2604.08
2006	7870	11238	1198	523	3449.4
2007	9353.32	14954	1213	337	3850.42
2008	10488.1	17747	1300	408	3805
2009	12153	22921	1246	469	4193
2010	14113.6	33511	1258	529	4988
2011	16251.9	40888	1278	613.44	5832

(Resource: National Bureau Statistics of China, 1996-2012)

(There is one data missing in Beijing's database, the education expenditure for 1995, which I use growth rate calculation to fix the missing point)

The first step is to smooth the data, where I take logarithm for each variable and then calculate the growth rate, as it shows below:

	Economy	innovation	Population	Educational expenditure	High-tech-zone enterprises output
1996	0.013341	-0.02411	0.001068	0.024683	0.145857
1997	0.007118	0.001193	0.017368	0.048176	0.060045
1998	-0.05769	0.016391	0.000737	0	0.05489
1999	0.085114	0.051906	0.003015	0.053569	0.093565
2000	0.001415	0.001494	-0.01696	0.048913	0.053667
2001	0.013213	0.006465	0.00189	0.049399	0.114513
2002	0.015254	0.001799	0.001765	0.043916	-0.03902
2003	0.016244	0.029959	0.001558	0.018058	0.011623
2004	0.019064	0.009737	0.001741	0.017807	0.020742
2005	0.056779	0.012603	0.00214	0.0223	0.043673
2006	0.015109	0.011579	0.002056	0.024981	0.035744
2007	0.019248	0.030629	0.001755	-0.07021	0.013501
2008	0.012524	0.017814	0.009755	0.032849	-0.00144
2009	0.015914	0.026149	-0.00592	0.023179	0.011778
2010	0.015902	0.037831	0.001345	0.019573	0.020815
2011	0.014764	0.019095	0.00221	0.023616	0.018359

(In order to calculate growth rate I use the difference between two years and then take division, therefore the growth rate for 1995 is not able to calculate)

Next step is to check whether the data for each variable is stationary (because if the all data have a trend, the database would be spurious and therefore I cannot use the data to run regression), which I use the E-views to have the Dickey-fuller test, the Null Hypothesis for this test is that GDP (smoothed) has an unit root; I just show the result of one variable here: for the smoothed GDP growth rate:

Null Hypothesis: GRP growth rate has a unit root

Exogenous: None

Lag Length: 0 (Automatic - based on SIC, maxlag=0)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.014855	0.0006
Test critical values:	1% level	-2.728252	
	5% level	-1.966270	
	10% level	-1.605026	

*MacKinnon (1996) one-sided p-values.

Warning: Probabilities and critical values calculated for 20 observations

and may not be accurate for a sample size of 15

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(GDP)

Method: Least Squares

Date: 05/11/13 Time: 13:01

Sample (adjusted): 1997 2011

Included observations: 15 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP(-1)	-1.071580	0.266904	-4.014855	0.0013

R-squared	0.535176	Mean dependent var	9.49E-05
Adjusted R-squared	0.535176	S.D. dependent var	0.050017
S.E. of regression	0.034100	Akaike info criterion	-3.854677
Sum squared resid	0.016280	Schwarz criterion	-3.807473
Log likelihood	29.91007	Hannan-Quinn criter.	-3.855179

Durbin-Watson stat	1.953783

Where the t-statistic is smaller than the critical value at 1%, 5% and 10% level, we reject our null-hypothesis and the data is stationary, the Durbin-Waston is 1.953, quite close to 2 which means that the data does not have the problem of auto-correlation, so we can go further to check the stationary for other variables, for Beijing, the DF test is shown as follows:

	T-statistics	Critical value (5%)	Stationary?
Economy	-4.01486	-1.96	Y
innovation	-2.02165	-1.96627	Y
Population	-4.12107	-1.96	Y
Education expenditure	-2.51099	-1.96627	Y
High-tech zone enterprises	-3.0664	-1.96627	Y

After checking for stationary of all the variables, I can run the regression on E-views, the result as shows below:

Dependent Variable: GRP

Method: Least Squares

Date: 05/11/13 Time: 13:25

Sample: 1996 2011

Included observations: 16

Variable	Coefficient	Std. Error	t-Statistic	Prob.
PATENTS	0.798728	0.443165	1.802324	0.0989
POPULATION	0.349086	1.058818	0.329694	0.7478
EDUCEXP	0.274837	0.262924	1.045310	0.3183
HIGHTECH	0.117000	0.170805	0.684994	0.5075
C	-0.007962	0.014613	-0.544835	0.5967

R-squared	0.273210	Mean dependent var	0.016457
Adjusted R-squared	0.008923	S.D. dependent var	0.028528
S.E. of regression	0.028401	Akaike info criterion	-4.034495
Sum squared resid	0.008873	Schwarz criterion	-3.793061
Log likelihood	37.27596	Hannan-Quinn criter.	-4.022131
F-statistic	1.033763	Durbin-Watson stat	2.173017
Prob(F-statistic)	0.432663		

