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The Impact of Population Change in China

Thesis presented by

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DECLARATION

This is to certify that the work I am submitting is my own and has not been submitted for another degree, either at University College Cork or elsewhere. All external references and sources are clearly acknowledged and identified within the contents. I have read and understood the regulations of University College Cork concerning plagiarism.

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ABSTRACT

China initiated its population control policy (One-Child Policy) in 1978 to ease the pressure of population growth, and implemented supporting policies in education and public health to improve population quality in each 'Five-Year Plan' since 2001. Considering the possible different impacts of population on economic growth, this thesis systematically examines the impacts of population changes in both quantity and quality on economic growth in China based on population quantity and quality policies.

Chapter One briefly introduces the background, rationale, data sources and thesis structure. Chapter Two provides an overview of the theoretical and empirical literatures on the impacts of population quantity changes on economic growth for provincial-level data (29 provinces) in China, from 1985 to 2013. Chapter Three focuses on population quality, which highlights that different definitions coincide with different research techniques, and also outlines key education and public health policies pursued in China over the period 1995 to 2015. Chapter Four identifies three cities selected for detailed analysis of population quality with some preliminary descriptive data analysis. The methods of index construction to produce indexes of population quality (based on education and health) for the three selected cities are also introduced and applied. In Chapter Five, using most up-to-date econometric techniques, the effect of population quality on economic growth is estimated, building on the themes of education and health presented in earlier chapters.

Tentative policy recommendations are put forward in Chapter Six drawing on the empirical estimation results from preceding chapters. Some limitations of this thesis and some suggestions for future research potential are also provided. Although increases in the non-agricultural population and working-age population can drive economic growth, total population growth remains a substantial barrier to economic growth in China. Improving population quality (measured as the education and health levels) is found to contribute to China's economic growth in the long-term.

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CHAPTER 1: INTRODUCTION

1.1 Introduction

The aim of this research is to explore aspects of the relationship between population, labour-force, and economic growth in China. There are three separate themes that generate three contributions from this research.

1. The nature and extent of the relationship between population - in quantity terms - and economic growth is investigated at province level for 29 Chinese provinces over the period 1985-2013.
2. The policy context that has underpinned Chinese economic development over the past two decades (in relevant 'Five-Year-Plans') is examined in detail as it relates to policies with potential impacts on population quality specifically through education and health.
3. The nature and extent of the relationship between population – in quality terms – and economic growth is investigated for three selected cities (Lanzhou, Guiyang and Beijing) using a specially created index of population quality, estimated using indicators of education and health status.

Few studies exist that examine the relationship between population and economic growth from a regional perspective. This research by including province-level investigations contribute to understanding the variation of the population/growth relationship pointing to regional differences as worthy of analysis. Further, the techniques used are the most up-to-date methods for investigating panel-level data.

To address the gap in related examinations of population-growth relationships, it was necessary to undertake a detailed consideration of the policy background. The research reviewed the key 'Five-Year-Plans' [1] to identify the relevant policies relating to

[1] Source: The Outlines of the 'Tenth Five-Year Plan', (2001), [online], available at:

population development. This facilitated identification of a range of relevant indicators, relating to education and health, to be included in empirical estimations.

The construction of two indexes to capture population quality is novel in this research as most existing studies employ either a few indicators or a single index in considering population quality. This research, however, creates an education index and a health index using multiple indicators, drawing on policy considerations arising from the review of several Five-Year-Plans.

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https://max.book118.com/html/2018/0331/159524223.shtm.
The Outlines of the 'Eleventh Five-Year Plan', (2006) [online], available at: http://www.chinanews.com/news/2006/2006-03-16/8/704064.shtml.
The Outlines of the 'Twelfth Five-Year Plan', (2011) [online], available at: http://zxjxqk.paperopen.com/docs/xwdt/details.aspx?documentid=35.
The Outlines of the 'Thirteenth Five-Year Plan', (2016) [online], available at: http://www.12371.cn/special/sswgh/.

1.2 Research Rationale

The relationship between population growth and economic growth is a topic that attracts both demographers and economists but a common understanding of the relationship has yet to emerge. As the discussion of Yao, Kinugasa and Hamori (2013: 1) indicates, “population policies have significant long-term impacts on populations and economies, and national governments have been beleaguered by problems surrounding the question of how to implement population policies that are rational”.

Population change in China is controlled by government policies which may have different effects at different stages on economic growth. At the beginning of the 1950s, China had a baby boom in population, encouraged in the past by the Chinese government prohibiting birth control and abortions for all women in 1952. In the years 1950 to 1980, the Chinese population increased dramatically and the total population was over 1 billion in 1980, which is a domestic bonus to economic growth (Yao, Kinugasa and Hamori, 2013).

The Chinese economy has experienced rapid growth since its economic reform in the late 1970s. The average annual GDP growth rate has been around 8%[2] in the period between 1979 and 1983. The Chinese economy is one of the fastest growing economies in the world and China is emerging as an economic power (Feng and Zhang, 2018; Yao, Kinugasa and Hamori, 2013; Bonnefond, 2015). It is argued that a large population may provide labour necessary for economic growth in China, while it might also generate a burden to economic growth over the longer-term (Li and Huang, 2009).

As a result, the Chinese government adopted a population control policy in 1980 to limit population growth because it was felt that the uncontrolled population was a burden to the development of China in future (Yao, Kinugasa and Hamori, 2013). Based

[2] Based on data from the database of the National Bureau of Statistics of China, available at: http://www.stats.gov.cn.

on the population control policy, even though the Chinese total population increased from 987 million to 1,361 million, the total fertility rate[3] declined from 2.7 in 1980 to 1.7 in 2011[4]. At the same time in 1980, the Chinese government published its Opening Up policy[5] to stimulate economic growth, which would benefit from the demographic bonus. Abundant and cheap labour attracted multinationals to set up their companies in the southern provinces in China like Guangdong (Sun, 2013). The Chinese economy entered a high growth phase, driven by significant capital investment and sufficient human resources so that the GDP per capita in China increased from $193 in 1980 to $9,700 in 2012[6]

Growth of the economy improved living standards and labour income, but also increased labour costs in China (Feng and Zhang, 2018). Increasingly, multinationals are choosing other countries with lower labour costs in their location decisions. Domestic factories and companies in China generated significant profits from cheaper and original equipment manufacturing (OEM) rather than the R&D as a source of competitive advantage (He, 2008). Based on this development, the Chinese government supported the development of innovation-based industries in an attempt to reduce dependence of foreign investment and technology. It is argued that high quality labour is needed to support the modern Chinese economy (Huo, 2011).

A further complication arises when there is imbalance in population quality between regions in China. A gap in quality exists between more-and less-developed regions. Policies have attempted to address this - specifically, the 10th. 11th and 12th Five-Year Plans - by focusing on education and health in order to support economic growth and development and address the population flows to the more developed areas (Sun, 2013).

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[3] The total fertility rate represents the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children in accordance with current age-specific fertility rates.
[4] Source: http://data.stats.gov.cn/workspace/index;jsessionid=D4A73B12A9626DE953821ECC98CB8901?m=fsnd, (the National Bureau of Statistics of China)
[5] Opening up policy is established from 1978 and the policy proposed to keep China open to trade with all countries on an equal basis, keeping any one power from total control of the country, and calling upon all powers, within their spheres of influence (Ding and Meng, 2017).
[6] Source: http://data.worldbank.org/indicator/NY.GDP.PCAP.CD (World Bank Database)

The empirical estimations conducted in this research provide some, albeit limited, evidence of the differential impact of these policies across three cities at different stages of development.

The issues examined in this thesis might also help Chinese government in its efforts for international business and FDI as it competes with other locations. Endogenous perspective where each country's growth is contingent not only on the factors in its Solow growth model context, such as labor and capital, but also in geopolitical factors of other and especially neighbouring and competing countries. Based on the above backgrounds of China, Li (2012) and Wu (2019) et., al still argue that countries in the Southeast Asia, such as Vietnam cannot replace China as the main manufacturing provider in the world especially in high-tech manufacturing. The issues and results of this thesis provide rational evidence of the advantage and disadvantage of population changes for Chinese government that might be useful to the further targeting policy editing combining the status of neighbouring and competing countries to take advantage in global business.

1.3 Data Overview

For the first part of the analysis (Chapter Two), 29 provinces are selected for analysis. Sichuan, Chongqing, Hong Kong, Macao and Taiwan are not included in the analysis because of missing data over several years. Data concerning Chongqing as a province created in 1997, were incorporated in the data for Sichuan that leads to a significant change in the data for Sichuan after 1997. Hong Kong and Macao have been set as Special Administrative Regions of China since the 1997 and 1999. Considering the possibility of different data collection methods and the lack of data, Taiwan and Hong Kong are dropped in this research. Key data sources are the National Bureau of Statistics of China, the Statistics Yearbook of each selected province and The Population & Employment Statistics Yearbook 1988-2013.

Table 1.1: Research Data Source Lists

Data Source Name	Time Period	Source
National Bureau of Statistics of China	1985-2013	URL: http://www.stats.gov.cn
Statistics Yearbook of 29 provinces	1988-2013	Online source: https://www.cnki.net Offline source: National Library of China
China Population & Employment Statistics Yearbook	1988-2013	Online source: https://www.cnki.net Offline source: National Library of China
Statistical Yearbooks of Lanzhou, Guiyang and Beijing	1996-2016	Online source: https://www.cnki.net Offline source: National Library of China

For the analyses of city level data, detailed health and education indicators were constructed and a set of control variables were also employed. For these analyses, data was collected from the website of the website of National Bureau of Statistics of China and the Statistics Yearbook of each province 1985-2013. Data for the detailed education and health indicators for index construction was collected from the Statistical Yearbooks of Lanzhou, Guiyang and Beijing, 1996-2016. All data sources are listed in the following table. Most of the research data after 1995 was collected from online sources. Data before 1995 were collected from multiple paper versions, accessed in China, from Statistics Yearbooks in National Library of China.

1.4 Structure of Thesis

The Thesis is structured into six Chapters

Chapter Two is an important Chapter serving many purposes. It provides an overview of the theoretical and empirical literature underpinning research into the sources of economic growth and the role of population and labour-force therein. Theoretical and empirical literature are considered. The main theoretical foundation of such research, the Solow model, is outlined. The specific model used in this research is set out with a discussion of data and modelling considerations. Findings are discussed in relation to time-series analyses of province-level relationships identified between economic growth and its sources with particular focus on population and labour-force considerations (focusing on quantity).

Chapter Three serves as a bridging chapter to link Chapters Two and Four with two main goals. One of the main goals of Chapter Three is to provide a review of key studies that incorporate population quality, which highlights that different definitions coincide with different research techniques. This includes an overview of definition, research methods and empirical results. Another key goal of this Chapter is to outline key education and public health policies pursued in China over the period 1995 to 2015. This is important because it provides a contextual backdrop to the empirical analyses which follow in Chapters Four and Five.

In Chapter Four, the first objective is to introduce the three cities selected for analysis. The second objective is to describe the data and present some preliminary descriptive data analysis. The third objective is to outline and apply methods of index construction to produce indexes of population quality for the three selected cities, which represent a significant contribution of this research.

Chapter Five presents the key empirical results of the research. Using up-to-date econometric techniques, the relationship between population quality and economic growth is examined, building on the themes of education and health presented in earlier chapters. Differential impacts across the three selected cities are identified and explained. The structure of Chapter Five reflects the aim to provide a step-by-step consideration of what can be considered robust and reliable results.

Conclusions are presented in Chapter Six. Tentative policy recommendations are put forward drawing on the empirical estimation results from the preceding Chapters. The final section identifies some limitations of the research with some suggestions for future research potential.

CHAPTER 2: EFFECTS OF POPULATION CHANGE ON GDP GROWTH IN CHINA

2.1 Introduction

This chapter focuses on the effect of population growth on economic growth in China. The analysis is undertaken at regional level based on data collected for 29 provinces over the period from 1985-2013. The main question addressed in this chapter is *How has population growth affected economic development in 29 provinces in China from 1986-2013?*

The relationship between population growth and economic growth has been of interest to many researchers in the past. Malthus (1798) and Boserup (1965) are two of the early writers to explore the impact of population on an economy. The Malthusian paradigm explained that the speed of population growth and technological development are the key determinants of population's impact on economic growth. If the speed of technological development is faster than population growth in society, peoples' quality of life will be improved; otherwise peoples' quality of life will decline (Malthus, 1798). However, Boserup (1965) argued that a high level of population growth can also improve economic development through its effect on capital and technology development. Another strand to the literature distinguishes between child population and adult population, i.e. population structure. It is argued that these two different components of population generate different potential outcomes for economic growth.

At the beginning of the 1950s, China experienced a baby boom, encouraged by the government prohibiting birth control for all women in 1952. In the years 1950 to 1980, the Chinese population increased dramatically and the total population was over 1 billion in 1980 (Yao, Kinugasa and Hamori, 2013). As a result, the Chinese government adopted a population control policy in 1980 to limit population growth because it was felt that the high population was a burden to the development of China. Based on the population control policy, even though the Chinese population increased from 987.05 million to 1360.72 million, the total fertility rate[7] declined from 2.7 in 1980 to 1.7 in 2011[8]. At the same time in 1980, the Chinese government published the opening up policy[9] to stimulate economic growth. Abundant and cheap labour attracted many multinationals to set up operations in the southern provinces of China, such as Guangdong (Yao, Kinugasa and Hamori 2013 please add further references). The Chinese economy enjoyed high growth driven by significant foreign investment and sufficient human resources so that the GDP per capita increased from $193 in 1980 to $6188 in 2012[10].

Within the above context, there are two main contributions of this chapter. First, this chapter expands on and builds on related studies in terms of the population-growth relationship to identify the current research themes and approaches. Empirical research focusing on studies of the Chinese economy as well as other countries is discussed.

Recent data is used and the focus of research area is expanded. For example, Yao, Kinugasa and Hamori (2013) examined the relationship between economic development and population growth in China using country level data from 1952-2007. In this Chapter a regional focus extends this research and data for 29 provinces (1985 to 2013) is used to explore the effect of population growth on economic growth across different provinces in China.

Second, this chapter employs up-to-date panel data methods and techniques to explore the population-growth relationship, and also includes additional explorative variables in. For example, the fixed effects model is used to empirically examine the relationship

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[7] The Total fertility rate represents the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children in accordance with current age-specific fertility rates.

[8] Source: http://data.stats.gov.cn/workspace/index;jsessionid=D4A73B12A9626DE953821ECC98CB8901?m=fsnd, (the National Bureau of Statistics of China)

[9] The opening up policy was established from 1978 and the policy proposed to keep China open to trade with all countries on an equal basis, keeping any one power from total control of the country, and calling upon all powers, within their spheres of influence (Bonnefond, 2015).

[10] Source: http://data.worldbank.org /indicator/NY.GDP.PCAP.CD (World Bank Database)

between population change and economic growth. This approach differs to that employed, for example, in Yao, Kinugasa and Hamori (2013) since a panel of data are used to consider the 29 provinces. This study advances their contribution by using province level data employing different modeling techniques including the System GMM approach.

The Chapter is structured as follows. Section 2.2 identifies the main perspectives and hypotheses proposed in the literature regarding the relationship between population and economic growth. The general model used in related studies is the Solow Growth Model (Solow, 1956) and this is introduced. This sub-section also highlights findings from across a range of studies of the relationship between economic growth and population categorizing these into research without a focus on China and China-oriented studies. Section 2.3 describes the main data sources used in this Chapter and presents some initial trends in the main variables used in the analysis. In Section 2.4, approaches for the current research, the research model and methods are explored. Section 2.5 provides the results of estimating the economic growth and population models. Results of hypotheses testing are provided. In Section 2.6, the main results are identified and discussed.

2.2 REVIEW OF SUPPORTING LITERATURE

In this section, the literature underpinning the relationship between population growth and economic growth is discussed. The review is discussed under three headings: theoretical literature, theoretical model (Solow Model), and empirical literature.

2.2.1 Theoretical Literature

Controversy still exists among the different schools of economics about the nature of the relationship between population growth and economic growth.

Perspective One

Malthus (1798) is a key early writer in this area who argues that population growth can hinder economic growth. Supporters of Malthus' view believe that population growth is related to technology development in society. If population growth is greater than the rate of technology development, the economy will decline (Malthus, 1798). Malthus (1798) put forth that economic growth increased people's income to stimulate an early marriage rate and fertility rate; but high population growth hinders economic growth by diminishing the marginal productivity of labour. Malthus (1798) also argued that population growth is limited by subsistence because population grows geometrically but subsistence grows arithmetically. This is the reason why population growth can lead to economic decline.

Yamaguchi (1973) supports the view of Malthus (1798). He argued that population growth has negative and direct effects on economic growth because it can reduce income per capita; but he also believed that population growth has an indirect but positive effect on economic growth by accelerating technological development. Other supporters of the negative relationship between population growth and economic growth include Barlow (1994) and Kelley and Schimidt (1995).

Perspective Two

Based on the Solow Growth model (discussed further later), population growth has a negative effect on economic growth but the *amount* of labour has a positive effect on economic growth. Kuznets (1966, 1973) argued that population growth has negative effects on income per capita, but has a positive effect on economic growth because population growth can provide enough labour to countries where the economy is highly dependent on labour-intensive industry. In addition, Boserup (1965) argued that population growth can also lead the development of technology by stimulating investment and consumption. Birdsall (1977) noted that population growth stimulates demand that drives consumption and investment and also provides high quality labour and technology.

Lucas (1988) argued that investment in labour (human capital development) is the key factor of economic growth rather than technology development. Because investment in labour has positive externality or spillover effects, it may generate increasing returns in a country to push economic growth. In other words, Lucas (1988) also argues that the externality effects of human capital accumulation mean that workers with equal ability can earn higher wages in a country with a higher average wage rate. This is basic reason for labour mobility. It also explains labour mobility from developing to developed countries. High quality labour can be seen as the basis of a country's development and a developed country with a higher average wage rate can attract high quality labour to develop its economy even further. Based on Lucas' (1988), population growth, especially when accompanied by investment in labour has a positive effect on a country's economic growth.

Perspective Three

The third perspective distinguishes between elements of the population structure i.e. child and adult population. Proponents of this view argue that these two kinds of population have different effects on economic growth. Becker and Barro (1989) focused on the relationship between population growth and economic growth and found that an increasing fertility rate has a negative effect on economic growth. Population growth has a positive effect on the labor quantity to push economic growth over the long term but has a negative effect on income per capita in the short term. However, if the fertility rate falls as income increases, more rapid progress can also raise fertility and the population growth rate. In other words, a higher fertility rate can provide enough labour to society when they grow up that is also positive to a country's economic growth in the long term (Becker and Barro, 1989). Various dynamic effects are at play.

Crenshaw (1997) argues that people are not only producers but also are consumers of wealth. Feeding children can be seen as the burden to working-age population. The more children, the more time and money families spend on children instead of working and other expenditures. However, when children grow and become part of the economically active population, they can create value to contribute to economic growth via their labour input. In other words, a high proportion of employed labour in the total population also mitigates the burden of children and old people on the government – which is helpful to economic growth of a country. So, population growth with a negative short-term effect on growth, may exhibit a long-term positive effect.