The Probability for patents is 0.0989 which means that the patents impact on economy is significant at 10% level, where as α value is 0.798, though the F-statistic shows a little bit high, that might be the problem of limited data; then I include 1 year lag for patents, as mentioned before, there might be a possibility that the current year's innovation lead to economic growth in the coming year, thus here I follow the regression result with 1 year lag:

Dependent Variable: GRP

Method: Least Squares

Date: 05/11/13 Time: 13:34

Sample (adjusted): 1997 2011

Included observations: 15 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
PATENTS(-1)	0.496388	0.657015	0.755519	0.4674
POPULATION	1.196588	1.632452	0.733000	0.4804
EDUCEXP	0.151283	0.308908	0.489734	0.6349
HIGHTECH	0.126528	0.253934	0.498270	0.6291
C	-0.000860	0.018434	-0.046639	0.9637

R-squared	0.114128	Mean dependent var	0.016665
Adjusted R-squared	-0.240220	S.D. dependent var	0.029517
S.E. of regression	0.032872	Akaike info criterion	-3.731203

Sum squared resid	0.010806	Schwarz criterion	-3.495186
Log likelihood	32.98402	Hannan-Quinn criter.	-3.733717
F-statistic	0.322079	Durbin-Watson stat	2.710097
Prob(F-statistic)	0.856902		

As you can see that the probability for patents is no longer significant, therefore we rule out this 1 year-lag situation.

In this way, using the smoothed data checking stationary and running regression, I have the summarized tested regression result of the rest cities as follows: (the detailed regression result for each city is put in the appendix section)

	stationary of the variables	Coefficient innovation	Significance	lag(1) coefficient for innovation	significance
Beijing	Y	0.798	Y (10%)	0.496	N(0.467)
Shanghai	Not for population	-0.0574	N(0.58)	-0.003	N(0.97)
Guangzhou	Y	-0.368	N(0.14)	-0.53	Y(0.0042)
Tianjin	Not for population and education expenditure	-0.21	N(0.44)	-0.23	N(0.28)
Wuhan	Y	-0.17	N(0.3075)	0.18	N(0.26)
Chongqing	Y	-0.38	Y(1%)(0.0018)	-0.2	N(0.167)

Where Y stands for Yes of checking stationary and the Significance of regression result, and N stands for No of the significance, for the stationary test, I have marked if the variable is not stationary. In the next section I will analysis this regression result.

After running regression, I looked up with the National Bureau of Statistics of China and find the percentage of different field of innovation in regional level; my first thought is to try to look for specific innovation field such as agriculture, industrial use, biotechnology, etc, however, there is not such data available but just has the general data for the whole country, therefore I collect the data of innovation division based on their application, follows with the result (calculated with 5-year-average percentage):

	Inventions	Utility models	Designs
Beijing	39%	48%	13%
Shanghai	19%	48.70%	32.30%
Guangzhou	14.20%	40%	45.80%
Tianjin	18%	64%	18%
Wuhan	16.60%	58.60%	24.80%
Chongqing	12%	56.40%	31.60%

(Resource: National Bureau Statistics of China, 2000-2012)

In this kind of division, the Inventions are new technical scheme application used for product, method or its improvements; the Utility models are practical newly technical scheme application used for shape of products, structure of products or combination of products; and the Designs refers to beautiful new designs applicable for industrial use based on products' shape, appearance, pattern or their combination and the combination among color, shape, and pattern (translated: Patent Law of the People's Republic of China, 2010 revision), from what I see, these different percentages in different kinds of division of innovation can somehow affect the various steps of economic growth.

7. Statistical analysis

7.1 The first Level cities in China:

As we can see from the above regression result table that only Beijing had reached the requirements for all the stationary of the tested variables and a significant result for innovation on GRP growth, 0.798, the lagged effect of innovation on GRP is not significant; for Shanghai the variable of population is not stationary thereby the regression is spurious and the result is not trustable; Guangzhou, on the other hand, innovation is not significant for the economic growth of the current year, but significant with the result of one year lag, the coefficient is -0.53, which means that the situation of innovation has a negative impact with one year lag on economy happens in Guangzhou with the relationship of -0.53. Though the result of relationship is not totally what I expected, not all first level cites have a significant result on the relationship between innovation and GRP, and some even have negative relationship, we can still analyze and draw some conclusions out of this.

Beijing, as the capital of China, had always been in the leading position in politics, economy, innovation and technology development. From the above regression we can see clearly that innovation does not significantly play a major role for every city's economic growth, although the literature review highlights the significance of innovation, as I mentioned before, there might be the possibility that limited quantity and quality of data resources might somehow bias the regression result. Beijing, the result in this region matches my expectation for this regression, which has a positive and significant result for the regression, which tested there exists a positive relationship between innovation and economy in this region ever since 1995. As mentioned in the theory part that different regions have different capabilities to innovate, it is not surprise to have a result that different a lot on the significance and coefficient of this variable, as for the lagged effect, in the first level cities just Guangzhou had significant result of -0.53. This does in some way matters that in a comprehensive view of economic developing, there are other factors that contribute more to the economic growth and therefore I reject my hypothesis that the cities will always have positive relationships between innovations. While running regressions, there are other variable that is significant for the regression, Guangzhou, for example, education element is positively significant for the regression, which means that capital input of education in this city plays a more crucial role for its economic development, however since this study is to look for the relationship between innovation and economic growth, I do not include other variables for analysis, but this can somehow explain that different cities have different focus of either labor or capital for its economic growth and as I have shown in the background review section, government had put lot of effort in building up high-tech parks, programs in promoting these technological enterprises to develop, which government plays a crucial role in this process; furthermore, by simply looking at the growth rate and innovation growth rate of these three cities, there is not a very clear trend that cities with higher innovation growth rate have a higher economic growth rate. (Averaged growth rate of GRP: Beijing > Guangzhou > shanghai; averaged growth rate of innovation: Shanghai > Guangzhou > Beijing). And for the first level cities and shares of different contributions of innovations, generally we can see that Utility models contributed most in its innovation; for the lagged effect, I think this could be explained by the different innovation focus for different cities, comparing Beijing and Guangzhou, where Beijing has a higher percentage of Inventions and Guangzhou has a higher percentage of Designs of innovation, or, if we can understand in this way that Inventions are usually put into practical production and cause economic boom for the current year while Design takes longer time to activate economy (maybe Designs need more time to put into practical use). On the other hand, the Solow model explains the economic growth through endogenous factor of capital, which is tested for Beijing and Guangzhou. Thus for the first level of cities, my opinion is shown as follows:

1. Except Beijing, it does not necessarily mean that there is always a linear, positive and significant relationship between innovation and economic growth for the three cities I choose in the first level ;
2. Different cities have different labor or capital input for its economic growth in the same level;
3. The application of Utility models take the biggest share among innovations;
4. Furthermore, based on the different focus of innovation field, there might be lagged effect exists between innovation and economic growth for different cities.

7.2 The second level of cities:

For the second level of cities, Tianjin, the variables are not stationary therefore the regression is spurious and not trustable; Wuhan does have a negative coefficient for the current year relationship and positive relationship with one year lag, however neither of them is significant; Chongqing has a negative and significant result for the current year and negative while insignificant result with one year lag. With limitations of data, this regression result for the second level cities is not that total out of expectations. In these cities we can see that it is not always positive and significant relationship exist between innovation and economic growth; similar analysis is as the first level cities, this time there is a clear trend for higher innovation with higher economic growth rate, for innovation: Chongqing > Wuhan > Tianjin; Economic growth rate: Chongqing > Wuhan > Tianjin (the figure are compared in averaged within the whole study period). But this cannot be considered as that there is a linear relationship between innovation and economic growth, after all, the data of observations are too limited, here I can only say that for the second level cities it might be the fact that higher innovation can result in higher economic growth; however I cannot use innovation to explain economic growth after all; by looking at other variables, for example, Chongqing and Tianjin both had strong positive significant result for their population, Wuhan had positive significant result for its other factor contribution (constant), from this point we can see that different focus of input of factors exist among second level cities as well; by looking at percentage shares of different kinds of innovation, Utility models still takes the greatest in general for these second level cities; and since none of these three cities has significant result for their lagged result, it is hard to say that whether it has similar situation to the first level that Designs take more time to impact on economic growth. Thereby for second level cities my conclusion is:

1. I reject my hypothesis that there is always a positive and significant relationship between innovation and economic growth ;
2. For these three second level cities I choose, there is a trend that cities with higher innovation have higher economic growth, but with limited data and not tested regression, I cannot generalize this result to other cities in the second level, this linear trend is mad among these three cities only;
3. Same with the first level cities, the application of Utility Models takes the biggest share in innovations;
4. Different cities have different focus in labor or capital input for its economic growth within the second level.

8. Conclusion

In this study I mainly explore the relationship between innovation and economic growth for different level of cities in China in a quantitative way, from China's economic historical background review; I talked about the significant role of innovation and China's innovation develop process in both national level and regional level, then the different relevant theories are discussed in the theoretical section, followed with research questions, hypothesis, data and regression, and I cite one example to show how I run the regression and summarized regression result for other cities, I separately analyzed my regression result based on different city levels, and end up with my final conclusion. Further in the end, there will be limitation discussion of this study and further possible study suggestions.

For this study research, where I mainly tend to explore the relationship between innovation and economic growth in regional level and try to explain economic growth through the original Solow model, however, due to data limit, I cannot generalize my conclusion but just limit within the target cities I choose, and based on different tiers of cities:

First level cities:

1. It does not necessarily mean that there is a linear, positive and significant relationship between innovation and economic growth, but the Solow growth model is tested for Beijing and Guangzhou;
2. Different cities have different labor or capital input for its economic growth in the same level;
3. The application of Utility models take the biggest share among innovations;
4. Furthermore, based on the different focus of innovation field, there might be lagged effect exists between innovation and economic growth for different cities.