Contributions of China-oriented Research

The population-growth debate has also been considered by economists focusing on the Chinese economy. Li (2001) argued that population growth can drive economic growth in China because a growing population can provide enough labour to Chinese industries, especially labour-intensive industries. Lai (2006) followed the views of Lucas (1988), Becker and Barro (1989), and argues that labour mobility is a key factor to economic growth in some developed areas in China, like Beijing and Shanghai. However, Zhang (2006) notes that population growth in China has a negative effect on economic growth because population growth in rural areas that generates low labour productivity is a drag on economic growth at national level in China.

In summary, there are three basic views about the relationship between population growth and economic growth. Economists like Malthus (1798) argue that population growth has a negative effect on economic growth when population growth is faster than technology and resource development. Others argue that population growth can provide enough labour to the country and can also stimulate investment and consumption, thereby having a positive effect on economic growth. Proponents of the third view argue that growth of the population of children has a negative effect on economic growth because it has a negative effect on income per capita in the short term and childcare represents also an opportunity cost of an adult working; however, the proportion of working age population in the labour force of a country has a positive effect on economic growth. So, the third view suggests that population growth has a negative effect on economic growth in the short term but has a positive effect in the long term.

2.2.2 Solow Growth Model

In this sub-section the theoretical model is introduced and the relationship between variables in this model is explained. Key variables are outlined first before proceeding to outline the Solow model.

Definition of key variables

Population change in this research means the population growth rate. As the explanation in Section 2.3 outlines, the growth rate of population reflects the change in total population. For the variables of population, most studies used the growth rate as the main variable, such as Zhang (2006), Chen (2011), Yao, Kinugasa and Hamori et al., (2013). Additional variables are also added into the model, such as the working age population or dependency ratio[11]. In this Chapter, the dependency ratio is used to represent the change in working age population.

Economic growth provides estimates of the efficiency of the economy as measured by core inputs (labour, capital and technology) to productivity growth. Productivity is usually defined as a ratio of a volume measure of output to a volume measure of input use (Simon, 1977; Yao, Kinugasa and Hamori, 2013). Productivity measurement not only can provide evidence of the growth in a country in both short and long terms, but can also feed into the explanation of the speed of regional economic growth, such as why a developing area has a higher growth rate than a developed area. Compared with the level of variables like capital and labour, labour productivity is another way to understand a country's development and economic growth.

Theoretical Frameworks and Model

Solow (1956) introduced the 'Solow Growth Model' that outlines how a country's level of output (and living standards) is determined. In Solow's model, economic growth is driven by the improvement of productivity via exogenous technological advance by improving the efficiency of labour, through a better skilled workforce and the process of growth is not determined in his model (Solow, 1956; Mankiw, Romer and Weil, 1990 Barlow et al., 1994).

The Solow Growth Model is the basic theoretical model of this research.[12] It represents the first attempt to model long-run growth analytically that has proven to be the 'workhorse' for understanding the key factors in explaining economic growth in an area. Various studies use the basic model of Solow (1956) to test the impact of key factors

[11] Dependency ratio refers the proportion of non-working age population expressed as a portion of the working-age population. The non-working age population was measured as the sum of population aged 0-14 and population aged 65 and over. The working age population refers to the population aged 15-64; source: http://data.stats.gov.cn/easyquery.htm?cn=C01.

[12] This section is largely sourced from Solow (1956), Mankiw (1990, 1992), Chen (2010) and Yao, Kinugasa and Hamori (2013).

on economic growth. Based on Solow (1956) and Mankiw, Romer and Weil (1990), the neoclassical stochastic growth model can be written as follows.

$\mathrm{Y}_t = (K_t)^a \, (A_t, L_t)^{1-a}, 0 < a < 1$ (2.1)

Equation 2.1 illustrates how a country's level of output (Y_t) is determined by growth in the capital stock (K_t), growth in the labour force (L_t). and technological advances insert A. In this context, capital is defined as inputs not consumed in production that generate services to create saleable output. Capital can include land, physical structures (factories) and equipment (e.g. computers) used for production. Technology (A_t) is seen as the factor that affects both labour and capital by improving productivity, but not affecting output directly because it is assumed that technology is non-competitive and non-excludable. Technology affects productivity via 'effective labour', which is represented by $(A_t, L_t)^{1-a}$ in equation 2.1, Solow (1956) in his model illustrates that the inputs (capital and labour) can increase the output in an economy based on increased levels of each factor employed.

If we focus on the change in each factor in an economy with full employment where the growth of labour supply or population is at rate *n*, then $L(t) = L_0 e^{nt}$, the growth rate of labour supply is $\frac{\Delta L(t)}{L(t)} = n$. If we also assume technology advances by rate *g* then $A(t) = A_0 e^{gt}$, and the growth rate of technology is $\frac{\Delta \mathrm{A(t)}}{A(t)} = g$. If we consider the consumption and investment elements of income then total savings in the economy is equal to total investment, and $\Delta \mathrm{K}(t) = sY(t) - \delta K(t)$. In this equation, *s* denotes the savings rate that it is exogenous and δ denotes the capital depreciation rate. Then the change in capital stock may be denoted as follows:

$\Delta \mathrm{K}(t) = sf\big(k(t)\big) - (n + g + \delta)k(t)$ (2.2);

In equation 2.2, $sf(k(t))$ denotes real investment per capita and the expression; $(n + g + \delta)k(t)$ denotes the investment required to keep the capital stock at a steady level, for example the investment to cover depreciation and investment in new capital for additional labour inputs. Change in ($sf(k)$), must be sufficient to cover the growth in $(n + g + \delta)k$ when the $\Delta\text{K}(t) = 0$, that is the steady state of the Solow Growth Model. The steady-state in the Solow growth model is also called 'balanced growth'.

The term 'convergence' explains the reason for faster growth in poorer countries than rich countries (Solow, 1956; Mankiw, Romer and Weil, 1990; Bonnefond, 2015). The convergence coefficient may be represented as follows:

$\lambda = (1 - \alpha_k)(n + g + \delta)$ (2.3)

If an economy is developing below its steady state level, it may exhibit a higher growth rate than economies at higher levels of output (per capita). This phenomenon can also mean that a country's economy will converge to a steady state whether it has higher or lower basic economic development level (Solow 1956, Mankiw, Romer and Weil 1990, Chen 2010).

The Solow growth model explains economic growth in a country in terms of labour and capital growth and technological change. There is a steady-state in the Solow growth model that balances the relationship between the productivities of capital and labour. In the Solow model, labour growth is a source of economic growth but *human capital* is not explicitly included. The extended model which many researchers use allows for the quality of labour (skills or human capital) to impact on economic growth in addition to quantity effects (Solow 1956, Mankiw, Romer and Weil 1990). In more recent models, known as endogenous growth models, capital is broadly defined to include knowledge (or human capital) and improvements in human capital have the potential to permanently boost growth, implying that a potentially constructive role for government exists to consider subsidising such investments in human capital (Romer, 1986, 1990). These issues are further considered in later chapters.

Population Growth and Output of Economy

Solow (1956) and Chen (2011) explain that because of the increases in the amount of labour, due to population growth at the speed *n*, the total capital stock needs to grow at speed n to maintain the steady state. That means population growth n can explain growth in total output (per capita output is constant) in the steady state. However, population growth cannot explain improvement in living standards in steady state.

However, if the economy in a country is not at the steady state, population growth plays a different role. If the total population increases that implies a decrease in the capital to labour ratio in the short term. We set k as the capital/labour ratio $\mathrm{k} = \frac{K}{L}$; y is the output to labour ratio $\mathrm{y} = \frac{Y}{L}$. The change in capital/labour ratio can be explained by the following equation.

$\Delta\mathrm{k} = \mathrm{i} - (\delta + \mathrm{n})\mathrm{k}$ (2.4)

In this equation investment is denoted as i and it is necessary that $(\delta - \mathrm{n})\mathrm{k}$ is equal to i to maintain the capital stock per worker unchanged. If we use $sf(k)$ instead of i, then

$\Delta\mathrm{k} = sf(k) - (\delta + \mathrm{n})\mathrm{k}$ (2.5)

In the steady state, assuming the savings rate (g) is zero, capital investment in the efficient worker ($sf(k)$) is equivalent to the population growth and depreciation on capital ($(\delta + \mathrm{n})\mathrm{k}$) that makes $\Delta\mathrm{k}$ equal to zero.

Research including Yamaguchi (1973) and Yao, Kinugasa and Hamori (2013) illustrates that population can have both direct and indirect effects on economic growth. The direct impact of population is a negative effect of population size on growth. For example, growth in population can decrease income per capita i.e. living standards. Abundant population leads a shortage of limited resources in a country or society that also affects the input of capital negatively – as capital available per unit of labour is limited; this is the basic rationale behind arguments for population control (Yamaguchi, 1973; Yao, Kinugasa and Hamori, 2013).

Population growth can include an increase in the labour force and also an increase in children and older people (the dependency rate). Becker and Barro (1989), Crenshaw (1997), Bloom and Williamson (1998) consider that growth of the proportion of as the opportunity cost of working and results in decreasing the total amount of labour. An increase in the dependency rate decreases the living standards in an economy by reducing the value of income per capita. Children and older people need more living costs that can decrease the savings rate in an economy that may have a short-term negative effect on capital stock and total output (Becker and Barro 1989; Crenshaw, 1997; Bloom and Williamson et al.,1998). So, growth in population may have a negative effect on economic growth.

Population growth also has indirect effects on economic growth through impacts on capital and technology. Based on Coale and Hoover (1958), Ma (1958), increases in population can stimulate consumption that is disadvantageous for capital formation and it is possible to fall into a Malthusian trap. Other research such as Higgins and Williamson (1998) have similar views that population change, especially in age structure, affect the capital stock via savings, consumption and the current account. For example, a higher dependency rate increases consumption and decreases the savings rate in the short term.

For the impact of population growth on technology, Yao, Kinugasa and Hamori (2013) outline that technology is a fundamental requirement for sustained economic growth. Romer (1990), Grossman and Helpman (1991) consider labour as a fundamental component of the production of research activities that high quality labour can change human capital, impacting on economic output in the long term. Yamaguchi (2001) concludes that population growth has a negative effect on technology because it decreases income per capita. Therefore, the size of the population can influence economic growth negatively but the labour force can influence economic growth positively.

Labour-force Growth and Output of Economy

In this Chapter, the quantity of labour is the focus of attention, rather than the quality of labour, which is considered in a later chapter. Based on Bloom and Williamson (1998) the amount of labour and population have different effects on the output of the economy. If we set Y as the total output, N as total population, L as the labour-force, then

$$\frac{\mathrm{Y}}{\mathrm{N}} = \frac{\mathrm{Y}}{\mathrm{L}} * \frac{L}{N} \quad (2.6)$$

If we take the logs of both sides in equation (2.6) and differentiating with respect to time t yields

$$\Delta \mathrm{Y} = \Delta \mathrm{y} + \Delta L - \Delta N \quad (2.7)$$

In equation (2.7), the growth rate of the labour force has a positive effect on the output per capita growth rate and the growth rate of population has a negative effect on output per capita growth rate.

In related arguments, Yao, Kinugasa and Hamori (2013) explain that the non-agricultural population can also improve the economic growth by providing relatively higher quality productivity from work other than farming. This opinion is similar to Lewis (1954) i.e. that industrialization and productivity growth occur when agricultural surpluses and surplus agricultural labour are applied to industry, thus spurring economic growth. Yao, Kinugasa and Hamori (2013) also judge that measured increases in the non-agricultural labour force in China from 1952-2008 is a key reason for economic growth.

2.2.3 Empirical Literature

Many empirical studies have applied the Solow model outlined above using a variety of different empirical methods across different economies. Relevant approaches and results are reported here organized in terms of international studies and those oriented specifically towards China.

Studies Focusing on Countries Other than China

Yamaguchi (1973) found that population growth had a direct and negative short-run effect on economic growth by decreasing income per capita (with a coefficient of -0.80), using data for Japan, Thailand, China and the Taiwan province of China from 1880-1970. The study also found that population growth had an insignificant impact on economic growth over the long run. Barlow (1994) found that population growth (measured as total population growth rate) had a negative effect on economic growth in the estimations for all sample countries, high and low income countries using pooled OLS and fixed effects estimations (with the coefficients ranging between -0.29, and -2.19 in different specifications), based on data for 86 countries which include developed and developing countries from 1968-1982. A stronger negative impact of total population growth is detected in the low-income countries than high income countries. The above studies only focus on the impact of total population growth on economic growth. Other population quantity change factors such as working age population and non-agricultural population are not included.

Thornton (2001) undertook a long-run relationship study between population growth and economic growth using data for Argentina, Brazil, Chile, Colombia, Mexico, Peru, and Venezuela from 1900-1994. He identified that a long-run relation between population and GDP per capita did not appear to exist. More meaningful results might be funded by Thornton (2001) if other time-series or panel data analysis techniques are applied. Banerjee (2012) found that population growth had a negative effect on productivity (with the coefficients of -0.43, -0.46, -0.82, -0.88, -0.97 in all five models) in Australia using the Vector-error Correction Model (VECM) over the period of 1970-2008.

Crenshaw (1997) estimated that population growth, especially adult population, had a negative effect on population growth using 75 developing countries from 1965-1990 (with a coefficient of -2.05). This research divided population growth into two parts: child population and adult population. The results indicated that child population growth had a negative effect on economic growth (with the coefficients of -1.85, -1.81, -1.66) and the adult population had a positive effect on economic growth (with the coefficients of 1.69, 1.57, 1.20). However, other advanced panel data analysis techniques such as fixed effect model or GMM could be applied to get more accurate coefficients of key variables.

Using data for Japan from 1956 to 2000, Li (2002) found that population growth had a significant negative effect (-0.25) on economic growth in the years 1956-1973; but population growth had a significant positive effect on economic growth in the years 1956-2000 (0.55) and 1990-2000 (0.30). For Japan, Li (2002) concluded that the negative effect of population growth was because of the dependency ratio after World War. Population growth between 1973 and 2000 not only provided sufficient labour to labour-intensive industries but also stimulated consumption in Japan when the economy subsequently declined. In later research Li (2009) argued that population growth had different effects on economic growth in different time periods and the relationship between population and economic development is more significant over a longer time period. More useful finding such as long-term and short-term impacts of key variables could be identified if the advanced econometric techniques are applied.

Huang (2012) found that population growth had a positive effect in the short term (0.87) but has an insignificant effect in the long term on economic growth. The study used a sample of 90 countries[13] spanning 1980–2007 and used the Autoregressive Distribute Lags (ADL) Model to test the long run and short run effects on economic growth and population growth. Huang (2012) also fund that population growth only had a negative short run effect (-1.57) on economic growth in medium income countries; it had insignificant long run and short run impacts on economic growth in both high and low

[13] 90 countries include developed and developing countries in the world.

income countries groups.

Konig (2015) used data across EU member states over the period 1993-2012to conduct pooled OLS estimation and divided the time period into four periods, 1993-1997, 1998-2002, 2003-2007, and 2008-2012. With significant period effects identified, population was estimated with negative and significant effects on economic growth in both OLS (-0.63, -0.92) and fixed effects (-0.83, -0.80) estimations. In the model including variables for human capital (i.e. the education level of population) the total population retained negative and significant effects on economic growth. Considering the development level and income gaps of target countries, grouping countries might identify more accurate impacts of population in different countries to make the results more meaningful.

Studies that Focus on China

For the Chinese economy, Zhang (2006) found that population growth has a significant negative effect on population growth in both long term (-0.43) and short term (-1.41). Based on national level data for China from 1978-2003 and using VAR estimation, Zhang found that population growth in China increased the labour supply and reduced income per capita via negative productivity effects. Working age population might be more suitable to added into research model to identify the impacts of population change in China.

In contrast, Chen (2011) found that population growth had a positive effect (0.04) on economic growth in China across 29 provinces from 1996-2008, using fixed and random effects models. Dividing the provinces geographically into eastern, central and western areas Chen (2011) also found that population growth had the most significant effect on economic growth in western areas with a coefficient of 0.08 and the least significant effect in eastern areas with a coefficient of 0.03.

Using national level data for China from 1952-2007, Yao, Kinugasa and Hamori (2013) found that population growth in China had negative and significant effects on economic growth in both long run (with the coefficients of -4.39, -7.27, -1.43, -1.87, -1.83, -1.80) and short run (with the coefficients of -1.73, -3.56, -1.64, -3.46), using the Vector-error Correction Model (VECM). In the study, the effect of population growth is determined within a model including population, savings, labour structure, technological progress and industrialization. They also found that working age population (with the coefficients of 4.75, 1.73, 0.05) and non-agricultural population (with the coefficients of 1.61, 1.55) had positive and significant long run effects on economic growth in China. The results could be more meaningful if the impacts of population change on economic growth in different time periods are identified.

In addition, Lai (2006) identified that population growth had a negative and weak effect (with a coefficient of -0.02) on economic growth in China by OLS estimation using data for 31 provinces in China for 2004. Lai (2006) suggested that to improve the effect of population growth on economic growth in China, the quality of population should be improved. The study also suggested that urbanization in developing provinces is also key to enhancing the population effect on Chinese economic growth. Advanced panel data analysis techniques such as fixed effects model and GMM might make the results more accurate and meaningful.

Bonnefond (2015) tested the relation between total population growth and economic growth in China based on province-level data across 29 provinces from 1995-2009. In this research, the fixed effects model and System GMM Estimation were used. Based on results, total population had a negative and significant effect (with the coefficients of -1.48, -1.33) on economic growth in the model with System GMM Estimator and the effect of total population was significant stronger than the positive impact of investment. In the model with System GMM Estimator and with a focus on conditional convergence, total population exhibited a negative and significant effect on economic growth (with a coefficient of 0.97); findings of a negative and significant effect on economic growth was also found using the fixed effects models with different control variables (with the coefficients of -0.83, -0.56, -0.72).

Generally, the results for China indicate that total population growth negatively impacts economic growth, Chen (2011) being an exception. Compared with total population growth, growth of working age population and non-agricultural population indicate different impacts on economic growth in China (Yao, Kinugasa and Hamori, 2013).

Considering the possible different impacts of population quantity changes on economic growth in different areas in China should be considered. Barlow (1994), Huang (2012) and Chen (2011) applied the estimations for different groups to identify the different impacts of population changes. Chen (2011) and Zhou, Liu and Zhu (2013) focusing on China applied geographical groups for Chinese provinces as the National Bureau of Statistics of China[14] and the significant different impacts of key variables are founded. Barlow (1994) and Huang (2012) used the division method based on average income levels to identify the different impacts of key variables based on the estimations for different groups.

Compared the average real GDP per capita of each province in different geographical group, geographical division method to Chinese provinces might not fully reflect the gap of economic output and growth for Chinese provinces. In this section, data in different geographical and economic output (measured by average real GDP per capita) groups are estimated separately to identify the possible different impacts of key variables on economic growth as the method of Chen (2011) and Zhou, Liu and Zhu (2013).

Results from the various empirical studies are provided for comparison purposes in Tables 2.1 and 2.2, the latter focusing on studies including China.

[14] Source: http://data.stats.gov.cn.

Table 2.1: Empirical Findings Summary of Other Countries' Studies

Author	Years	Areas/Countries Examined	Empirical Techniques	Estimated coefficients of population growth on economic growth[15]
Banerjee (2012)	1870-2008	Australia	VECM model	Population growth (-0.43, -0.46, -0.82, -0.88, -0.97)
Barlow (1994)	1968-1983	86 countries - developed & developing countries	Pooled OLS estimation	Population growth in all countries (-0.978, -1.351); High income countries (-0.286, -1.757) Low income countries (-1.695, -2.789)
Crenshaw (1997)	1965-1990	75 developing countries	Pooled OLS estimation	Total population growth (-2.05) Adult population growth (1.69, 1.57, 1.20); child population (-1.85, -1.81, -1.66)
Huang (2012)	1980-2007	90 countries - developed & developing countries	Autoregressive Distribute Lags (ADL) Model	All countries: short run (0.872), long run (insignificant); High income countries: short run (insignificant), long run (insignificant); Medium income countries: short run (-1.574), long run (insignificant); Low income countries: short run (insignificant), long run (insignificant)
Konig (2015)	1993-2012	Malta, Luxemburg, Cyprus, Estonia, Slovenia, Lithuania, Croatia, Ireland, Finland, Slovakia, Demark, Bulgaria, Austria, Sweden, Hungry, Czech Republic, Portugal, Belgium, Greece,	Fixed effect model; Pooled OLS estimation	Population growth in OLS estimation (-0.626, -0.920), Fixed effect model (-0.826, -0.803); In the model with the variable about human capital, such as the education level of population, the total population

[15] '+' means positive effect on economic growth'-'means negative effect on economic growth.

		Netherland, Romania, Poland, Spain, Italy, UK, France, Germany		growth still has the negative and significant effect on economic growth
Li (2002)	1965-2000	Japan	OLS estimation	1956-1973 population growth (-0.245); 1990-2000 population growth (0.301), 1956-2000 (0.549)
Thornton (2001)	1900-1994	Argentina, Brazil, Chile, Colombia, Mexico, Peru, and Venezuela	VAR model and Schwarz Bayesian criterion	A long-run relation between population and economic growth does not appear to exist
Yamaguchi (1973)	1880-1970	Japan, Thailand, China and Taiwan province of China	VAR and ADL models	Population growth in short run (-0.798), long run (insignificant)

Source: Author's Analysis

Table 2.2: Empirical Findings Summary of Chinese Studies

Author	Years	Areas/Countries Examined	Empirical Techniques	Results about the effect of population growth on economic growth
Bonnefond (2015)	1995-2009	29 provinces of China	Fixed effect model and System GMM Estimation	Fixed effect model (-0.831, -0.563, -0.721) System GMM Estimation (-1.480, -1.332, -0.973)
Chen (2011)	1996-2008	29 provinces level data in China	Fix and Random effect Models	Population growth has the most significant and positive effect on the economic growth in western areas (0.079) but has the least significant and positive effect on eastern areas (0.032). All provinces (0.039)
Lai (2006)	1995-2004	31 provinces - China	Pooled OLS estimation	Population growth (-0.017)
Li (2006)	1980-2004	National - China	OLS estimation	Population growth (0.09); To improve the positive effect of population growth on economic growth in China, the quality of population should be improved.
Li (2009)	1978-2008	National - China	Hierarchy process analysis	Population growth (0.029); Urbanization gathered the labour from city and rural area that maximized the positive effect of population growth on economic growth in China
Yao, Kinugasa and Hamori (2013)	1952-2007	National- China	VECM model	Population growth in long run (-4.39, -7.27, -1.43, -1.87, -1.83, -1.80); short run (-1.73, -3.56, -1.64, -3.46)
Zhang (2006)	1978-2003	National - China	VAR model	Population growth: long run (-0.43); short run (-1.405)

Source: Authors Analysis

2.3: DATA INTRODUCTION AND DESCRIPTION

The purpose of this section is to describe the data used in analysis.

2.3.1 Discussion of Data, Sources and Quality

The original dataset used in this Chapter consists of a panel of twenty-nine Chinese provinces with annual data for the period 1985-2013. All province level data is collected from various editions of the Statistical Yearbooks of each selected province 1985-2013, which are published by the National Bureau of Statistics of China; China Population & Employment Statistics Yearbook 1988-2013 and the websites of National Bureau of Statistics of China.

Based on the discussion of e.g. Bonnefond (2015), the quality and reliability of Chinese official data have been largely disputed in the literature, such as Maddison, (1998) Rawski, (2001) and Holz, (2006). Holz (2006) argues that the institutional arrangements of data compilation in China raise major problem about the nominal and real GDP. Chinese official economic data does not include deflators, but the implicit deflators can be obtained by dividing the official growth rate of the nominal values by the official real growth rate. A separate independently constructed price index is applied for the statistics agencies of most countries estimate real GDP by deflating nominal GDP, but this is not the case in China (Kerola, 2018).

Despite the above problems for the quality and reliability of the data of China, there is now a rough consensus on the fact that despite of some errors and statistical discrepancies, official statistics can be considered as reliable (Holz, 2006; Chow, 2006; Bonnefond, 2015). Three points are relied on the arguments to stand for the reliability of Chinese official data by Chow (2006), which are the assigned responsibility of the officials preparing the data; the use of official data in government decision-making; and their use in many empirical articles that have been published in internationally refereed journals. In terms of this study, for example, to use appropriate economic growth measures real GDP was measured using nominal data deflated by the Consumer Price Index to remove inflation effects following approaches in Zhang, 2006; Lai, 2006; Chen, 2011; Yao, Kinugasa and Hamori, 2013; Bonnefond et., al 2015. While official published GDP indices are available, these do not follow internationally consistent methods in their estimation.,

2.3.2 Data Introduction

This chapter focuses on the effect of population growth on economic growth, with GDP as the dependent variable. Real GDP per capita (in growth rate) is used as a measure of economic growth. Total GDP refers to the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources[16]. The data for total GDP across 29 provinces from 1985 to 2013 was collected from the website of National Bureau of Statistics of China and the Statistics Yearbook of each selected province 1985-2013. The unit of GDP per capita in this chapter is Yuan.

The Consumer Price Index (CPI) is applied to express GDP per capita in real terms with the base year of 1985. The data for CPI of the 29 provinces from 1985-2013 was also collected from the website of National Bureau of Statistics of China and the Statistics Yearbook of each selected province 1985-2013.

Another key variable in the model is total population. The data for total population in each province relates to the population at 24 pm 31st December each year. Population data for 1981, and before, are from household registrations; for the years 1982, 1990, 2000 and 2010 census year estimates are available. The remainder of the population

[16] Source: https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=CN&view=chart.

data were estimated on the basis of annual national sample surveys. Sample surveys of population in each province were conducted to estimate the total population and other detailed characteristics of the population, for example, age structure[17]. Surveys focus on people who are resident of each province but not necessarily living and working in the province - such as military personnel and students who study in a different province (or country) that are not calculated in the total population in the provinces. The data for total population in 29 provinces from 1985 to 2013 was collected from the website of the National Bureau of Statistics of China and China Population & Employment Statistics Yearbook 1988-2013. Total population includes people who have been registered in the census in each province. For the regression analysis, the growth rate of total population in each province was computed from 1986-2013.

Data on non-working and the working age population were used to compute the Dependency Ratio i.e. The definition follows that used in the World Bank Database and the National Bureau of Statistics of China[18]. The data for the working age population and non-working age population in 29 provinces from 1985 to 2013 are available from the Statistics Yearbook 1985-2013 of each selected province and China Population & Employment Statistics Yearbook 1988-2013. The growth rate of dependency ratio in each province was computed from 1986-2013 for the regression analysis.

The non-agricultural population ratio is also used in this chapter to examine the effect of non-agricultural population on provincial economic growth, which means the proportion of non-agricultural population in total population. Non-agricultural population includes all people residing and registering within a province who are within the workforce, outside of agriculture. There are two types of residents in the 'Hukou' system in each province, i.e. urban and rural (Bai and Zou, 2014). Non-agricultural population includes total permanent residents who registered as urban. The data for

[17] Source: http://data.stats.gov.cn/english/easyquery.htm?cn=C01.
[18] The definition of dependency ratio can be find by the following links, http://data.worldbank.org/indicator/SP.POP.DPND and http://data.stats.gov.cn/english/easyquery.htm?cn=E0103

non-agricultural population for each province is collected from the Statistics Yearbook 1985-2013 of each selected province and China Population & Employment Statistics Yearbooks, 1985-2013. The growth rate of dependency ratio in each province was computed from 1986-2013 for the regression analysis.

The three different population measures account for the different kinds of permanent residents in each province in China. Because of the 'Hukou' system, some Chinese people work and live in other provinces but register in their hometown because the system forbids them to register elsewhere[19]. Based on the statistical detail of the National Bureau of Statistics of China, permanent residents mean people living in an area for over 6 months in one year or with a financial connection with the area[20]. For example, a person may be registered in Shanghai who holds a bank account in Shanghai and transfers most of their income into the account in Shanghai even while working in Beijing for over 6 months in a year. If most of the income is deposited to an account in Beijing, then the person is a permanent resident of Beijing. In addition, military personnel, students registered in one area but studying in another province and people living in other areas to visit relatives or receive health treatment are not the permanent residents of the original province (Bai and Zou, 2014).

Fixed asset investment (FAI) is included in estimations to examine the effect of capital on economic growth. FAI refers to the volume of activities in construction and purchases of fixed assets of the whole country and related fees, expressed in monetary terms during the reference period. It is a comprehensive indicator which shows the size, structure and growth of investment in fixed assets, providing a basis for observing the progress of construction projects and evaluating results of investment. Total investment in fixed assets includes, by type of ownership, the investment by State-owned units, collective-owned units, joint ownership units, share-holding units, private units,

[19] Source: http://www.gov.cn/zwgk/2012-02/23/content_2075082.htm.

[20] Financial connection means people not only have a bank account in a local bank in, but also transfer most of their income to the account.

individuals as well as investments by entrepreneurs from Hong Kong, Macao and Taiwan, foreign investors and others[21]. The data on fixed asset investment in 29 provinces from 1985 to 2013 is collected from the website of the National Bureau of Statistics of China and the Statistics Yearbook 1985-2013 of each selected province. To convert the data into real terms, the CPI was used.

New patents applications are included in estimations to examine the effect of innovation and technology on economic growth. It is measured as the number of new patents applied for by all companies in each province, which includes invention, utility and design. The data for new patent applications in 29 provinces from 1985 to 2013 is collected from the National Bureau of Statistics of China and the Statistics Yearbook 1985-2013 of each selected province. To measure technological advance, the growth rate of new patent application per 10,000 people in each province from 1986-2013 was used in the regression analysis.

2.3.3 Data Description

In this section, the data is described and preliminary data analysis is undertaken. This chapter uses province level data rather than country level data. There are 34 provinces in China, as listed in Table 2.5.

In this chapter, only 29 provinces are included. Sichuan, Chongqing, Hong Kong, Macao and Taiwan are not included in the analysis. In these five provinces, there is a structural break in data of Chongqing and Sichuan. Chongqing was a part of Sichuan before 1997, and there is a significant fall in the key data for population and real GDP in Sichuan from 1998. If we add the data of Chongqing and Sichuan together after the year of 1997, it will affect the validity of the results. To ensure the reliability of regression analysis, the data of Chongqing and Sichuan are dropped. Hong Kong and

[21] Source: http://data.stats.gov.cn/english/easyquery.htm?cn=C01.

Macao were not official territories of China before 1997 and 1999, respectively. Based on the possibility of different statistical methods and the lack of data in some years, the data of these two provinces are also dropped from analysis. As Taiwan province has been controlled by another political party and also based on the possibility of different data collection methods and the lack of data in some years, the data of Taiwan is also dropped from analysis.

Table 2.3 List of 34 Provinces in Research

1. Beijing	2. Tianjin	3. Hebei	4. Shanxi	5. Inner Mongolia	6. Liaoning
7. Jilin	8. Heilongjiang	9. Shanghai	10. Jiangsu	11. Zhejiang	12. Anhui
13. Fujian	14. Jiangxi	15. Shandong	16. Henan	17. Hubei	18. Hunan
19. Guangdong	20. Guangxi	21. Hainan	22. Guizhou	23. Yunnan	24. Tibet
25. Shaanxi	26. Gansu	27. Qinghai	28. Ningxia	29. Xinjiang	30. Chongqing
31. Sichuan	32. Taiwan	33. Hong Kong	34. Macao		

Source: Websites of National Bureau of Statistics of China

Table 2.4 presents the descriptive statistics of each variable for the years between 1985 and 2013 to provide background into data across the 29 provinces. The regions with the top 3 shares are presented in bold in the table while the regions with the bottom 3 shares are in italics.

As the developed directly cities, Beijing, Tianjin and Shanghai have the higher levels of real GDP per capita, industrialization (measured as non-agricultural population ratio) and capital investment than other provinces. Tianjin, Inner Mongolia and Jiangsu have higher levels of standard deviation in real GDP per capita, which reflects a significant of its changes during 1985-2013. Poor economic outputs are identified in Guizhou, Yunnan and Gansu by lower means and standard deviations than other areas; same features are also detected in the capital investment.

Table 2.4: Provincial Descriptive Statistics of China between 1985 and 2013[22]

	Real GDP per capita		Total Population		Dependency Ratio		Non-agricultural Population Ratio		Real Fixed Asset Investment per capita		New Patents Application Number per Million People	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Beijing	6746.67	4408.18	14.02	3.42	31.36	6.24	76.29	7.90	2648.39	1547.66	13.09	13.20
Tianjin	7173.84	5833.78	10.25	1.75	36.31	6.73	68.53	8.65	3618.63	3857.59	7.70	9.05
Hebei	3350.40	2655.57	65.18	5.47	44.22	8.38	29.34	10.85	1807.03	2113.50	0.90	0.94
Shanxi	2533.74	2017.76	31.70	2.87	45.56	8.63	35.29	9.36	1334.61	1586.55	0.99	1.42
In. Mongolia	4187.23	4439.65	23.10	1.43	40.12	9.59	42.35	8.86	2677.31	3631.75	0.59	0.55
Liaoning	4514.36	3528.13	41.25	1.98	35.76	6.26	49.59	8.48	2761.95	3489.26	2.94	2.86
Jilin	3314.95	2850.30	26.07	1.43	35.66	8.75	47.51	5.59	2009.45	2550.86	1.21	0.95
Heilongjiang	3123.01	2134.11	37.02	1.58	36.18	9.53	49.76	5.07	1420.73	1692.02	1.72	2.36
Shanghai	8076.31	4339.28	16.72	3.91	34.15	6.78	76.90	8.88	2920.68	1269.98	11.03	12.01
Jiangsu	4999.81	4345.89	72.17	5.14	40.60	5.35	39.99	14.20	2361.66	2632.94	10.13	19.43
Zhejiang	5163.42	4138.18	46.70	4.79	38.47	6.38	44.95	13.93	2284.05	2154.87	9.10	14.93
Anhui	2018.92	1712.24	59.17	3.10	48.42	5.88	28.78	10.26	1288.05	1758.84	2.01	4.35
Fujian	4200.01	3528.72	33.22	3.13	48.27	11.08	39.90	13.01	1936.16	2330.75	2.53	3.54
Jiangxi	2179.15	1873.96	41.06	3.09	51.85	9.03	30.90	9.24	1334.32	1781.77	0.68	0.82
Shandong	4222.94	3609.36	88.79	5.56	42.68	7.13	35.88	12.25	2076.02	2381.81	3.05	4.17
Henan	2646.53	2284.73	90.67	5.70	49.34	7.65	25.66	9.25	1414.00	1812.35	1.04	1.44
Hubei	2584.00	2188.25	56.10	2.56	44.64	8.80	37.64	9.30	1336.44	1664.60	1.99	2.79
Hunan	2112.46	1794.16	63.47	2.91	46.06	6.82	30.29	9.90	1002.96	1287.82	1.34	1.61
Guangdong	4944.60	3716.25	80.04	16.86	50.84	12.05	48.95	14.35	1591.78	1228.80	5.64	6.90
Guangxi	1993.64	1719.68	45.42	2.87	54.22	9.18	24.42	11.37	1063.55	1422.24	0.66	0.98
Hainan	2329.12	1668.15	7.59	0.91	53.96	10.88	36.26	12.31	1253.38	1334.00	0.61	0.60
Guizhou	1303.14	1154.13	35.01	2.50	55.23	6.48	23.60	6.97	757.13	1037.18	0.65	1.00
Yunnan	1683.44	1181.37	41.41	3.87	50.68	8.70	24.61	8.11	915.02	1052.43	0.55	0.59
Tibet	1950.16	1469.15	2.56	0.33	54.70	11.34	20.75	2.43	1457.77	1558.79	0.21	0.29
Shaanxi	2389.43	2263.76	35.23	2.30	45.69	9.06	32.56	9.36	1498.87	2032.60	2.21	3.68
Gansu	1635.20	1215.68	24.23	1.69	45.33	5.89	24.08	8.52	959.84	1208.93	0.68	1.05
Qinghai	2088.35	1553.98	5.03	0.51	48.74	9.75	35.85	5.92	1444.02	1635.59	0.47	0.42
Ningxia	2454.69	2108.93	5.43	0.71	51.49	10.59	35.29	8.73	1754.40	2039.46	0.91	1.12
Xinjiang	2619.23	1769.74	18.05	2.80	50.55	11.13	36.04	3.74	1521.05	1523.22	0.85	0.98

Source: Author's analysis based on data collected from the Website of National Bureau of Statistics of China, Statistics Yearbook 1985-2013 of each selected province and China Population & Employment Statistics Yearbook 1988-2013.

Henan, Shandong and Guangdong as the populous provinces in China have higher

[22] Values in red color represent the top three shares and the values in blue indicate the bottom three provinces.

levels in both means and standard deviation in total population than other provinces. Slight changes in total population between 1985 and 2013 are identified in the provinces with few population such as Tibet, Qinghai and Ningxia.

Rich working age population are detected in Beijing, Heilongjiang and Shanghai, which have lower level of dependency ratio; Guangxi, Guizhou and Tibet have lower proportions of working age population than other provinces. Guangdong, Significant changes in working age proportion are detected in Guangdong, Tibet and Xinjiang; Jiangsu, Anhui and Gansu have stable proportions of working population than other provinces.

Gansu, Guizhou and Tibet have lower proportion of non-agricultural population than other provinces. It seems than the proportion of non-agricultural population has significant changes in Jiangsu, Zhejiang and Guangdong reflecting by higher standard deviations; it has lower levels of standard deviations in Heilongjiang, Tibet and Xinjiang.

Tianjin, Jilin and Jiangsu have higher standard deviations of capital investment than other provinces; Guizhou, Yunnan and Gansu have lower standard deviations and means of capital investment than other provinces.

For the new patent applications, top three means are identified in Beijing, Shanghai and Jiangsu and top three standard deviations are identified in Beijing, Jiangsu and Zhejiang. Yunnan, Tibet and Qinghai have lower level of new patent applications; Inner Mongolia, Tibet and Qinghai have lower standard deviations than other provinces.