Second level cities:

1. I reject my hypothesis that there is always a positive and significant relationship between innovation and economic growth , the Solow growth model is tested for Chongqing;
2. For these three second level cities I choose, there is a trend that cities with higher innovation have higher economic growth, but with limited data and not tested regression, I cannot generalize this result to other cities in the second level, this linear trend is mad among these three cities;
3. Same with the first level cities, the application of Utility Models takes the biggest share in innovations;
4. Different cities have different focus in labor or capital input for its economic growth within the second level.

9. Limitations of the study and further suggestions:

1. The problem of one city's innovation increase result in another city's economic growth; this problem is similar to the lag problem that with lag effect the impact of innovation on economy is lagged for one year, but I could not solve the city problem due to the data limitation-the impact of innovation in another city than its registered place (which requires more detailed data where the innovation was applied to or spread in specific regions), in my study I have to make the assumption that the place where the innovation is registered is the target city where the innovation product is applied to, so the effect of innovation is signally in that city. If data is available in the further, this could be done with more details and the result would be more precise and reliable.
2. Data's validity reliability; as I discussed in the data section that in China the data system is not that complete and transparent compared to developed world, there will be inevitable data bias, exaggerating, or other issues cause the data not punctual and lead to bias in the study result, but since the data resource I use is the only official statistical data, what we can do is to randomly check the data with other literature resources and trust the data. Here I sincerely wish that the Chinese government could make the system better, increase the availability of data, and make the data resources more transparent.
3. China's economic development is outstanding and remarkable, further study on this topic with innovation and economic growth could be focused on the lagged effect if in the further more data details are available; 1) more lagged effects could run; 2) the impact of different focus of innovation could be further checked; 3) may be the check of different percentage of labor and capital inputs.
4. Qualitatively, government enrollment in the regional innovation process is significant, they not only promote policies for enterprises, URIs, and social institutions to develop, the regional innovation capacity is also greatly improved, for further study, another aspect might be that comparing with the innovation policies among cities to find out common characters and difference, in innovation system one way is to apply successful innovation system to target regions, and this kind of study can help find the most appropriate policies for a city.
5. With this model I build, Solow model can explain long-run economic growth through technology (capital factor), which is exogenous factor, for later research, if data is available, the model could be built on endogenous factor to explore the relationship with "effective workers" and explain the economic growth further away..

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11. Appendix:

Country	1980–90	1990–2000	2000–7
World	3.1	2.9	3.2
China	10.2	10.6	10.3
United States	3.0	3.5	2.6
Japan	4.0	1.1	1.7
United Kingdom	3.2	2.7	2.6
Russia	1.9	−4.7	6.6
India	5.8	5.9	7.8
South Korea	9.4	5.8	4.7
Taiwan	7.9	6.4	3.8
Singapore	6.4	7.6	5.8
Hong Kong	6.9	3.6	5.2
Vietnam	.	7.9	9.8
Botswana	10.3	6.0	5.3

11.1 Beijing:

	Economy（100 million RMB）	innovation(case）	Population(10000 persons）	Education expenditure(100 million RMB）	High-tech zone enterprises output(100 million RMB）
1995	1829.42	4025	1070	84.25561	101
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1997	2134.85	3327	1217	117	272
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2001	2845.65	6246	1122.3	250.3	1986.49
2002	3212.71	6345	1136.3	319	1477
2003	3663	8248	1148.82	354	1607.75
2004	4283.31	9005	1163	393	1873.8
2005	6886.31	10100	1180.7	449	2604.08
2006	7870	11238	1198	523	3449.4
2007	9353.32	14954	1213	337	3850.42
2008	10488.1	17747	1300	408	3805
2009	12153	22921	1246	469	4193
2010	14113.6	33511	1258	529	4988
2011	16251.9	40888	1278	613.44	5832

11.2 Stationary test for variables of Beijing:

Null Hypothesis: GDP has a unit root

Exogenous: None

Lag Length: 0 (Automatic - based on SIC, maxlag=0)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.014855	0.0006
Test critical values:	1% level	-2.728252	
	5% level	-1.966270	
	10% level	-1.605026	

*MacKinnon (1996) one-sided p-values.

Warning: Probabilities and critical values calculated for 20 observations

and may not be accurate for a sample size of 15

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(GDP)

Method: Least Squares

Date: 05/11/13 Time: 13:01

Sample (adjusted): 1997 2011

Included observations: 15 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP(-1)	-1.071580	0.266904	-4.014855	0.0013

R-squared	0.535176	Mean dependent var	9.49E-05
Adjusted R-squared	0.535176	S.D. dependent var	0.050017

S.E. of regression	0.034100	Akaike info criterion	-3.854677
Sum squared resid	0.016280	Schwarz criterion	-3.807473
Log likelihood	29.91007	Hannan-Quinn criter.	-3.855179
Durbin-Watson stat	1.953783		

Null Hypothesis: PATENTS has a unit root

Exogenous: None

Lag Length: 0 (Automatic - based on SIC, maxlag=0)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.021654	0.0447
Test critical values:	1% level	-2.728252	
	5% level	-1.966270	
	10% level	-1.605026	

*MacKinnon (1996) one-sided p-values.