To provide background into the variation in the data across the 29 provinces, Table 2.5 presents the contribution of each province to each variable for the years of 1985 and 2013. The regions with the top 3 shares are presented in bold in the table while the regions with the bottom 3 shares are in italics. The shares for each measure in 1985 and

2013 are also provided. The main trends evident from the table are indicated below:

Table 2.5: Provincial Shares in Total Value of China in 1985 and 2013[23]

	Real GDP per capita		Total Population		Dependency Ratio		Non-agricultural Population Ratio		Real Fixed Asset Investment per capita		New Patents Application Number per Million People	
Year	1985	2013	1985	2013	1985	2013	1985	2013	1985	2013	1985	2013
Beijing	9.28	5.54	1.02	1.70	2.14	2.27	8.52	5.45	10.74	3.68	38.73	11.56
Tianjin	7.53	7.26	0.85	1.18	2.29	2.94	7.67	5.17	8.94	4.79	12.76	6.64
Hebei	2.48	3.27	5.87	5.89	3.15	3.70	1.99	3.04	2.19	2.90	0.72	0.94
Shanxi	2.89	2.48	2.78	2.92	3.37	3.12	2.98	3.32	3.83	3.70	1.26	1.36
In. Mongolia	2.83	5.26	2.12	2.01	3.48	2.88	4.12	3.70	2.86	3.84	1.03	0.52
Liaoning	4.87	4.77	3.90	3.53	2.77	2.60	5.82	4.19	4.23	6.70	4.07	2.33
Jilin	3.02	3.73	2.43	2.21	3.25	2.73	5.26	3.42	2.97	3.75	2.96	0.83
Heilongjiang	3.71	2.84	3.50	3.08	3.42	2.65	5.82	3.62	3.70	4.80	2.32	2.33
Shanghai	13.28	5.75	1.29	1.94	2.11	2.50	9.23	5.65	10.68	2.70	15.15	7.89
Jiangsu	3.63	5.48	6.57	6.38	2.90	3.45	2.56	4.05	3.39	2.94	1.90	18.07
Zhejiang	3.69	5.09	4.26	4.42	2.96	2.68	2.27	4.04	2.78	2.82	1.76	14.29
Anhui	2.23	2.32	5.46	4.85	3.70	4.09	1.99	3.02	1.72	3.30	0.42	4.28
Fujian	2.56	4.57	2.87	3.03	3.80	3.35	2.27	3.83	2.25	2.57	1.35	3.35
Jiangxi	2.08	2.46	3.66	3.63	4.20	4.04	2.56	3.08	1.40	3.14	0.74	0.79
Shandong	3.06	4.48	8.14	7.82	3.18	3.61	1.85	3.39	2.77	2.76	0.93	3.47
Henan	2.03	2.84	8.16	7.56	3.69	4.23	1.70	2.76	1.80	2.68	0.84	1.32
Hubei	2.78	2.95	5.22	4.66	3.48	3.32	2.98	3.44	2.29	3.60	1.95	2.39
Hunan	2.16	2.39	5.95	5.38	3.50	4.06	1.99	3.03	1.63	3.08	1.67	1.44
Guangdong	3.20	4.60	6.62	8.55	3.56	3.16	3.13	4.28	3.24	1.13	1.01	5.64
Guangxi	1.62	2.27	4.10	3.79	4.07	4.45	1.70	2.83	1.20	2.50	0.57	1.08
Hainan	2.50	2.31	0.63	0.72	4.17	3.69	1.85	3.33	2.81	2.65	0.00	0.56
Guizhou	1.45	1.65	3.14	2.81	4.05	4.58	1.70	2.39	1.22	2.78	0.71	0.98
Yunnan	1.68	1.71	3.60	3.77	3.87	3.91	1.56	2.55	1.49	2.50	0.96	0.57
Tibet	3.08	2.00	0.21	0.25	3.94	3.98	1.99	1.50	4.13	3.28	0.00	0.08
Shaanxi	2.09	2.96	3.18	3.02	3.32	3.33	2.56	3.24	2.12	3.78	2.41	3.51
Gansu	2.09	1.67	2.16	2.07	3.09	3.49	2.13	2.53	1.82	2.81	1.59	1.12
Qinghai	2.81	2.14	0.43	0.46	4.19	3.72	4.12	3.06	4.63	5.69	0.97	0.38
Ningxia	2.52	2.74	0.44	0.53	4.29	3.77	3.13	3.28	3.60	5.08	0.48	1.25
Xinjiang	2.86	2.46	1.44	1.82	4.08	3.75	4.55	2.81	3.58	4.07	0.72	1.03

Source: Author's analysis based on data collected from the Website of National Bureau of Statistics of China, Statistics Yearbook 1985-2013 of each selected province and China Population & Employment Statistics Yearbook 1988-2013.

23 Values in red color represent the top three shares and the values in blue indicate the bottom three provinces; Total value of China in this table is calculated by 29 selected provinces without Sichuan, Chongqing, Hongkong, Macao and Taiwan provinces.

- **Descriptive Statistics**

This section provides some basic statistical analysis of the data such as average value, standard deviation and median value. The basic correlations between variable are also introduced.

Table 2.6 provides the descriptive statistics of data averaged across the 29 selected provinces from 1985 to 2013. The mean values for each variable are provided (without weighting).

Table 2.6: Descriptive Statistics of Data for Key Variables, 1985-2013

Variables Name	Mean	Standard Deviation	Median
Real GDP per capita (RMB)	3397.89	3404.09	2070.00
Total Population (million)	38.5	25.14	36.3
Dependency Ratio (%)	45.21	10.96	44.33
Non-agricultural Population Ratio	39.45	14.47	35.24
New Patent Applications per 10,000 People	2.94	7.23	0.63
Real Fixed Asset Investment per capita (RMB)	1739.62	2159.33	784.70
GDP per capita - Growth Rate	8.87	6.21	8.97
Total Population - Growth Rate	1.17	1.75	0.97
Dependency Ratio - Growth Rate	-1.98	4.98	-2.20
Non-agricultural Population Ratio - Growth Rate	3.44	4.13	2.94
New Patent Applications - Growth Rate	27.27	46.92	16.90
Real Fixed Asset Investment per capita - Growth Rate	13.28	14.86	13.91

Source: Author's analysis based on data collected from the Website of National Bureau of Statistics of China, Statistics Yearbook 1985-2013 of each selected province and China Population & Employment Statistics Yearbook 1988-2013.

Geographical location is a basic method of provinces grouping in China because of the similar nature and economic environment of different provinces in a same geographical area, which the significant gaps of economic development between different geographical areas are observed (Chen, 2011; Zhou, Liu and Zhu, 2013). In addition to considering the different provinces of China from an economic development perspective based on GDP per capita, some studies cited earlier (Chen, 2011; Zhou, Liu and Zhu, 2013; Mao and Zhai, et., al 2013;) offer geography-based groupings of the provinces of China. These may be presented as in Table 2.7 which shows the provinces in different geographical and development groupings.

Table 2.7: Specific Provinces in Geographical and Development Level Groups

Geographical Group	Development Level Group
Eastern area (11): Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan	Developed area (10): Shanghai, Tianjin, Beijing, Zhejiang, Jiangsu, Guangdong, Liaoning, Shandong, Fujian and Inner Mongolia
Middle area (8): Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan	Developing area (10): Hebei, Jilin, Heilongjiang, Henan, Xinjiang, Hubei, Shanxi, Ningxia, Shaanxi, Hainan
Western Area (10): Inner Mongolia, Guangxi, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang	Less developed area (9): Jiangxi, Hunan, Qinghai, Anhui, Guangxi, Tibet, Yunnan, Gansu and Guizhou

Source: Author's analysis based on data collected from the Statistics Yearbook 1985-2013 of each selected province and China Population & Employment Statistics Yearbook 1988-2013.

Table 2.8 provides the descriptive statistics for all key variables in both geographical and development level groups. For real GDP per capita greater differences are evident between the development than geographical groups. The highest means of real GDP per capita and growth rates are identified in the Eastern area and developed area.

Larger gaps in both the average dependency ratio and non-agricultural population ratio are identified in the development levels group than the geographical group. The Middle and Developing areas have the lowest average growth rate of dependency ratio.

For the non-agricultural population ratio, the Eastern and Developed areas have the highest mean values and the Western and less-developed areas have the lowest mean values. It is interesting that the highest average growth rates are detected in the Eastern area among the geographical groups but it also identified in the less-developed area among the development level groups.

Table 2.8: Descriptive Statistics for Key Variables - Geographical and Development Groups, 1985-2013

Variables		**Eastern Area**	**Middle Area**	**Western Area**	**Developed Area**	**Developing Area**	**Less Developed Area**
Real GDP per capita	Mean	5065.59	2909.95	2230.45	5422.92	2734.51	1884.94
	SD	4247.29	2178.15	2233.27	1327.46	362.34	269.81
Real GDP per capita (%)	Mean	8.92	8.86	8.82	9.11	9.06	8.39
	SD	6.15	5.95	6.46	6.02	5.95	6.56
Total Population	Mean	43.26	50.65	23.54	42.63	43.83	28.01
	SD	28.94	16.96	15.01	27.99	24.23	18.78
Total Population (%)	Mean	1.52	0.72	1.12	1.50	0.94	1.04
	SD	2.44	1.06	1.02	2.07	1.83	1.07
Dependency Ratio	Mean	41.51	44.71	49.67	39.86	45.57	50.76
	SD	10.74	9.89	10.38	9.92	10.59	9.49
Dependency Ratio (%)	Mean	-1.85	-2.07	-2.05	-1.92	-2.10	-1.94
	SD	5.04	5.05	4.91	5.07	4.89	5.04
Non-agri. Population ratio	Mean	49.68	35.72	29.95	52.17	35.31	28.34
	SD	19.72	11.97	9.45	18.65	11.19	10.52
Non-agri. Population ratio (%)	Mean	3.63	3.38	3.27	3.26	3.20	3.88
	SD	4.11	3.34	4.69	3.68	3.67	4.98
Real FAI per capita	Mean	2296.22	1392.57	1404.89	2487.66	1509.93	1163.71
	SD	2449.24	1813.40	1931.71	2671.74	1899.19	1439.88
Real FAI per capita (%)	Mean	12.33	14.01	13.71	12.38	13.93	13.53
	SD	15.31	14.44	14.61	15.09	13.75	15.69
NPA per 10,000 people	Mean	6.06	1.37	0.77	6.58	1.28	0.76
	SD	10.77	2.29	1.49	11.17	1.97	1.73
NPA per 10,000 people (%)	Mean	27.89	27.02	29.92	27.19	28.92	29.01
	SD	45.96	44.76	75.08	40.14	71.58	56.09
Notes: 'SD' denotes standard deviation; '%' denotes growth rate; 'FAI' denotes fixed asset investment; 'NPA' denotes new patents application numbers							

Source: Author's analysis based on data collected from the Website of National Bureau of Statistics of China, Statistics Yearbook 1985-2013 of each selected province and China Population & Employment Statistics Yearbook 1988-2013.

For real fixed asset investment per capita the highest average values are identified in the Eastern area and Developed areas. The highest growth rates are identified in the Middle and Less developed areas. For patents, the highest average new patents growth rates are identified in the Western area and the less developed area.

Based on the above, different average values and growth rates between the geographical and development level groups are identified and different impacts of key variables would be expected from separate estimations focusing either on developmental or geographical classification of regions. Chinese economic policies focusing on regional development are applied at geographical level. Examples of targeted economic policies based on such geographical approaches include as the 'Great Western Development', 'Revitalizing Old Industrial Bases in Northeast China', and "Rise of Central China" (Goodman, 2004; Bonnefond, 2015). In addition, it is interesting that variables such as dependency ratio and non-agricultural population ratio exhibit different trends between geographical and development level groups, which might lead the different interpretations of the above two variables on economic growth.

Pearson's correlation coefficient[24] is used to measure the correlation between any two independent variables. A positive value of the correlation coefficient means that two variables have a positive relationship and a negative value of Pearson correlation coefficient means that two variables have negative relationship. If the value of Pearson's correlation coefficient is between 0 and 0.19, the correlation relationship between two variables is very weak; if the value of Pearson correlation coefficient is between 0.2 and 0.39, the correlation relationship between two variables is weak; if the value of Pearson correlation coefficient is between 0.4 and 0.69, the correlation relationship between two variables is medium; if the value of Pearson correlation coefficient is between 0.7 and 0.89, the correlation relationship between two variables

[24] See Zhong and Zhang (2009), Chapter 8.

is high; if the value of Pearson correlation coefficient is between 0.9 and 1, the correlation relationship between two variables is very high (Rodgers and Nicewander, 1988).

The formula for Pearson's correlation coefficient is as follows:

$$r = \frac{\sum(X-\bar{X})(Y-\bar{Y})}{\sqrt{\sum(X-\bar{X})^2 \sum(Y-\bar{Y})^2}} \quad (2.9)$$

In this formula, X and Y denote two independent variables.

In Table 2.9, real GDP per capita displays a weak and positive correlation with real fixed asset investment per capita; it has a very weak and positive correlation with new patent applications and non-agricultural population ratio but has very weak and negative correlation with the dependency ratio; it also has a weak and negative correlation with total population.

Table 2.9: Pearson's Correlation Coefficient

	RGDP per capita	Total Population	Dependency Ratio	Non-agricultural Population Ratio	New Patents Application Number per 10,000 People	RFAI per capita
RGDP per capita	1					
Total Population	-0.37	1				
Dependency Ratio	-0.05	-0.14	1			
Non-agricultural Population Ratio	0.11	0.21	-0.11	1		
New Patents Application Number per 10,000 People	0.13	0.27	-0.47	0.24	1	
RFAI per capita	0.41	-0.11	-0.35	0.19	0.32	1

Source: Author's Analysis

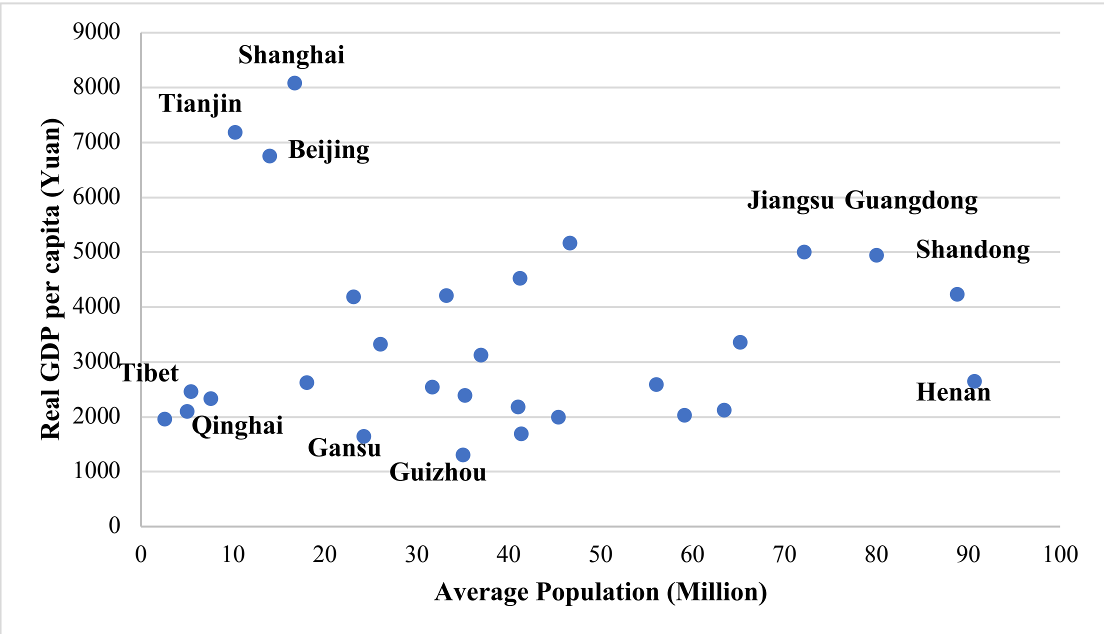
For the correlations between total population and other variables, it has a very weak and negative correlation with the dependency ratio and real fixed asset investment per capita; it has weak and positive correlation with new patent applications and non-agricultural population ratio. The dependency ratio has a weak and negative correlation with the real fixed asset investment per capita and new patent applications but also has a very weak and negative correlation with the non-agricultural population ratio. New patents application has a weak and positive correlation with the real fixed asset investment per capita and non-agricultural population ratio.

In cases of high correlation between independent variables, autocorrelation may affect regression results. However, the above table only shows the correlation between variables in levels rather than growth rates. Expressing variables in growth rates can mitigate impacts in regression and econometric analysis.

- **Graphical Analyses**

Graphical analyses indicate the trends in the data. From Figure 2.1, provinces like Shanghai, Tianjin and Beijing exhibit relatively high real GDP (per capita) and enjoy lower population shares. Provinces like Henan, Shandong, Guangdong and Jiangsu higher population shares but lower GDP per capita. Some provinces (like Jiangsu) with a relatively high level of real GDP do not have high level of real GDP per capita indicating lower efficiency compared with the province like Beijing and Shanghai (Jiangsu and Shandong have also growing dependency shares over the period – see Table 2.4). Provinces like Guizhou, Gansu, Tibet and Qinghai have both lower levels of real GDP per capita and total population.

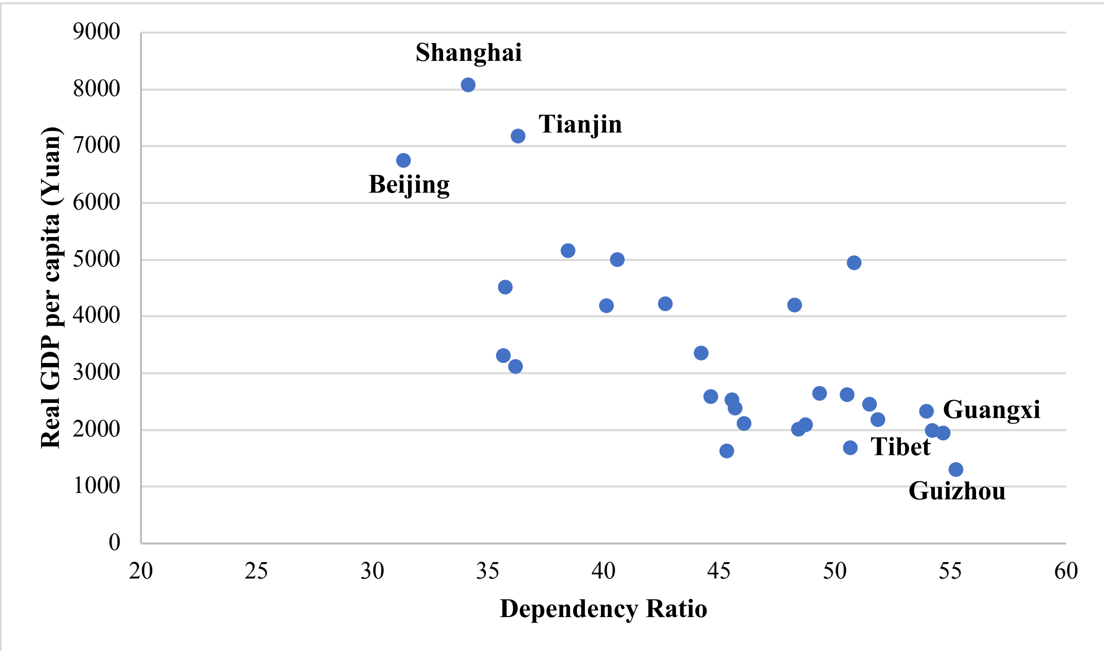
Figure 2.1: Average Population and Real GDP per capita 29 Provinces 1985-2013



Source: Author's analysis based on data collected from the Statistics Yearbook 1985-2013 of each selected province and China Population & Employment Statistics Yearbook 1988-2013.

From Figure 2.2, provinces such as Shanghai, Beijing and Tianjin enjoy a higher level of real GDP per capita and a lower dependency ratio. Developing provinces like Guizhou, Guangxi and Tibet have a higher dependency ratio and lower real GDP per capita. The dependency ratio displays a negative relationship with real GDP per capita. Pan (2012) and Wang (2004) explain that people living in provinces with low GDP often find a good job in other provinces with higher economic development such as Guangdong; they move to other provinces, and leave their parents and children in their hometown to save on living costs.

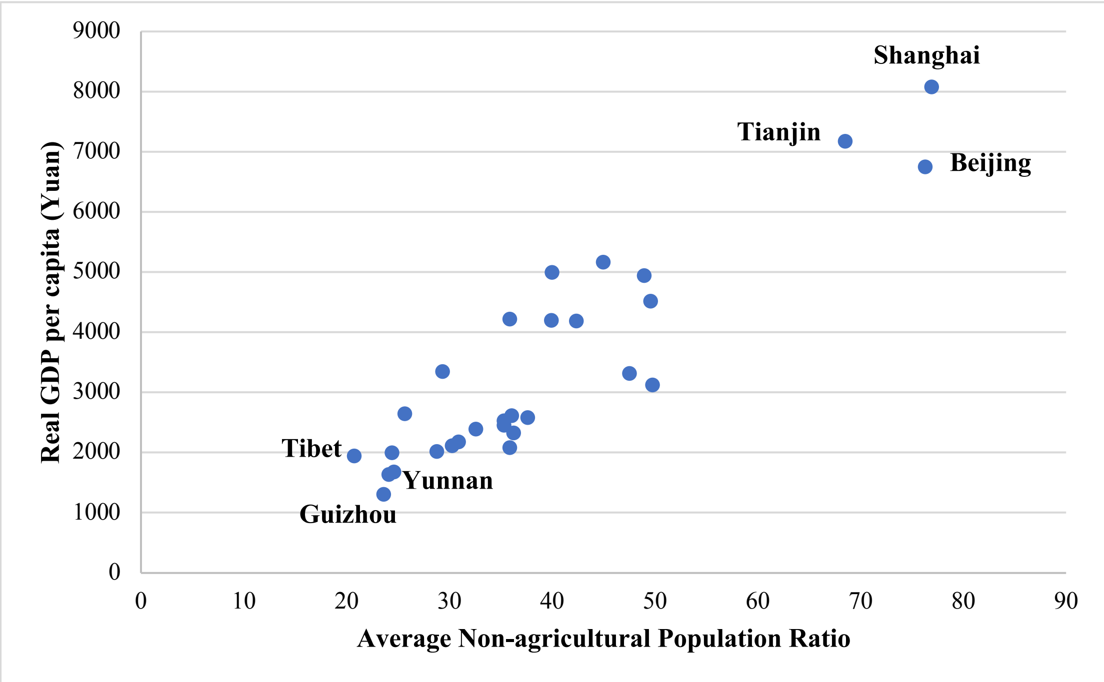
Figure 2.2: Average Dependency Ratio and Real GDP per capita: 29 Provinces 1985-2013



Source: Author's analysis based on data collected from the Statistics Yearbook 1985-2013 of each selected province and China Population & Employment Statistics Yearbook 1988-2013.

From Figure 2.3, Shanghai, Tianjin and Beijing enjoy both high GDP per capita and also higher non-agricultural population ratio. Provinces like Guizhou, Yunnan and Tibet have both lower levels of real GDP per capita and non-agricultural population ratio: these provinces are undeveloped and agriculture is their main economic activity. The general trend evident in these data is positive.

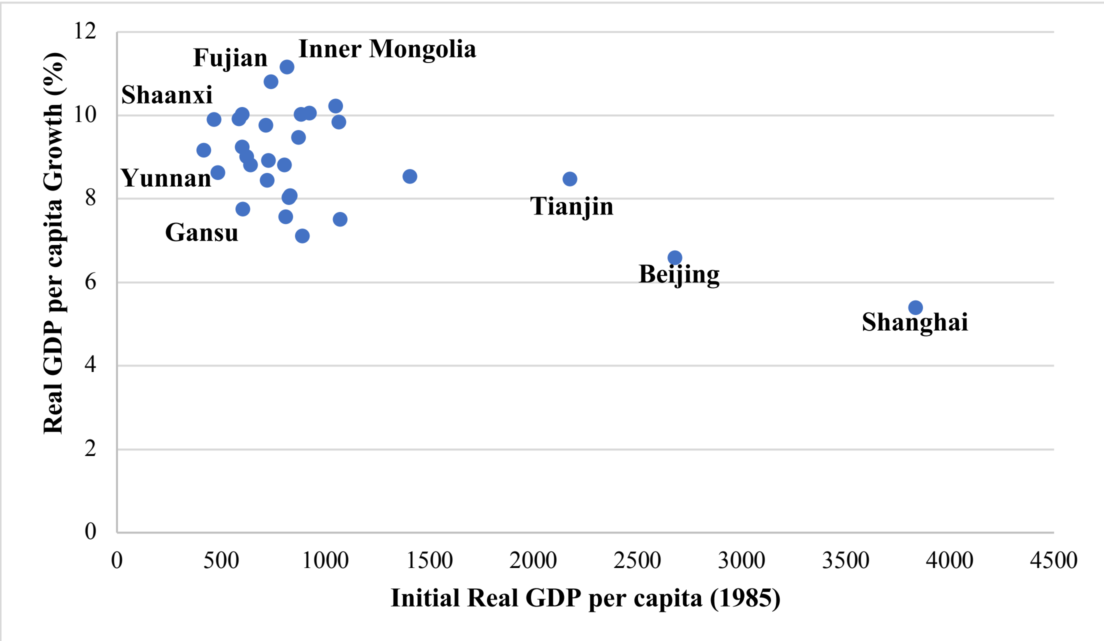
Figure 2.3: Average Non-agricultural Population Ratio and Real GDP per capita in 29 Provinces 1985-2013



Source: Author's analysis based on data collected from the Statistics Yearbook 1985-2013 of each selected province and China Population & Employment Statistics Yearbook 1988-2013.

From Figure 2.4, Shanghai, Tianjin and Beijing have high initial GDP per capita in 1985 and lower average GDP per capita growth rates. Provinces like Fujian, Inner Mongolia and Shaanxi exhibit lower initial levels of GDP per capita and higher average growth rates of GDP per capita. The above findings reflect convergence in above provinces. Yunnan and Gansu exhibit both lower initial GDP per capita in 1985 and average GDP per capita growth. The basic feature in Figure 2.4 seems in line with the convergence.

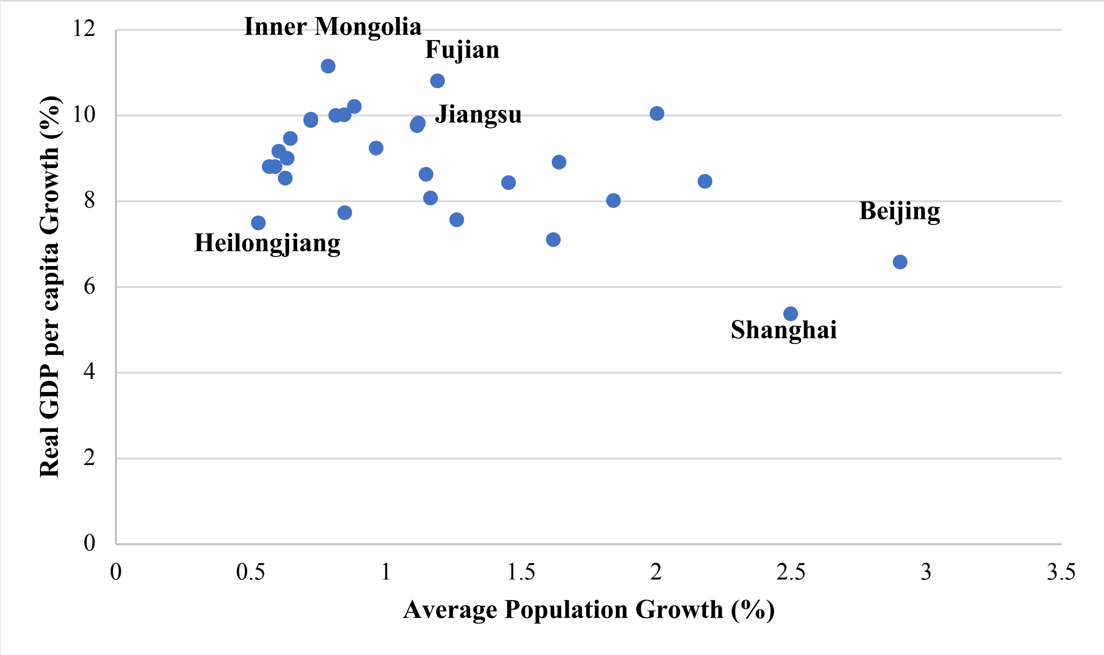
Figure 2.4: Average Real GDP per capita Growth Rates and Initial Level (1985): 29 Provinces 1986-2013



Source: Author's analysis based on data collected from the Statistics Yearbook 1985-2013 of each selected province and China Population & Employment Statistics Yearbook 1988-2013.

Figure 2.5 indicates that developed provinces like Shanghai and Beijing exhibit higher population growth rates but the lowest real GDP per capita growth. Provinces like Fujian, Jiangsu and Inner Mongolia have relatively high GDP per capita growth but lower population growth. Provinces with a lower level of average GDP growth exhibit higher levels of real GDP per capita, (e.g. Shanghai and Beijing), in line with convergence. Provinces like Heilongjiang have relatively low GDP per capita growth and lower population growth.

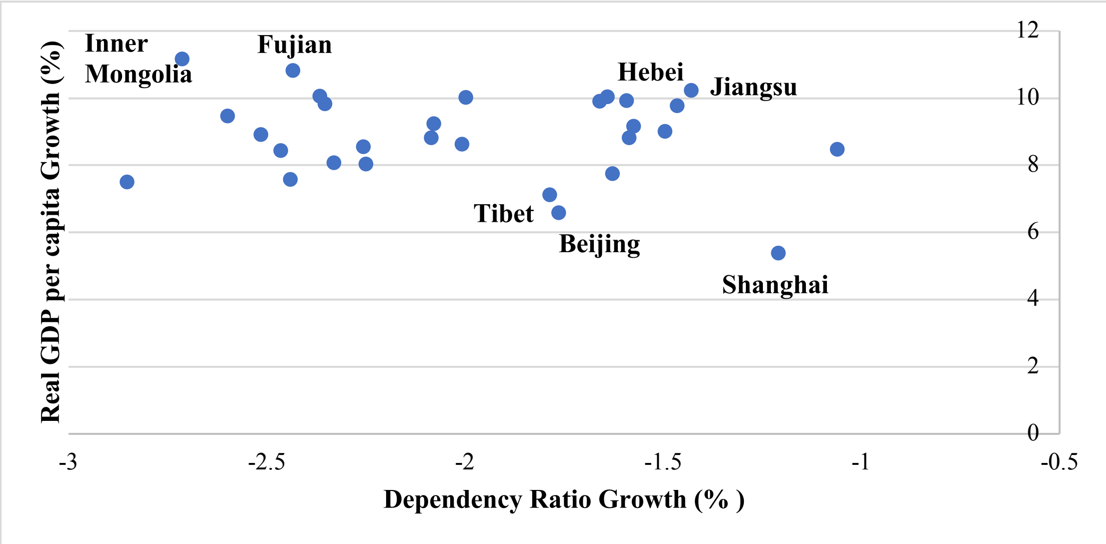
Figure 2.5: Average Population Growth Rates and Average Real GDP per capita Growth Rates: 29 Provinces 1986-2013



Source: Author's analysis based on data collected from the Statistics Yearbook 1985-2013 of each selected province and China Population & Employment Statistics Yearbook 1988-2013.

In Figure 2.6, Provinces like Shanghai, Beijing and Tibet exhibit lower GDP per capita growth but have a higher levels of dependency ratio growth. Provinces like Fujian and Inner Mongolia have lower levels of dependency growth and GDP per capita growth. Provinces Jiangsu and Hebei exhibits higher GDP per capita growth and also have a higher level of growth in the dependency ratio.

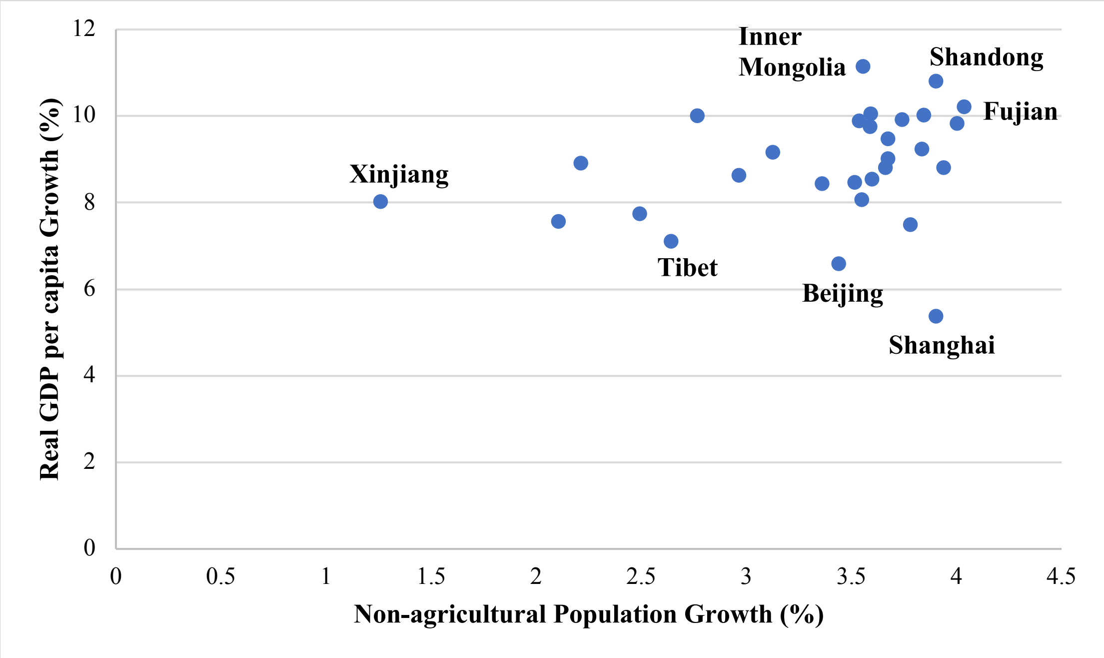
Figure 2.6: Average Dependency Ratio Growth Rates and Average Real GDP per capita Growth Rates: 29 Provinces 1986-2013



Source: Author's analysis based on data collected from the Statistics Yearbook 1985-2013 of each selected province and China Population & Employment Statistics Yearbook 1988-2013.

Figure 2.7 (see next page) presents growth rates of non-agricultural population ratio and real GDP per capita in 29 provinces from 1985-2013. Provinces like Shanghai, Beijing and Tibet have lower GDP per capita growth rates and also lower non-agricultural population ratio growth. Provinces like Shandong, Inner Mongolia and Fujian have higher levels of non-agricultural population ratio growth and real GDP per capita growth. Provinces like Xinjiang have higher GDP per capita growth rates but have lower non-agricultural population ratio growth.

Figure 2.7: Average Non-agricultural Population Ratio Growth Rates and Average Real GDP per capita Growth Rates: 29 Provinces 1986-2013



Source: Author's analysis based on data collected from the Statistics Yearbook 1985-2013 of each selected province and China Population & Employment Statistics Yearbook 1988-2013.

2.4 RESEARCH METHODS

In this section, approaches for the current research, the research model and methods are explored.

2.4.1 Implications for Current Research

Based on literature explored above, this chapter sets out to empirically test the relationship between population growth and economic growth in China using recently available data at province level.

- **Data**

This chapter add to the debate about the impact of population growth on economic growth in China. This chapter uses updated province level data rather than the aggregate data in China; this is the key difference compared to the studies of Zhang (2006), Li (2009), Yao, Kinugasa and Hamori (2013). Because of the longer time period of data, this chapter can be seen as a continuation of the research using province level data of China, including studies by Bonnefond (2015) and Chen (2011). Also, some studies use only total population, such as Bonnefond (2015), but this chapter also includes the dependency ratio that examines the effect of working age population on economic growth in China, and also compares the effect of working age population and total population. While similar variables are used in this chapter compared to previous studies relevant differences are illustrated in the next sub section.

- **Research Methods & Techniques**

This chapter mainly uses panel data methods and the fixed effects model, random effects model and System GMM similar to Konig (2015), Bonnefond (2015) and Dippel (2014). The VECM model, which is used in the study of Yao, Kinugasa and Hamori

(2013), is suitable for time series data but not for panel data; and panel data is used in this analysis.

- **Research Development**

In terms of studies using similar research methods and data, such as Bonnefond (2015), this chapter divides 29 provinces into different groups based on geographical location (following divisions used by the National Bureau of Statistics of China) and development level (based on real GDP per capita from 1985-2013) to examine the differences between different provinces and groupings of provinces in China. The key reason for grouping provinces is the substantial gap between the economic growth in developed provinces and undeveloped areas (evident in earlier Figures and Tables). The focus remains on different measures of population, without accounting directly for quality.

2.4.2 Research Model and Variables

The basic model takes the form:

$$Y_{it} = a_0 + a_1 POP_{it} + a_2 Z_{it} + \varepsilon_{it} \quad (2.10)$$

In this Solow-type equation, the dependent variable Y_{it} is the growth rate of real GDP per capita; population variables (POP) and a vector of conditioning information that controls for other factors associated with economic growth (Z) in provinces of China; ε is the error term.

In estimation, GDP_{it} is the dependent variable which denotes the growth rate of real GDP per capita, as in Yao, Kinugasa and Hamori (2013) and Huang (2012).

The set of variables for population include three variables, POP1, POP2, POP3.

POP1 presents the total population growth rate; this is similar to the research of Zhang (2006) and Chen (2011). Bonnefond (2015) used a different approach where population measured of the natural growth rate, calculated as (birth rate - death rate) + rate of technical progress + depreciation rate.

POP2 represents the dependency ratio growth rate. Yao, Kinugasa and Hamori (2013) used the inverse of this i.e. the working age population rather than the dependency ratio.

POP3 is the non-agricultural population ratio growth rate, which refers to the proportion of total non-agricultural population in total population.