Warning: Probabilities and critical values calculated for 20 observations

and may not be accurate for a sample size of 15

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(PATENTS)

Method: Least Squares

Date: 05/11/13 Time: 13:14

Sample (adjusted): 1997 2011

Included observations: 15 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.

PATENTS(-1)	-0.438395	0.216850	-2.021654	0.0628

R-squared	0.211989	Mean dependent var	0.002880
Adjusted R-squared	0.211989	S.D. dependent var	0.022186
S.E. of regression	0.019695	Akaike info criterion	-4.952606
Sum squared resid	0.005430	Schwarz criterion	-4.905402
Log likelihood	38.14454	Hannan-Quinn criter.	-4.953109
Durbin-Watson stat	2.056192		

Null Hypothesis: POPULATION has a unit root

Exogenous: None

Lag Length: 0 (Automatic - based on SIC, maxlag=0)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.121071	0.0005
Test critical values:	1% level	-2.728252	
	5% level	-1.966270	
	10% level	-1.605026	

*MacKinnon (1996) one-sided p-values.

Warning: Probabilities and critical values calculated for 20 observations

and may not be accurate for a sample size of 15

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(POPULATION)

Method: Least Squares

Date: 05/11/13 Time: 13:15

Sample (adjusted): 1997 2011

Included observations: 15 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
POPULATION(-1)	-1.098755	0.266619	-4.121071	0.0010

R-squared	0.548119	Mean dependent var	7.61E-05
Adjusted R-squared	0.548119	S.D. dependent var	0.010906
S.E. of regression	0.007331	Akaike info criterion	-6.929050
Sum squared resid	0.000752	Schwarz criterion	-6.881846
Log likelihood	52.96787	Hannan-Quinn criter.	-6.929552
Durbin-Watson stat	1.627273		

Null Hypothesis: EDUCEXP has a unit root

Exogenous: None

Lag Length: 0 (Automatic - based on SIC, maxlag=0)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.510993	0.0160
Test critical values:	1% level	-2.728252	
	5% level	-1.966270	
	10% level	-1.605026	

*MacKinnon (1996) one-sided p-values.

Warning: Probabilities and critical values calculated for 20 observations

and may not be accurate for a sample size of 15

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(EDUCEXP)

Method: Least Squares

Date: 05/11/13 Time: 13:15

Sample (adjusted): 1997 2011

Included observations: 15 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
EDUCEXP(-1)	-0.619821	0.246843	-2.510993	0.0249

R-squared	0.310516	Mean dependent var	-7.11E-05
Adjusted R-squared	0.310516	S.D. dependent var	0.043340
S.E. of regression	0.035987	Akaike info criterion	-3.746963
Sum squared resid	0.018131	Schwarz criterion	-3.699759
Log likelihood	29.10222	Hannan-Quinn criter.	-3.747465
Durbin-Watson stat	2.252180		

Null Hypothesis: HIGHTECH has a unit root

Exogenous: None

Lag Length: 0 (Automatic - based on SIC, maxlag=0)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.066401	0.0047
Test critical values:	1% level	-2.728252	
	5% level	-1.966270	
	10% level	-1.605026	

*MacKinnon (1996) one-sided p-values.

Warning: Probabilities and critical values calculated for 20 observations and may not be accurate for a sample size of 15

Augmented Dickey-Fuller Test Equation

Dependent Variable: D(HIGHTECH)

Method: Least Squares

Date: 05/11/13 Time: 13:16

Sample (adjusted): 1997 2011

Included observations: 15 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
HIGHTECH(-1)	-0.536120	0.174837	-3.066401	0.0084

R-squared	0.385926	Mean dependent var	-0.008500
Adjusted R-squared	0.385926	S.D. dependent var	0.054042
S.E. of regression	0.042349	Akaike info criterion	-3.421416
Sum squared resid	0.025108	Schwarz criterion	-3.374213
Log likelihood	26.66062	Hannan-Quinn criter.	-3.421919
Durbin-Watson stat	2.475121		