The control variables include rates of new patent applications (NP) and real fixed asset investment per capita growth rate (RFAI) as additional independent variables (included in Z, it from Equation 2.8). NP denotes the growth rate of new patent applications per 10,000 people that tests the effect of technology on economic growth. In related research, Yao, Kinugasa and Hamori (2013), used TFP as the variable of innovation calculated following a DEA approach and Solow residual. The DEA approach developed by Coelli (1996) uses linear programming to measure annual production frontier shifts. Because it is difficult to find a variable at province level to measure technological process, this chapter selects the growth rate of new patent applications per 10,000 people. Preliminary analysis in section 2.3 shows that the growth in new patent applications has a positive relationship with real GDP per capita growth.

RFAI denotes the growth rate of real fixed asset investment per capita. This variable is included to test the effect of capital investment on economic growth (as in Huang, 2012). Bonnefond (2015) used ‘investment’ as a variable in empirical research which is calculated as the proportion of gross fixed capital formation in real total GDP. Yao, Kinugasa and Hamori (2013) used the savings rate to represent the effect of capital on economic growth. This chapter initially considered using the same measure as in Yao, Kinugasa and Hamori (2013) but the data in some years is incomplete. Therefore, real fixed asset investment per capita is used instead. Earlier indications in Section 2.3 suggests that growth in real fixed asset investment per capita has a positive relationship with GDP per capita growth.

Given the earlier discussion of the literature, a number of hypotheses are identified for testing.

Hypothesis 1:
H0: Total population growth does not have a negative relationship with GDP per capita growth.
H1: Total population growth has a negative relationship with GDP per capita growth.

Hypothesis 2:
H0: Growth in the dependency ratio does not have a negative relationship with GDP per capita growth.
H1: Growth in the dependency ratio has a negative relationship with GDP per capita growth.

Hypothesis 3:
H0: The non-agricultural population ratio growth does not have a positive relationship with GDP per capita growth.
H1: The non-agricultural population ratio growth has a positive relationship with GDP per capita growth.

Hypothesis 4:
H0: Growth in New patent applications does not have a positive relationship with real GDP per capita growth.
H1: Growth in New patent applications has a positive relationship with real GDP per capita growth.

Hypothesis 5:

H0: Growth in Real fixed asset investment per capita does not have a positive relationship with GDP per capita growth.

H1: Growth in Real fixed asset investment per capita has a positive relationship with GDP per capita growth.

- **Panel Estimation of the Hypotheses**

Panel data estimation is applied in this chapter to measure the effect of population on economic growth in 29 provinces between 1985-2013. Panel data (also known as longitudinal or cross-sectional time-series data) is a dataset in which the behaviour of entities is observed across time. The panel data allows to control for variables which cannot be observed or measured like cultural factors or differences in business practices across companies; or variables that change over time but not across entities (i.e. national policies, federal regulations, international agreements, etc.). Individual heterogeneity is also accounted for (Reyna, 2007).

Both Fixed/Random effects model and Generalized Method of Moments (GMM) estimation for panel data estimation are used to test the relationship between population growth and economic growth. As panel data are used, VAR and VECM models are not appropriate.

As discussed in Reyna (2007) and Wooldridge (2013), fixed effects models explore the relationship between predictor and outcome variables within an entity (country, person, company, etc.). Each entity has its own individual characteristics that may or may not influence the predictor variables. The model assumes that factors within the individual may impact or bias the predictor or outcome variables. However, fixed effects models also remove the effect of those time-invariant characteristics so that the net effect of the predictors on the outcome variable can be accessed (Reyna, 2007). Fixed effects models assume that time-invariant characteristics are unique to the individual and should not be correlated with other individual characteristics. Each entity is different therefore the entity's error term and the constant (which captures individual characteristics) should not be correlated with the others. If the error terms are correlated, then fixed effects model is not suitable since inferences may not be correct and random effects models probably should be applied (Reyna, 2007; Wooldridge, 2013).

Unlike the fixed effects model, the random effects model assumes that the variation across entities is random and uncorrelated with the predictor or independent variables included in the model. An advantage of the random effects model is that the time invariant variables (i.e. location development level) can be included which these variables are only absorbed by the intercept in the fixed effects model. Random effects models assume that the entity's error term is not correlated with the predictors which allows for time-invariant variables to play a role as explanatory variables in this chapter (Reyna, 2007; Wooldridge, 2013).

The GMM estimation is used for the dynamic panel data estimation. When the strict exogeneity assumption is violated, commonly used static panel data techniques such as fixed effects estimators are inconsistent, because these estimators require strict exogeneity. Unlike static panel data models, dynamic panel data models include lagged levels of the dependent variable as regressors. Including a lagged dependent variable as a regressor violates strict exogeneity, because the lagged dependent variable is necessarily correlated with the idiosyncratic error (Arellano and Bond 1991).

Further details of the fixed/random effects model are presented later.

2.4.3 Steps in Estimation

To deal with the panel data, there are three main steps to follow.

- **Step 1: Unit Root Test**

The first step is to run a unit root test. The unit root test is set to examine whether the data are stationarity. Non-stationarity data with a unit root leads to unreliable regression results (spurious regression). For the unit root test of panel data[25], Levin and Lin (1993) propose the LL test. Levin, Lin and Chu (2002) further developed the method and put forward the LLC method. The advantage of LLC method is that it can be used on data with different intercept and time series, heteroscedasticity and higher-order serial correlation. Levin, Lin and Chu (2002) recommend using their test with panels of "moderate" size, which they describe as having between 10 and 250 panels and 25 to 250 observations per panel. Even though there are other methods of unit root test like IPS, Fisher-PP and Fisher-ADF, Gu (2010) argues the method of LLC has the lowest failure rate of unit root test for the same panel data. In this chapter, LLC is the main method used to test for unit roots.

The LLC test is based on the method of the Dickey-Fuller (DF) or Augmented Dickey-Fuller (ADF) test. Compared with the LLC test, the ADF test is simpler that is more suitable to time-series data (Wooldridge, 2013). The formula for the LLC test is as follows.

$$\Delta y_{it} = \delta y_{it-1} + \sum_{L=1}^{pi} \theta_{iL}\, \Delta y_{it-L} + z_{it}\gamma_i + \varepsilon_{it},\ m = 1,2,3 \ldots (2.11)$$

In equation (2.11), i denotes panels; t denotes time; y_{it} is the variable being tested; and ε_{it} is a stationary error term. The z_{it} term can represent panel-specific means, panel-specific means and a time trend, or nothing, depending on the options specified. By default, z_{it} = 1, so that the term $z_{it}\gamma_i$ represents panel-specific means (fixed

[25]Discussion of unit root test is sourced from Levin and Lin (1993) and Levin, Lin and Chu (2002).

effects). If trend is specified, $z_{it} = (1, t)$ that $z_{it}\gamma_i$represents panel-specific means and linear time trends (Levin, Lin and Chu 2002).

The hypotheses of LLC test are as following:

$\mathrm{H}_0 = \delta_1 = \delta_2 = \cdots = \delta_n = 0$ (2.12)

$\mathrm{H}_1 = \delta_1 = \delta_2 = \cdots = \delta_n < 0$ (2.13)

Then, the data is combined and computed t_δ and t_δ^* by t-test. If both t_δ and t_δ^* converge to the standard normal distribution, then the null hypothesis (or not) can be rejected by checking the table of normal distribution (Levin, Lin and Chu, 2002).

If the original data are not stationarity, the data cannot be used to do co-integration test or run the estimations. The data may be changed to the same order by using logs or by converting them into first differences (for example) to make them the same order. If the data, however, is balanced and stationary, the estimations can be run directly without co-integration tests. If the data are of the same order but not stationary, we can turn to co-integration test (Wooldridge, 2013).

- **Step 2: Co-integration Test**

The second step for dealing with panel data is the co-integration test. The co-integration test is used to test the co-integrating relationship (a stable, long-run relationship) between variables when the original data are nonstationary data at same order of differences (Wooldridge, 2013). A stationary process has a time-invariant mean and a time-invariant variance. A nonstationary process may wander arbitrarily over time because its first two moments vary over time. The first difference, denoted I(1), of a nonstationary process is stationary, the process is said to be integrated of order one. The series are said to be cointegrated when a linear combination of several I(1) series is stationary that I(1) series are in a long-run equilibrium and move together (Engle and Granger 1987).

Multiple co-integration tests - such as Kao test and Pedroni test – are available in Stata and are applied in estimations, and the null hypothesis are set as 'no cointegration among the series.

- **Step 3: Fixed/Random Effects Model**[26]

The final step is choosing the estimation approach appropriate to the panel data. The two main models are the fixed effects and random effects models. Compared with time series data, using panel data regression has some advantages. First, more observations can improve the accuracy of the estimates. Second, the panel data techniques estimate the macro relationship between variables in different panels removing the time period impact that explains more accurately the relationship between variables for short periods of data. Third, compared with time series data, using panel data in the regression model can explain the macro dynamic process of variables for multiple provinces rather than single province (Allison, 2009; Wooldridge, 2013).

Wooldridge (1999: 484) notes that 'first differencing is just one of the many ways to eliminate the fixed effect,α_i. An alternative method, which works better under certain assumptions, is called the fixed effects transformation'.

To employ a fixed effects model, a general regression is always run first, such as:

$\mathrm{Y} = \alpha + \beta\mathrm{X} + \varepsilon$ (2.14)

If panel data is used, equation (2.15) applies.

$Y_{it} = \alpha_i + \beta X_{it} + \varepsilon_{it}\ i = 1,2 \ldots n;\ t = 1,2 \ldots T$ (2.15)

In equation (2.15), 'i' denotes the number of the unit in the panel data and 't' denotes the length of the time. For the fixed effects model, equation (2.15) should be transformed into equation (2.16) by adding γ_i as the unit-specific error term; it differs between units, but for any particular unit, its value is constant.

[26] The principles of the Fixed Effect Model and the Random Effect Model are sourced from 'Introductory Econometrics' 5th Edition (2013), authored by Wooldridge; 'Econometric Analysis of Panel Data' (2008) Bai.

$Y_{it} = \alpha_i + \beta X_{it} + \gamma_i + \varepsilon_{it}\; i = 1,2 \dots n;\; t = 1,2 \dots T$ (2.16)

In this model, $\gamma_i + \varepsilon_{it}$ denotes the error term and β is the coefficient of independent variable; γ_i denotes the unit-specific error term; it differs between units, but its value is constant for any particular unit. ε_{it} is the 'usual' error term with the usual properties (mean 0, uncorrelated with itself, uncorrelated with X_{it}, uncorrelated with γ_i, and homoskedastic), although in a more thorough development. Transforming equation (2.16) to (2.17)

$\bar{y}_i = \beta_i \bar{x}_i + \gamma_i + \bar{\mu}_i$ (2.17)

Where $\bar{y}_i = T^{-1}\sum_{t=1}^{T} y_{it}$, $\bar{x}_i = T^{-1}\sum_{t=1}^{T} x_{it}$, $\bar{\mu}_i = T^{-1}\sum_{t=1}^{T} \mu_{it}$. If we subtract (2.17) from (2.16) for each t, such that

$y_{it} - \bar{y}_i = \beta_1(x_{it} - x_i) + \mu_{it} - \ddot{\mu}_i, t = 1,2 \dots \dots T$ (2.18) or

$\ddot{y}_{it} = \beta_1 \ddot{x}_{it} + \ddot{\mu}_{it}\;\; t = 1,2 \dots \dots T$ (2.19)

Where $\ddot{y}_{it} = y_{it} - \bar{y}_i$ denotes the time-demeaned data on y, and similarly for $\ddot{x}_{it}$ and $\ddot{\mu}_{it}$.

The fixed effects transformation is also called the 'within' transformation. There is an unobserved effect γ_i which disappears, in equation (2.18) and (2.19), that needs to be estimated by pooled OLS. A pooled OLS estimator that is based on the time-demeaned variables is called the fixed effects estimator or the 'within' estimator. For equations (2.18) and (2.19), pooled OLS uses the time variation in *y* and *x* within each cross-sectional observation.

The 'between' estimator is obtained as the OLS estimator from the cross-sectional equation (2.17) (where an intercept, β_0 is included): the time averages for both *y* and *x* is used and then a cross-sectional regression is run. The 'between' estimator ignores important information on how the variables change over time (Allison, 2009; Wooldridge, 2013).

Based on an exogeneity assumption on the explanatory variables, the fixed effects estimator is unbiased: the μ_{it} should be uncorrelated with each explanatory variable across all time periods. The fixed effects estimator also allows for arbitrary correlation between γ_i and the explanatory variables in any time period. Any explanatory variable that is constant over time for all i gets swept away by the fixed effects transformation: $\ddot{x}_{it} = 0$ for all i and t. However, $\ddot{x}_{it}$ cannot be a constant across *t* that means that time irrelevant dummy variables such as geographical and development level cannot be explained in the fixed effect estimation (Allison, 2009; Wooldridge, 2013).

An example of how the fixed effects model is used is Garcia-Milà (1996), who found that public investment had a positive effect on economic growth of 48 contiguous states in the U.S from 1970-1983. Nair-Reichert (2001) used a similar method with the fixed effects model to find that FDI promoted economic growth in 24 developing countries from 1971 to 1995. Other examples include De Silva (2015), König (2015), Dippel (2014) and Bonnefond (2015).

As a basic panel data estimation technique, the fixed effects model is applied for the basic research model[27], which is transformed to equation (2.20) as follows.

$Y_{it} = a_0 + \alpha_1 POP_{it} + a_2 Z_{it} + \delta_i + \lambda_t + \varepsilon_{it}$ (2.20)

Where δ_i incorporates the individual-specific (time-invariant) effect and λ_t time-specific (individual-invariant) effect.

- **Random Effects Model**

The random effects model is an alternative to the fixed effects model. The random effects model has a similar starting point:

$$Y_{it} = \alpha_i + \beta_0 + \beta_1 X_{it1} + \beta_2 X_{it2} + \cdots + \beta_j X_{itk} + \varepsilon_{it}, j = 1,2 \ldots k;\ t = 1,2 \ldots T$$
(2.21)

[27] See equation (2.15).

This equation includes an intercept and leads the means of α_i equal to zero. One of the basic goals for the fixed effects model is eliminating α_i because it is thought to be correlated with one or more of the X_{itj}. However, α_i is uncorrelated with each explanatory variable in all time periods so that a transformation to eliminate α_i results in inefficient estimators. Equation (2.21) can be transformed to the random effects model when the unobserved effect α_i is uncorrelated with each independent variable (Allison, 2009; Wooldridge, 2013).

$\mathrm{Cov}(X_{itj}, \gamma_i) = 0, \; j = 1,2 \ldots k; \; t = 1,2 \ldots T$ (2.22)

The ideal random effects assumptions include all of the fixed effects assumptions plus the additional requirement that α_i is independent of all explanatory variables in all time periods. If the unobserved effect α_i is correlated with any explanatory variables, the first differencing or fixed effects model should be used. For the estimating of β_j, α_i is uncorrelated with the explanatory variables that β_j can be consistently estimated by using a single cross section. Using a single cross section disregards much useful information in the other time periods. The pooled OLS can also use for data estimation of Y_{it} on the explanatory variables (Allison, 2009; Wooldridge, 2013).

The composite error term of the random effects model is defined as the $v_{it} = \gamma_{it} + \mu_{it}$ and the formula is d as following:

$Y_{it} = \alpha_i + \beta_0 + \beta_1 X_{it1} + \beta_2 X_{it2} + \cdots + \beta_k X_{itk} + v_{it}$ (2.23)

Where α_i is in the composite error in each time period, the v_{it} are serially correlated across time. Wooldridge (1999) argues that the usual pooled OLS standard errors ignore the positive correlation of serial correlation in the error term and it can be substantial. Based on this phenomenon, generalized least squares (GLS) can be used to estimate models with autoregressive serial correlation.

Bai (2008) also put forward a similar argument to Wooldridge (1999). The random effects model assumes that the unobserved effect is uncorrelated with all independent variables, whether the independent variables are fixed over time or not. In many applications, the whole reason for using panel data is to allow the unobserved effect to be correlated with the independent variables. If the θ which the value is between 0 and 1 is set and added to the equation (2.23), the parameter θ can always be estimated by pooled OLS or fixed effects.

$$y_{it} - \theta\bar{y}_i = +\beta_0(1-\theta) + \beta_1(X_{it1} - \theta\bar{X}_{i1}) + \cdots + \beta_k(X_{itk} - \theta\bar{X}_{ik}) + v_{it} \quad (2.24)$$

Wooldridge (1999) notes that when econometrics packages support estimation of random effects models and automatically compute some version of $\hat{\theta}$, feasible GLS estimator that uses $\hat{\theta}$ in place of θ is called the random effects estimator. For the relationship between fixed effects and random effects model, pooled OLS is obtained when $\theta = 0$, and fixed effect is obtained when $\theta = 1$. If $\hat{\theta}$ is close to zero, the random effect estimates will be close to the pooled OLS estimates. In other words, if the time period of dataset is large enough and $\hat{\theta}$ close to 1 that the random effect is similar to the fixed effect.

For the method of distinguishing between fixed effects and random effects models, Wooldridge (1999) and Bai (2008) state that if the key independent variable is constant over time, fixed effects cannot be use to estimate its effect. If random effects model is used, as many time-constant controls as possible are included among the independent variables, the random effect model is preferred to pooled OLS because it is generally more efficient. The Hausman test is used to choose between the fixed or random effects model. In this test, the null hypothesis is random effects estimation and the P value is higher than 0.05 that means there is random effect parameters in the regression, the null hypothesis cannot be rejected that the random effects model should be used.

- **GMM Estimation**[28]

GMM estimation is applied in this chapter to identify the dynamic impacts of population quantity changes on economic growth by adding the lagged dependent variable as the independent variable, which is different to the fixed/random model. Based on Matyas and Sevestre (2008), the fixed-effects estimator (also called within estimator) is obtained by ordinary least squares (OLS) on the deviations from the means of each variable but this estimator can provide biased estimations if the number of time periods is small or the lagged value of the dependent variable is correlated with individual effects. Bond (2001) also explains that the estimation of growth regressions may raise several problems such as the explanatory variables can be endogenous because of reverse causality or measurement errors; the within estimator has been shown to produce estimations of parameters that are inconsistent and biased downward in presence of endogeneity (Nickell, 1981); omitted variables also can bias the estimations (Bonnefond, 2015). Mileva (2007) argues that there are some problems that may arise from the panel data estimation. For example, time-invariant country characteristics (fixed effects), such as geography and demographics, may be correlated with the independent variables. Lagged dependent variables may raise the autocorrelation and sometimes panel data will have a short time period but with a large cross-section.