11.3 Shanghai

	Economy（100 million RMB）	innovation（case）	Population(10000 persons）	Educational expenditure(100 million RMB）	High-tech zone enterprises output(100 million RMB）
1995	4529.93	1436	1301	89.54886934	89
1996	5246.8	1610	1304	99	88
1997	5854	1886	1305	121	120
1998	5756.5	2334	1306.58	122	357
1999	5659	3665	1313.12	150.3	549
2000	6204.52	4050	1321.63	174	675
2001	4950.84	5371	1327.14	201	939.42
2002	5408.76	6695	1334.23	232	944
2003	6250.81	16671	1341.77	274	1236
2004	7450.27	10625	1352	307	1771.06
2005	9154.18	12603	1360.26	383	2254
2006	10366.37	16602	1368	423	2430
2007	12188.85	24481	1379	371	2661
2008	13698.2	24468	1391	432	2790.8
2009	15047	34913	1400	482	3374
2010	17166	48215	1412	494	3772.2
2011	19195.7	47960	1419	558.21	4032

11.3.1 Regression result for Shanghai

Dependent Variable: GRP

Method: Least Squares

Date: 05/21/13 Time: 11:55

Sample: 1996 2011

Included observations: 16

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.012108	0.016911	0.716023	0.4889
PATENTS	-0.057438	0.102831	-0.558565	0.5876
POPULATION	3.765868	13.93801	0.270187	0.7920
EDUCEXP	-0.028338	0.219604	-0.129042	0.8997
HIGHTECH	-0.069765	0.076688	-0.909732	0.3825

R-squared	0.196671	Mean dependent var	0.010008
Adjusted R-squared	-0.095449	S.D. dependent var	0.011679
S.E. of regression	0.012224	Akaike info criterion	-5.720594
Sum squared resid	0.001644	Schwarz criterion	-5.479160
Log likelihood	50.76475	Hannan-Quinn criter.	-5.708230
F-statistic	0.673253	Durbin-Watson stat	1.629287
Prob(F-statistic)	0.624210		

11.3.2 Regression with one year lag:

Dependent Variable: GRP

Method: Least Squares

Date: 05/21/13 Time: 11:58

Sample (adjusted): 1997 2011

Included observations: 15 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.003719	0.019259	0.193087	0.8508
PATENTS(-1)	-0.003114	0.115995	-0.026845	0.9791

POPULATION	10.42089	17.34140	0.600926	0.5613
EDUCEXP	-0.024792	0.227847	-0.108810	0.9155
HIGHTECH	-0.039877	0.091727	-0.434735	0.6730

R-squared	0.189423	Mean dependent var	0.009511
Adjusted R-squared	-0.134808	S.D. dependent var	0.011913
S.E. of regression	0.012691	Akaike info criterion	-5.634719
Sum squared resid	0.001610	Schwarz criterion	-5.398703
Log likelihood	47.26040	Hannan-Quinn criter.	-5.637233
F-statistic	0.584222	Durbin-Watson stat	1.634458
Prob(F-statistic)	0.681339		

11.4 Guangzhou

	Economy（100 million RMB）	innovation（case）	Population(10000 persons）	Educational expenditure(100 million RMB）	High-tech zone enterprises output(100 million RMB）
1995	1849.49	4611	647	217.8553132	21
1996	2211.48	5273	656	225	34
1997	2526.2	7173	666	240	48
1998	2510.5	10707	674.14	248	44
1999	2494.8	14328	685	273	55
2000	2568.57	15799	700.69	295	82.5
2001	2685.75	18259	712.6	314	268
2002	3001.47	22761	720.62	361	259
2003	3496.87	29235	725.19	520	423
2004	4115.8	31446	738	622	613.62

2005	5154.23	36894	750.53	709	728.58
2006	6074	43516	761	807	988
2007	7109.18	56451	773	865	1213
2008	8215.8	62031	784	1073	1421.06
2009	9138	83621	795	1166	1882
2010	10748.3	119343	806	1284.3	2689.45
2011	12423.4	128413	815	1533	3223

11.4.1 Regression result for Guangzhou

Dependent Variable: GRP

Method: Least Squares

Date: 05/21/13 Time: 12:03

Sample: 1996 2011

Included observations: 16

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.034869	0.019360	1.801032	0.0991
PATENTS	-0.368649	0.238053	-1.548600	0.1498
POPULATION	-5.491286	5.742837	-0.956197	0.3595
EDUCEXP	-0.015340	0.230563	-0.066534	0.9481
HIGHTECH	-0.008053	0.032349	-0.248945	0.8080

R-squared	0.269132	Mean dependent var	0.014237
Adjusted R-squared	0.003362	S.D. dependent var	0.008246
S.E. of regression	0.008232	Akaike info criterion	-6.511163
Sum squared resid	0.000746	Schwarz criterion	-6.269729
Log likelihood	57.08930	Hannan-Quinn criter.	-6.498799
F-statistic	1.012650	Durbin-Watson stat	1.204191

Prob(F-statistic)	0.442186

11.4.2 Regression with one year lag:

Dependent Variable: GRP

Method: Least Squares

Date: 05/21/13 Time: 12:06

Sample (adjusted): 1997 2011

Included observations: 15 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.014436	0.009585	1.506009	0.1630
PATENTS(-1)	-0.530775	0.143877	-3.689094	0.0042
POPULATION	3.270871	3.557482	0.919434	0.3795
EDUCEXP	0.320122	0.137998	2.319753	0.0428
HIGHTECH	-0.049200	0.024985	-1.969202	0.0772