To address the above problems, Holtz-Eakin (1988) and Arellano and Bond (1991) suggest estimating dynamic panel data models using the Generalized Method of Moments (GMM), which includes the lagged endogenous variable as an explanatory variable to consider the impacts of previous changes in endogenous variable on current endogenous variable in a certain dynamic time period, for example:

$$y_{it} = +\beta_0 + \beta_1 y_{it-1} + \beta_2 X_{it} + \varphi_{it} + \varepsilon_{it} \quad (2.27)$$

Equation (2.28) is an equation of the system GMM that propose to estimate the

[28] This part is mainly source from the Mileva (2007), Matyas and Sevestre (2008), Holtz-Eakin(1988) and Arellano and Bond (1991).

regression equation with a first-differentiated GMM estimator. y_{it-1} is the lagged dependent variable and the φ_{it} is an unobserved regional-specific effect. For the specific effect of individuals,

$$y_{it} - y_{it-1} = \beta_1(y_{it-1} - y_{it-2}) + \beta_2(X_{it} - X_{it-1}) + (\varphi_{it} - \varphi_{it-1}) + (\varepsilon_{it} - \varepsilon_{it-1}) \quad (2.28)$$

To measure the dynamic process of the panel data, instrumental variables[29] are applied in the GMM estimation which is another key difference with the fixed effects model. Arellano and Bond (1991) suggest to use the lagged levels of the lagged endogenous variable y_{it-1} as instruments for $(y_{it-1} - y_{it-2})$, and the lagged levels of the explanatory variables X_{it} as instruments for $(X_{it} - X_{it-1})$. Some limitations have been identified for the above approach. Blundell and Bond (1998) point out that the first-differentiated GMM estimator may provide biased results in the case of finite sample sizes, and that the lagged levels of the variables cannot be considered as reliable instruments when the dependent and the independent variables are continuous.

Bonnefond (2015) states that $(y_{it-1} - y_{it-2})$ might be correlated with the error term$(\varepsilon_{it} - \varepsilon_{it-1})$. As a consequence, it is necessary to resort to instrumental variables techniques (for t> 2). Because there are also some problems about the GMM model such as weak instrument problem, Arellano and Bover (1995) and Blunchangedell and Bond (1998) suggest another method based on the system GMM estimator. This estimator combines the standard set of equations in first-differences, $(y_{it-1} - y_{it-2})$ and $(X_{it} - X_{it-1})$ variables, with suitably lagged levels as instruments; and also with an additional set of equations in levels, y_{it-1} and X_{it} variables, with suitably lagged

[29] An instrumental variable (sometimes called an "instrument" variable) is a third variable which used in regression analysis when you have endogenous variables—variables that are influenced by other variables in the model. In other words, it is used to account for unexpected behavior between variables. Using an instrumental variable to identify the hidden (unobserved) correlation allows you to see the true correlation between the explanatory variable and response variable; source: https://www.statisticshowto.datasciencecentral.com/instrumental-variable/.

first-differences as instruments.

There is also a two-step method to address the problem of heteroscedasticity of GMM. The first step is getting the residuals from the first-step estimation and the second step is to use them in order to perform a robust estimation of the variance-covariance matrix. In other words, to eliminate this potential bias, Windmeijer (2005) proposes a finite sample correction for the variance-covariance matrix when using the two-step GMM estimator.

There are two issues with the system GMM estimator. First, the set of instrumental variables must be valid, for example it must be uncorrelated with the error terms. This hypothesis is tested using Hansen test of over-identifying restrictions. Second, the absence of second-order autocorrelation (AR2) in residuals must be verified, while a negative first-order autocorrelation (AR1) may be detected. This second hypothesis is tested using Arellano-Bond tests for AR1 and AR2 (Arellano and Bond, 1991). So, the System GMM estimation might provide more accurate coefficients of dynamic panel data regression compared with the fixed effects model because the endogenous biases are avoided.

To test the dynamic effects of population on economic growth in China, the System GMM estimation with two steps is used to avoid the possible limitation raised above. Based on the standard panel data equation (2.20), it is transformed as follows:

$Y_{it} = a_0 + \varphi_{it} + \gamma_0 RGDPPC_{it-1} + \alpha_1 POP_{it} + a_2 Z_{it} + \varepsilon_{it}$ (with suitably lagged first-differenced explanatory variables, such as $D.POP_{it-1}$ as instruments) (2.29)

In the above equation, $D.RGDPPC_{it-1}$ represents the lag of the first-differenced real GDP per capita growth rate, $D.POP_{it}$ is the first-differenced variables for population and $D.Z_{it}$ are the first-differenced vectors of conditioning information that control for other factors associated with economic growth. φ_{it} is an unobserved province specific effect. The System GMM estimation includes the lagged endogenous variable as independent variables to first-difference the equation in order to eliminate individual specific effects identified in Holtz-Eakin (1988) and Arellano and Bond (1991). Roodman (2009) argues that using too many instruments can produce biased results in GMM estimation. Arellano and Bover (1995) also suggest to use only the most recent difference as an instrument for the level specification of explanatory variables, because other lagged first-differences would result in redundant moment conditions. So, the GMM estimations in this chapter limit the number of lags for both the dependent and explanatory variables to one.

- **Granger Causality Test**

Considering the limitation of observations, a Granger Causality test is applied to identify the impact of population variables on economic growth in each province as additional results.

Granger causality is a statistical hypothesis test for determining whether one time series is useful in forecasting another (Granger, 1969). Two principles for the causality relationship are defined by Granger (1969), which are:
(1) The cause happens prior to its effect.
(2) The cause has unique information about the future values of its effect.

For a stationary time-series dataset, the Granger Causality test is performed using the level values of two (or more) variables. If the variables are non-stationary, then the test is done using first (or higher) differences. Any particular lagged value of one of the variables is retained in the regression if it is significant according to a t-test, and the other lagged values of the variable jointly add explanatory power to the model according to an F-test. Then the null hypothesis of no Granger causality is not rejected if and only if no lagged values of an explanatory variable have been retained in the regression (Granger, 1969; Walter, 2004).

For example, assume Y and X are stationary time series variables. To test the null hypothesis that X does *not* Granger-cause Y, one first finds the appropriate lagged values of Y to include in a univariate autoregression of Y as the equation (2.30)

$$Y_t = a_0 + a_1 Y_{t-1} + \cdots a_m Y_{t-m} + \varepsilon_t \quad (2.30)$$

Then, the autoregression is augmented by including lagged values of X as in equation (2.31).

$$Y_t = a_0 + a_1 Y_{t-1} + \cdots a_m Y_{t-m} + b_p X_{t-p} + \cdots + b_q X_{t-q} + \varepsilon_t \quad (2.31)$$

One retains in this regression all lagged values of X that are individually significant according to their T-statistics, provided that collectively they add explanatory power to the regression according to an F-test. In the notation of the above augmented regression, p is the shortest, and q is the longest, lag length for which the lagged value of X is significant. The null hypothesis which 'X does not Granger-cause Y' cannot be rejected only if no lagged values of X are retained in the regression (Granger, 1969, 2004; Walter, 2004).

2.5: EMPIRICAL RESULTS

This section provides the results of estimating the economic growth and population models. Results of hypotheses testing is provided.

2.5.1 Relationship between Population Growth and Economic Growth by Provinces in China

In this sub section, estimates of the relationship between population growth and economic growth are provided using a panel of data and employing the fixed effects model, random effects model and the System GMM Estimation. The first set of estimations focuses on the model using province-level data.

Table 2.10 shows the results of the unit root test and the LLC test is applied. The LLC unit root test is applied for all data and the results reject the null hypotheses of non-stationarity.

Table 2.10: Results of Unit Root Tests

Variables	**29 Provinces**	**Eastern Area**	**Middle Area**	**Western Area**	**Developed Area**	**Developing Area**	**Less Developed Area**
ΔReal GDP per capita	-5.87***	-5.45***	-2.62***	-1.96**	-4.19***	-2.95***	-2.94***
ΔPOP1	-6.86***	-4.95***	-3.93***	-3.02***	-4.34***	-4.41***	-3.53***
ΔPOP2	-13.97***	-8.77***	-8.48***	-6.91***	-8.65***	-9.01***	-6.26***
ΔPOP3	-8.61***	-4.80***	-4.24***	-6.06***	-3.93***	-5.15***	-6.23***
ΔNP	-8.29***	-4.37***	-4.89***	-5.32***	-5.56***	-5.57***	-4.95***
ΔRFAI	-7.02***	-7.14***	-6.99***	-6.01***	-6.83***	-4.70***	-7.59***
Notes: Symbols ***, ** and * show the null hypotheses of non-stationarity are rejected at 1%, 5% and 10% level of significance respectively.							

Source: Source: Author's Analysis

Table 2.11 shows some key results. The relationship between economic growth and population variables was computed using growth rate data of 29 provinces from 1986 to 2013. Three sets of results are provided based on different estimation methods; Fixed Effects (FE), Random Effects (RE), and General Method of Moments (GMM). The result of Hausman test for FE and RE models indicates that the RE is the focus of the results. For the GMM estimation, the result of Hansen test reflects validity of additional moment restrictions, which means the instruments in GMM estimation are valid. The Arellano-Bond test results in Table 2.10 reflects that estimations are in line with the System GMM assumptions.

Table 2.11: Relationship between Population Growth and Economic Growth in China using Data of 29 provinces, 1986-2013

Variables	Dependent Variable: ΔReal GDP per capita		
	FE	RE	GMM
ΔPOP1	-0.48*** (0.12)	-0.44*** (0.05)	-1.44*** (0.56)
ΔPOP2	-0.12*** (0.04)	-0.12*** (0.03)	-0.34*** (0.12)
ΔPOP3	-0.06 (0.21)	-0.07 (0.19)	0.20*** (0.04)
ΔNP	-0.01 (0.03)	-0.01 (0.01)	0.02 (0.01)
ΔRFAI	0.19*** (0.01)	0.19*** (0.01)	0.26*** (0.04)
$\Delta \mathbf{RGDPPC}_{\mathbf{i\,t-1}}$			-0.08 (0.10)
Constant	6.81*** (0.37)	6.83*** (0.41)	9.01*** (1.29)
R-square	0.37	0.26	
Hansen Test			0.893
AR(1)			0.002
AR(2)			0.564
Notes: Standard error is presented below the corresponding coefficient. Symbols ***, ** and * show 1%, 5% and 10% level of significance respectively.			

Source: Author's Analysis

The Hausman Test results indicate that the RE is preferable, which means the data has stronger effects 'between' groups than the individual-specific effects within groups (Allison, 2009; Wooldridge, 2013). In Table 2.10, for the RE results, total population growth in China, $\Delta POP1$, has a negative and significant effect on economic growth (1% level of significance) with a coefficient of -0.44. This finding is similar in sign and size to findings internationally and the Chinese economy: Konig (2015), Bonnefond (2015), Banerjee (2012) and Yamaguchi et al., (1973). The result indicates that an 1% increase in population growth is associated with a 0.44% decline in the growth rate of GDP per capita, so we reject the null hypothesis.

These results are in line with the pessimistic view of the effect of population growth on economic development. Compared with the coefficients of other variables, total population exhibits the strongest effect on GDP growth and it is much higher than the coefficients on the dependency ratio ($\Delta POP2$) and real fixed investment growth rate ($\Delta RFAI$).

The dependency ratio growth rate ($\Delta POP2$) has a negative and significant effect on the real GDP per capita growth with a coefficient of -0.12, which is in line with the results of Crenshaw (1997) and Yao, Kinugasa and Hamori (2013). The result indicates that an 1% increase in dependency ratio growth rate leads a 0.12% decline in the growth rate of GDP per capita. As the relative size of the working-age population across the provinces in China increased, the country's economic development has benefited significantly. The null hypothesis on the relationship between the dependency ratio and economic growth is rejected.

The non-agricultural population ratio growth rate ($\Delta POP3$) reflects impacts of both the changes proportion of the non-agricultural population and the extent of industrialization across the provinces. The results indicate that increasing non-agricultural population ratio growth rate has no statistically significant effect on economic growth. The null hypothesis cannot be rejected based on RE estimation.

The growth rate of real fixed asset investment also exhibits a positive and significant effect on GDP growth (with a coefficient of 0.19), which means an 1% increase in the real fixed asset investment per capita growth rate leads a 0.19% increase in the real GDP per capita growth rate. This result is similar with the studies of Bonnefond (2015), Yao, Kinugasa and Hamori (2013), Huang (2012), Chen (2011), Li et al., (2009) which reflects a key role of capital investment in the Chinese economy. The null hypothesis is rejected.

In these estimations, the growth rate of new patent applications has an insignificant effect on economic growth in China.

To identify the dynamic impacts of the model, lagged dependent variables should be included in an extended model, which might generate problems of endogeneity. The System GMM estimation is applied to avoid biased estimations if the number of time periods is small, and if the lagged value of the dependent variable is correlated with the individual effects (Matyas and Sevestre, 2008). System GMM can be seen as a method to measure dynamic processes for panel data with accurate coefficients by avoiding the multiple potential problems by using FE or RE models.

In Table 2.10 (column 3 results), total population has a stronger negative impact on economic growth, with a coefficient of -1.44. The negative impacts of growth in dependency ratio on economic growth is negative and stronger than random effects estimation result, with a coefficient of -0.34. The positive impact of the real fixed asset investment growth rate in dynamic panel estimation is stronger than the random effects estimation, with the coefficient of 0.58. A positive and significant impact of the non-agricultural population ratio is found in the System GMM estimation with a coefficient of 0.25. One-year lagged real GDP per capita growth rate which is added in the GMM estimation to measure the dynamic process of the panel data is insignificant in the model.

The above results indicate that growth in population represents a substantial barrier to economic growth in China. In the case of POP2, the change in working-age population has a more significant impact on economic growth than for POP3, the change in non-agricultural population. The contribution of capital investment to economic growth is a key finding of the results where the size of the impacts of capital investment ranges between 0.19 and 0.26.

Insignificant impacts of new patents growth rates based on both two model indicates an insignificant contribution of technological advance in economic growth across provinces in China.

Next, the 29 provinces are divided into groups based on different geographical areas and development levels, as introduced in Section 2.3.

2.5.2 Population growth and Economic Growth: Chinese Provinces in Different Groups

In this sub section, the relationship between the population growth and economic growth in different geographical and development level areas of China is discussed.

Table 2.12 presents the more detailed results of the different geographical areas. Comparing results between Table 2.10 and 2.11, the results are broadly similar.

Table 2.12 Relationship between Population Growth and Economic Growth in Different Geographical Areas of China (Different Group Regression)

Variables	Dependent Variable: Real GDP per capita Growth Rate					
	Eastern Area		Middle Area		Western Area	
	RE	GMM	RE	GMM	RE	GMM
ΔPOP1	-0.49***	-1.25**	-0.26***	-0.67***	-0.65***	-1.10***
	(0.12)	(0.74)	(0.08)	(0.17)	(0.36)	(0.09)
ΔPOP2	-0.17***	0.16	0.02	0.08	-0.16**	-0.27**
	(0.06)	(0.41)	(0.08)	(0.13)	(0.07)	(0.10)
ΔPOP3	0.05	0.64	0.21**	0.22***	0.02	0.03
	(0.06)	(0.47)	(0.09)	(0.08)	(0.09)	(0.13)
ΔNP	0.07*	0.03*	0.01	0.05	0.01	0.01
	(0.04)	(0.02)	(0.01)	(0.14)	(0.05)	(0.01)
ΔRFAI	0.20***	0.17**	0.19***	0.21***	0.20**	0.25***
	(0.02)	(0.08)	(0.03)	(0.02)	(0.03)	(0.05)
$\Delta\mathbf{RGDPPC}_{i\,t-1}$		0.34		0.03**		0.11
		(0.36)		(0.01)		(0.17)
Intercept	7.09***	2.06**	6.85***	5.36**	6.44***	5.38**
	(0.70)	(0.41)	(0.77)	(1.04)	(0.88)	(1.93)
R-square	0.34		0.25		0.22	
Hansen Test		0.789		0.830		0.896
AR(1)		0.044		0.012		0.007
AR(2)		0.723		0.186		0.725

Notes: Standard error is presented below the corresponding coefficient. Symbols ***, ** and * show 1%, 5% and 10% level of significance respectively.

Source: Author's Analysis

Comparing the coefficients of for different geographical areas, total population growth (POP1) exhibits strong negative impacts on economic growth in all three regions. Negative impacts of the dependency ratio growth are only detected for both models in the western area, and for the RE model in the Eastern area. The positive impacts of non-agricultural population ratio are identified in both models for the middle area alone which shows the importance of industrialization to economic growth. The results also indicate the similar contribution of the capital investment to economic growth in all three areas with coefficients between 0.17 and 0.25. Technological advance (NP) only plays a role in economic growth in the eastern area with relatively small coefficients of 0.3 and 0.7.

Results by geographical region are provided below:

Eastern Area:

- Population growth (Δ*POP1*) has negative and significant effects on real GDP per capita growth based on both models.
- Dependency ratio growth (Δ*POP2*) only has a negative effect on real GDP per capita growth in the RE estimation.
- Non-agricultural population ratio growth (Δ*POP3*) has insignificant effects on economic growth in both models
- New patent applications growth (Δ*NP*) has positive but weak effects on GDP per capita growth based on both models.
- Real fixed asset investment per capita growth (Δ*RFAI*) has positive effects on real GDP growth in both models.

Middle Area:

- Population growth (Δ*POP1*) has negative and strong effects on real GDP per capita growth in both models.
- Dependency ratio growth (Δ*POP2*) has insignificant effects on real GDP per capita growth in both models.

- Non-agricultural population ratio growth (Δ*POP3*) has a positive and significant effect on GDP per capita growth in both models.
- New patent applications growth (Δ*NP*) has insignificant effects on GDP per capita growth in both models.
- Real fixed asset investment per capita growth (Δ*RFAI*) has positive effects on real GDP growth in both models.

Western Area:

- Population growth (Δ*POP1*) has negative and strong effects on real GDP per capita growth in both models.
- Dependency ratio growth (Δ*POP2*) has negative effects on real GDP per capita growth in both models.
- Non-agricultural population ratio growth (Δ*POP3*) has insignificant effects on GDP per capita growth in both models
- New patent applications growth (Δ*NP*) has insignificant effects on GDP per capita growth in both models.
- Real fixed asset investment per capita growth (Δ*RFAI*) has positive effects on real GDP growth in both models.

Table 2.13 illustrates the results for three development areas. The results in Table 2.11 are broadly similar with those in Table 2.10 with minor differences.

Table 2.13 Relationship between Population Growth and Economic Growth in Different Development Level Areas of China (Different Group Regression)

Variables	Dependent Variable: Real GDP per capita Growth Rate					
	Developed Area		Developing Area		Less Developed Area	
	RE	GMM	RE	GMM	RE	GMM
ΔPOP1	-0.01	-0.93***	-0.85***	-1.38**	-1.58***	-2.49**
	(0.16)	(0.17)	(0.17)	(0.56)	(0.40)	(1.10)
ΔPOP2	-0.23***	-0.44***	-0.01	-0.09	-0.18**	-0.16**
	(0.06)	(0.08)	(0.05)	(0.15)	(0.08)	(0.07)
ΔPOP3	-0.13	-0.22	0.17**	0.26***	0.04	-0.02
	(0.10)	(0.19)	(0.07)	(0.05)	(0.07)	(0.18)
ΔNP	0.02*	0.06*	0.01	0.04	0.01	-0.04
	(0.01)	(0.02)	(0.04)	(0.08)	(0.07)	(0.19)
ΔRFAI	0.16***	0.25***	0.21***	0.28***	0.20***	0.26***
	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)	(0.07)
$\mathbf{\Delta RGDPPC_{i\,t-1}}$		0.04**		0.04		0.03***
		(0.01)		(0.11)		(0.01)
Intercept	7.41***	6.20**	7.47***	6.76***	6.57***	7.22***
	(0.91)	(0.62)	(0.59)	(0.89)	(0.76)	(1.50)
R-square	0.23		0.37		0.49	
Hansen Test		0.894		0.889		0.685
AR(1)		0.005		0.029		0.009
AR(2)		0.710		0.490		0.463

Notes: Standard error is presented below the corresponding coefficient. Symbols ***, ** and * show 1%, 5% and 10% level of significance respectively. The 'FE' and 'RE' with red color means the model should choose after the Hausman test.