R-squared	0.658311	Mean dependent var	0.013602
Adjusted R-squared	0.521635	S.D. dependent var	0.008121
S.E. of regression	0.005617	Akaike info criterion	-7.264959
Sum squared resid	0.000315	Schwarz criterion	-7.028942
Log likelihood	59.48719	Hannan-Quinn criter.	-7.267473
F-statistic	4.816592	Durbin-Watson stat	1.579731
Prob(F-statistic)	0.019988		

11.5 Tianjin

	Economy （ 100 million RMB）	innovation （case）	Population(10000 persons）	Educational expenditure(100 million RMB）	High-tech zone enterprises output(100 million RMB）
1995	2012.9	1034	895	32.93969119	40
1996	2664.71	899	898	36	86
1997	2987.03	940	900	43	123.05
1998	2700.8469	1042	905.09	43	152.4
1999	2414.6638	1508	910.17	51	196
2000	2127.3819	1611	912	58	275
2001	1840.1	1829	913.98	69	383
2002	2051.16	1827	919.05	86	416.64
2003	2447.66	2505	926	98	482.09
2004	2931.88	2578	933	112	598.67
2005	3697.62	3045	939.31	124	627.44
2006	4359.15	4159	949	148	781.36
2007	5050.4	5584	959	143	941.57
2008	6354.4	6790	969	166	1321.9
2009	7522	7404	980	206	1568.46
2010	9224.5	11006	985	238	1845
2011	11307.3	13982	996	292.1	1923

11.5.1 Regression result for Tianjin

Dependent Variable: GRP

Method: Least Squares

Date: 05/21/13 Time: 12:10

Sample: 1996 2011

Included observations: 16

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.016125	0.019914	-0.809743	0.4353
PATENTS	-0.211738	0.269261	-0.786364	0.4483
POPULATION	26.75277	10.51897	2.543288	0.0273
EDUCEXP	0.062423	0.272908	0.228734	0.8233
HIGHTECH	0.115010	0.118387	0.971471	0.3522

R-squared	0.392736	Mean dependent var	0.013010
Adjusted R-squared	0.171913	S.D. dependent var	0.017879
S.E. of regression	0.016270	Akaike info criterion	-5.148670
Sum squared resid	0.002912	Schwarz criterion	-4.907236
Log likelihood	46.18936	Hannan-Quinn criter.	-5.136307
F-statistic	1.778508	Durbin-Watson stat	1.581596
Prob(F-statistic)	0.203362		

11.5.2 Regression with one year lag

Dependent Variable: GRP

Method: Least Squares

Date: 05/21/13 Time: 12:12

Sample (adjusted): 1997 2011

Included observations: 15 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000247	0.018592	0.013309	0.9896

PATENTS(-1)	-0.234356	0.206061	-1.137312	0.2819
POPULATION	21.04998	10.65768	1.975101	0.0765
EDUCEXP	0.109831	0.233650	0.470067	0.6484
HIGHTECH	-0.244223	0.217202	-1.124403	0.2871

R-squared	0.538518	Mean dependent var	0.011420
Adjusted R-squared	0.353925	S.D. dependent var	0.017295
S.E. of regression	0.013901	Akaike info criterion	-5.452447
Sum squared resid	0.001933	Schwarz criterion	-5.216430
Log likelihood	45.89335	Hannan-Quinn criter.	-5.454961
F-statistic	2.917331	Durbin-Watson stat	1.933388
Prob(F-statistic)	0.077287		

11.6 Wuhan

	Economy (100 million RMB）	innovation(cases）	Population(10 000 persons）	Educational expenditure(100 million RMB）	High-tech zone enterprises output(100 million RMB）
1995	871.7457	432	710	103.0149504	21
1996	1122.4985	324	716	102	64
1997	1275.5088	260	724	100	95
1998	1073.6232	403	731.79	111	106
1999	871.7376	597	740.20	142	153.8
2000	1109.7701 5	1019	749.19	154	213.35
2001	1347.8027	1038	758.23	171	333.58

2002	1492.7435	1057	768.1	199	313.2
2003	1662.1797	1194	781.19	230	376.8
2004	1956	1559	786	253	493.73
2005	2238	1945	801.36	299	629
2006	2590.7569	2382	819	339	889.42
2007	3141.9048	2855	828	290.5	1156
2008	3960.1	4044	833	369	1574.33
2009	4621	4812.975646	836	452	1975.5
2010	5565.9	5250.672401	837	519.44	2508
2011	6762.2	5484.228634	856	587	3191

11.6.1 Regression result for Wuhan:

Dependent Variable: GRP

Method: Least Squares

Date: 05/21/13 Time: 12:14

Sample: 1996 2011

Included observations: 16

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.028443	0.013901	2.046178	0.0654
PATENTS	-0.172403	0.161110	-1.070099	0.3075
POPULATION	-1.261680	5.189948	-0.243101	0.8124
EDUCEXP	-0.277714	0.281670	-0.985956	0.3453
HIGHTECH	0.002106	0.065884	0.031972	0.9751

R-squared	0.289181	Mean dependent var	0.016817
Adjusted R-squared	0.030701	S.D. dependent var	0.018362
S.E. of regression	0.018078	Akaike info criterion	-4.937985

Sum squared resid	0.003595	Schwarz criterion	-4.696551
Log likelihood	44.50388	Hannan-Quinn criter.	-4.925621
F-statistic	1.118777	Durbin-Watson stat	1.564202
Prob(F-statistic)	0.396331		

11.6.2 Regression with one year lag

Dependent Variable: GRP

Method: Least Squares

Date: 05/21/13 Time: 12:15

Sample (adjusted): 1997 2011

Included observations: 15 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.028790	0.015535	1.853266	0.0935
PATENTS(-1)	0.182147	0.153414	1.187292	0.2625
POPULATION	-0.729076	5.328978	-0.136814	0.8939
EDUCEXP	-0.517990	0.295785	-1.751237	0.1105
HIGHTECH	-0.112166	0.200315	-0.559948	0.5878

R-squared	0.252219	Mean dependent var	0.015449
Adjusted R-squared	-0.046893	S.D. dependent var	0.018142
S.E. of regression	0.018563	Akaike info criterion	-4.874124
Sum squared resid	0.003446	Schwarz criterion	-4.638107
Log likelihood	41.55593	Hannan-Quinn criter.	-4.876638
F-statistic	0.843225	Durbin-Watson stat	1.844638
Prob(F-statistic)	0.528678		

11.7 Chongqing

	Economy（100 million RMB）	innovation（case）	Population(10000 persons）	Educational expenditure(100 million RMB）	High-tech zone enterprises output(100 million RMB）
1995	1076.95	217.66	1520.00	38.14	14.00
1996	1235.07	252.30	1530.00	40.00	31.00
1997	1766.38	339.00	3043.00	44.00	54.00
1998	1520.91	612.00	3059.69	44.00	85.00
1999	1275.43	1078.00	3072.34	53.00	99.00
2000	1512.60	1158.00	3091.09	60.00	157.40
2001	1749.77	1197.00	3097.91	70.00	293.00
2002	1971.30	1761.00	3113.83	87.00	334.00
2003	2250.56	2883.00	3130.10	107.00	512.00
2004	2665.39	3601.00	3144.00	121.00	305.00
2005	3070.49	3591.00	3169.16	143.00	716.30
2006	3491.57	4590.00	3199.00	173.00	841.00
2007	4122.51	4994.00	3235.00	168.00	1189.00
2008	5096.70	4820.00	3257.00	231.00	1646.82
2009	6530.00	7501.00	3276.00	266.00	612.00
2010	7925.60	12080.00	3303.00	331.00	687.00
2011	10011.40	15525.00	3330.00	407.00	1007.29

11.7.1 Regression result for Chongqing

Dependent Variable: GRP

Method: Least Squares

Date: 05/21/13 Time: 12:17

Sample: 1996 2011

Included observations: 16

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.031602	0.007924	3.988250	0.0021
PATENTS	-0.383249	0.093845	-4.083837	0.0018
POPULATION	0.494003	0.127871	3.863301	0.0026
EDUCEXP	0.004032	0.163094	0.024723	0.9807
HIGHTECH	-0.044852	0.030766	-1.457808	0.1728

R-squared	0.711865	Mean dependent var	0.017614
Adjusted R-squared	0.607089	S.D. dependent var	0.017469
S.E. of regression	0.010950	Akaike info criterion	-5.940634
Sum squared resid	0.001319	Schwarz criterion	-5.699200
Log likelihood	52.52508	Hannan-Quinn criter.	-5.928271
F-statistic	6.794137	Durbin-Watson stat	1.248801
Prob(F-statistic)	0.005240		

11.7.2 Result with one year lag

Dependent Variable: GRP

Method: Least Squares

Date: 05/21/13 Time: 12:18

Sample (adjusted): 1997 2011

Included observations: 15 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.020683	0.010959	1.887383	0.0884
PATENTS(-1)	-0.204431	0.134934	-1.515047	0.1607
POPULATION	0.413868	0.194977	2.122646	0.0598
EDUCEXP	0.112392	0.240028	0.468245	0.6496
HIGHTECH	-0.039368	0.058506	-0.672891	0.5163

R-squared	0.449981	Mean dependent var	0.017480
Adjusted R-squared	0.229974	S.D. dependent var	0.018074
S.E. of regression	0.015860	Akaike info criterion	-5.188846
Sum squared resid	0.002515	Schwarz criterion	-4.952829
Log likelihood	43.91635	Hannan-Quinn criter.	-5.191360
F-statistic	2.045299	Durbin-Watson stat	1.771291
Prob(F-statistic)	0.163591		