Source: Author's Analysis

Comparing results between Table 2.11 and 2.12, total population growth still exerts strong and negative impacts on economic growth in three regions especially in the less developed area where coefficients are more than twice those estimated for the western area. Growth in dependency ratio plays a more important role in reducing economic growth in developed and less developed areas with insignificant effects for developing areas. The growth in non-agricultural population ratio only significantly affects the economic growth (in both models) for the developing area. Growth in fixed asset investment has a positive and similar impact on economic growth in the three regions (with coefficients of between 0.16 and 0.25). Technological advance affects economic growth in the developed area only with coefficients of 0.2 and 0.6 and displaying weaker coefficients than for any of the other variables in both models. One-year lagged real GDP per capita growth positively affects real GDP per capita growth in developed and less developed areas but with modest coefficients, which means increasing economic growth rates will impact economic growth positively over time in these areas. The R square values are generally higher here for developing and less developed areas relative to middle and western areas.

Results by development region are provided below:

Developed Area:

- Population growth ($\Delta POP1$) only has a negative and strong effect on real GDP per capita growth based on the System GMM estimation.
- Dependency ratio growth ($\Delta POP2$) has negative effects on real GDP per capita growth based on two models
- Non-agricultural population ratio growth ($\Delta POP3$) has an insignificant effect on real GDP per capita growth in both two models.
- New patent applications growth (ΔNP) has a positive but weak effect on GDP per capita growth based on both models.
- Real fixed asset investment per capita growth ($\Delta RFAI$) has a positive effect on real GDP growth based on both models.
- 1-year lagged real GDP per capita growth rate has a positive but very weak effect on real GDP per capita growth rate.

Developing Area:

- Population growth ($\Delta POP1$) has negative and strong effects on real GDP per capita growth based on both models.

- Dependency ratio growth ($\Delta POP2$) only has insignificant effects on real GDP per capita growth based on the System GMM estimation.
- Non-agricultural population ratio growth ($\Delta POP3$) has positive and significant impacts on economic growth based on two models
- New patent applications growth (ΔNP) has insignificants effects on GDP per capita growth based on both models.
- Real fixed asset investment per capita growth ($\Delta RFAI$) has positive effects on real GDP growth based on both models.
- 1-year lagged real GDP per capita growth rate has an insignificant effect on real GDP per capita growth rate.

Less Developed Area:

- Population growth ($\Delta POP1$) has a negative and strong effect on real GDP per capita growth based on both models.
- Dependency ratio growth ($\Delta POP2$) has negative and significant effects on real GDP per capita growth based on both models.
- Non-agricultural population ratio growth ($\Delta POP3$) has insignificant effects on GDP per capita growth based on both models.
- New patent applications growth (ΔNP) has insignificant effects on GDP per capita growth based on both models.
- Real fixed asset investment per capita growth ($\Delta RFAI$) has positive effects on real GDP growth based on both models.
- 1-year lagged real GDP per capita growth rate has a positive but very weak effect on real GDP per capita growth rate.

2.5.3 Population growth and Economic Growth: Granger Causality Tests for Chinese Provinces

Granger Causality tests are applied here to identify the basic relationship between growth in real GDP per capita and key population variables for each province.

Table 2.14 shows the Granger Causality test results for 29 provinces in China. Each province's classification within geographical and developmental areas is identified.

Table 2.14: Granger Causality Results for 29 Provinces in China

Province	Y Granger cause the POP1	POP1 Granger cause Y	Y Granger cause the POP2	POP2 Granger cause Y	Y Granger cause POP3	POP3 Granger cause Y
Beijing (1)(A)	No	No	No	No	No	Yes
Tianjin(1)(A)	No	No	No	No	No	No
Hebei (1) (B)	No	Yes	No	No	Yes	No
Shanxi (2)(B)	No	No	No	No	No	Yes
In. Mongolia (3)(B)	No	Yes	No	No	Yes	No
Liaoning (1)(A)	No	No	Yes	Yes	Yes	No
Jilin (2)(A)	No	No	No	No	No	Yes
Heilongjiang (2)(A)	No	Yes	No	No	No	No
Shanghai (1)(A)	Yes	No	Yes	No	No	No
Jiangsu (1)(A)	No	No	No	Yes	Yes	No
Zhejiang (1)(A)	No	No	Yes	No	Yes	Yes
Anhui (2)(C)	No	No	No	No	No	Yes
Fujian (1)(B)	Yes	No	No	No	Yes	Yes
Jiangxi (2)(C)	Yes	Yes	No	No	Yes	Yes
Shandong (1)(B)	No	No	No	Yes	No	Yes
Henan (2)(C)	No	No	No	No	No	Yes
Hubei (2)(B)	No	No	No	Yes	No	Yes
Hunan (2)(B)	No	No	No	No	No	No
Guangdong (1)(B)	No	No	No	No	No	No
Guangxi (3)(C)	No	Yes	No	Yes	No	No
Hainan (1)(C)	No	Yes	No	No	No	No
Guizhou (3)(C)	No	No	No	No	Yes	No
Yunnan (3)(C)	Yes	No	Yes	No	No	No

Tibet (3)(B)	Yes	Yes	No	No	No	No
Shaanxi (3)(C)	No	Yes	No	No	No	No
Gansu (3)(C)	Yes	Yes	No	Yes	No	Yes
Qinghai (3)(A)	Yes	Yes	No	No	No	Yes
Ningxia (3)(B)	No	Yes	No	No	No	No
Xinjiang (3)(A)	No	No	No	No	Yes	No

Notes: Y denotes the independent variable which is the real GDP per capita growth rate;
POP1 denotes the total population growth rate,
POP2 denotes the dependency ratio growth rate
POP3 denotes the non-agricultural population ratio growth rate;
(1) denotes the province in the eastern area;
(2) denotes the province in middle area;
(3) denotes the province in the western area;
(A) denotes developed province;
(B) denotes developing province;
(C) denotes less developed province.

Source: Author's Analysis

From the results, 4 provinces are located in the western area of the 7 provinces for which growth in real GDP per capita granger causes total population growth. Total population growth in 7 provinces in the western area Granger cause economic growth. In all, of 4 provinces in which economic growth Granger causes the dependency ratio growth, 3 are located in the Eastern area. Half of the provinces for which the dependency ratio growth Granger causes economic growth are located in the Eastern area. Economic growth in 6 eastern area provinces Granger cause growth in the non-agricultural population ratio. In all, of the 9 provinces for which non-agricultural population ratio Granger causes economic growth, 5 are located in the Eastern area. Half of the total (12) provinces in which the dependency ratio growth Granger causes economic growth are located in the middle area.

Considering provinces in different development groups, in total 7 provinces for which growth in real GDP per capita Granger cause total population growth, 5 of them are in less developed areas. In total 5 developing provinces and 5 less developed provinces are identified among the 11 provinces for which population growth Granger causes economic growth. In total 4 provinces for which economic growth Granger cause the dependency ratio growth, 3 are located in the developed area; 3 developed provinces are detected in the 6 provinces for which the dependency growth Granger causes economic growth. Economic growth in 5 developed provinces is identified as Granger causing growth in the non-agricultural population ratio. For the 12 provinces for which the non-agricultural population ratio Granger causes economic growth, 4 are developed provinces, 4 are developing provinces and the remaining 4 are less developed provinces.

From the above results, it appears that the Granger causality relationship between economic growth and different kinds of population change are identified more significantly in the Eastern (denoted 1) and developed (denoted A) provinces.

In the next section, conclusions are identified and discussed.

2.6 Conclusion and Discussion of the Econometric Results

This section summarises the key findings of this chapter as the evidence for the propose recommendations providing in Chapter Six.

- **Key Results for Total Population Change**

The results from the estimations in this Chapter suggest that the total population growth has a strong negative impact on economic growth across the estimations carried out using both the RE model and System GMM estimation. It means that provinces with a higher population growth rate tend to record lower growth in their real GDP per capita. This result is in line with Solow (1956, p. 90), which suggests that a slower population growth results in a higher equilibrium level of both the output and capital stock per worker. The result is also in line with the perspectives of Malthus (1798) and Yamaguchi (1973) where population growth would hinder economic growth by diminishing the marginal productivity of labour, and decreasing the income per capita (Malthus, 1798; Yamaguchi, 1973).

Results are also in line with other empirical studies that analyze the relationship between population growth and economic growth, such as Yamaguchi (1973), Barlow (1994), Banerjee (2012), and Konig et al., (2015). Close coefficient values of the total population growth in this Chapter with the study of Barlow (1994) and Bonnefond (2015) are identified, which applied panel data and econometric models with this Chapter. Lower coefficients of total population growth based on Vector Error Corrections Model (VECM) is identified by Yao, Kinugasa and Hamori (2013), which can be explained by the time-series econometric techniques and different time periods data applied. The coefficients of total population in this Chapter and literatures focusing on China (e.g. Bonnefond, 2015 and Yao, Kinugasa and Hamori, 2013) are lower (more negative) than the existing studies focusing on other countries, which reflects a stronger negative impact on economic growth of total population in China relative to other countries. This result offers a context for the 'One Child Policy' implementation in China.

The findings of a negative impact of total population growth on economic growth differ from the results found by Li (2006), Li (2009), Chen (2011) and Huang (2012). In these studies, Huang (2012), applied a different dataset (for different countries) compared to the data considered in this Chapter. Li (2006) and Li (2009) used national level data for China and also different econometric techniques. Chen (2011) applied panel data approaches for 29 provinces over a shorter time-frame (sixteen years less than in this chapter) from 1996-2008 using similar econometric techniques. Relative to the research conducted in Bonnefond (2015), this chapter uses different population variables and time periods. Few researchers, such as Ding and Knight (2011), argue that population restriction might exert a positive impact on the growth of Chinese GDP per capita through the reduction of resource pressures, despite the controversy over the humanity of this tightened demographic policy.

Provinces were classified into different geographical locations and development levels to identify the possible different impacts of key variables between province-groups. This analysis revealed that total population growth plays the role of the main barrier to economic growth in each sub group. These negative impacts appear stronger in the Western and less-developed categories. This result is similar with findings in Barlow (1994) and Chen (2011), which suggest a stronger impact (both positive and negative) of total population growth is identified in the areas with a lower economic output. As with Barlow (1994) and Chen (2011), other positive factors such as technology advance and capital investment might have less impacts in the areas with weak economic growth that maximize the negative impact of population growth. Change in total population can be identified as a factor which negatively affects economic growth because of its negative effect on income per capita.

- **Key Results for Dependency Ratio and Non-agricultural Population**

The empirical model for this Chapter includes different kinds of population variables such as dependency ratio and non-agricultural population ratio, as in Yao, Kinugasa and Hamori (2013), to measure different impacts of population quantity change on economic growth. Negative impacts of the growth in dependency ratio on economic growth are identified in this chapter. These results are similar to those in Crenshaw (1997) and Yao, Kinugasa and Hamori (2013) but with lower coefficients. Different specifications, econometric techniques and time periods may explain these differences. The results indicate that the country's economic development has benefited significantly from the increasing relative size of the working age population in China. This is in line with the perspectives of Becker and Barro (1989), Crenshaw (1997), Bloom and Williamson (1998) that growth in non-working age population can be seen as a burden to both working-age population and economic growth. An increase in the proportion of employed labour in the total population also mitigates the burden of children and old people on the government, which is helpful to economic growth of a country. Dependency ratio impacts on economic growth have more significant impacts in the western and less developed areas.

A positive and significant impact of the growth in non-agricultural population is detected here, which is a similar result with Yao, Kinugasa and Hamori (2013). This result reflects that the speed of industrialization (measured as the growth in non-agricultural population ratio) has generally spurred economic development in China (following Lewis 1954). Positive and significant impacts of non-agricultural population growth on economic growth are detected in the middle and developing areas (in both estimations). Based on the view of Yao, Kinugasa and Hamori (2013), the positive impact of working dividend is limited by progress in industrialization and by industry's employment capacity, especially in the weak economic output areas in China with poor industrial basis. Significant impacts of non-agricultural population growth on economic growth are identified in the areas with industrial development potential and good economic environment, such as the middle area and developing area.

- **Key Results for Other Factors**

Growth in capital investment has positively affected real GDP per capita growth in all estimations in this Chapter in line with similar results in Yao, Kinugasa and Hamori (2013) and Bonnefond (2015). The coefficients on capital investment growth in this Chapter are similar to the coefficients estimated in Bonnefond (2015), but lower than in Yao, Kinugasa and Hamori (2013). Capital investment growth has a slightly stronger impact in the middle and developing areas which reflects an accumulation of physical capital as a key engine of economic growth in the areas with economic development potential (Yao, Kinugasa and Hamori, 2013).

Technological advance (new patents) only positively affects economic growth in developed and eastern areas, which reflect a weak role of the technology advancing to economic growth in China as a whole. Weak basis of technological advance in less developed and western areas as the education and health development in African countries, might leads low input and its efficiency in technological advance, which be the main reason about the insignificant impacts of the variable in regression (Eggoh, 2015) . The middle and developing area paid more attention to the capital investment rather than the technological advance by related supporting policy to stimulate economic growth in a short term (Zhang, Lou and Li, 2016). Based on the historical experience in China, strong supporting policy might be an effective method to stimulate technological advance in non-developed areas in China.

- **Other Concluding Remarks**

As outlined in the introduction to this Chapter, significant growth in economic output in each province in China is identified in past years. Geographical location is a basic method of provinces grouping in China such as the 'Great Western Development' because of the similar nature and economic environment of different provinces in a same geographical area. (Bonnefond, 2015). However, as explained in Bonnefond et., al (2015), larger gaps in economic output between provinces in China still is a problem to Chinese economic development, even though a number of regional support policies have been implemented in certain geographical areas. The gaps in economic output between the provinces appear largest in the western area.

Based on the main results of this Chapter, the change in population, especially total population growth is a significant barrier to regional economic growth in China. However, provinces like Gansu and Guizhou exhibit relatively lower levels of total population growth [30]. Considering the lower level of capital investment and industrialization in the provinces like Guizhou and Gansu (observed in Tables 2.4 and 2.5 in this Chapter), changes in population quantity and capital investment may not have immediate significant effect on economic growth because of their weak development levels. Increased in labour productivity generated by improvements in population quality might be effective for economic growth in provinces like Gansu and Guizhou (Yao, Kinugasa and Hamori, 2013; Bonnefond, 2015).

This chapter focuses on the effect of population change in economic growth in China. Total population, dependency ratio and non-agricultural population ratio are used as variables in the models estimated. The results indicate strong negative impacts of total population on economic growth, even though other population variables are added into the model.

Other key factors however, such as the variables of population quality need to be examined. As the view of Yao, Kinugasa and Hamori (2013), based on the strong negative impacts of population growth, the education sector could be promoted to

[30] For the average total population growth between 1985 and 2013, Gansu ranked 17th and Guizhou ranked 26th in total 29 provinces; source: author's analysis based on data collected from the Statistics Yearbook 1985-2013 of each selected province.

develop untapped human resources and also improve population quality, to spur technological progress and economic growth in China. These specific effects of population quality will be examined in the following chapters. These factors may also have an effect on innovation, which in this chapter, appeared to have a weak effect on economic growth.

CHAPTER 3: AN OVERVIEW OF EDUCATION AND PUBLIC HEALTH POLICIES

In the last Chapter, the results indicate that population growth has a negative effect on province-level economic growth. Population quality is another important factor of population change, distinct from the quantity impact, that many empirical studies have identified as another key driver of economic growth.

One of the main goals of this Chapter is to provide a review of key studies that incorporate population quality. This includes an overview of the definition of population quality, and of associated research methods and empirical results. The review highlights that different definitions coincide with different research techniques. Empirical studies generate a range of different impacts of population quality on economic growth.

Another key goal of this Chapter is to outline key education and public health policies pursued in China over the period 1995 to 2015. This is important because it provides a backdrop to the empirical analyses which follow in Chapters Four and Five.

The Chapter is structured as follows. In Section 3.1 the concept of 'population quality' used in previous studies is discussed. Section 3.2 identifies literature underpinning the relationship between population quality and economic growth. Empirical techniques and the results of related studies are also identified and discussed. Section 3.3 outlines published policies focusing on improving education and health levels in China. Section 3.4 concludes the Chapter and presents some key themes that inform subsequent analysis and results.

3.1 Concept of Population Quality

The concepts of population quality are evident from a review of the literature. Many economists use the educational attainment of the population and population health as proxies for population quality (Eggoh, Houeninvo and Sossou, 2015; Zhang and Yu, 2014). However, some economists argue that the morality level is also an important factor of population quality (Xu, 2005).

Blackwell (2002) and Dalmazzo (2007) argue that population quality can be distinguished by innate ability, and acquired ability (like the educational attainment of the population). Barro (2001) emphasizes that educational attainment is an important part of population quality which can affect the quality of labour force. Hanushek (2007) believes that educational attainment is an important factor of population quality, i.e. average schooling years and it should have a positive effect on economic growth by increasing productivity. Jalil (2012) suggests that the educational level can represent population quality and that it also pushes economic growth. Schündeln (2014) argues that educational attainment (indicating population quality in an area) should have a positive effect on economic growth by improving the knowledge and skill of the workforce.

Xu (2005) examines the effect of population quality on economic growth in two provinces in China; Guangdong and Liaoning. In his view, population quality should also include population morality factors, measured as the crime rate, to make it comprehensive.

Xin (1997) also emphasizes the importance of morality’s impact on population quality. He argues that morality is a factor of population quality that has a positive effect on economic growth. Morality (measured as the crime rate) has a close relationship with regional economic growth. Better morality can help people forego some bad habits and lead to a reduction in some crimes, such as drug use. On the other hand, a high morality level of population also results in technology and knowledge being used legally and in ways that are beneficial to both population quality and economic growth.

Although population quality may arguably include the morality level, it is an abstract variable that is difficult to quantify. Variables of population quality, therefore, generally consist of just population health and educational measures.

Zhang and Yu (2014) argue that population quality includes population health, educational attainment and the technical capability of the population. The 'professional level' reflects the level of labour's professional techniques, which is used to identify the technical capability, such as the number of new patent applications per thousand people. Zhang and Yu (2014) argue that although the technical capability of the population should have a positive relationship with educational attainment, people with a high level of technical capability (for example, those that apply for patents) still comprise a very small proportion[31] of the population.

The above discussion indicates that economists argue that both the health level and education level impact on population quality and they have measured its impact on economic growth. Many economists prefer to use educational attainment only to reflect population quality (Romer, 1986, 1990, Lucas 1988). These authors state that the educational level of the population has a close relationship with the quality of human capital. Some economists from China also emphasize the importance of morality to population quality. However, few studies use the variable of morality in empirical research because it is very difficult to find a suitable variable to quantify or operationalize morality. Based on the above findings, education is a key element of population in both studies focusing on China and other geographies. Public health only has been considered as an element of population quality in Chinese studies.

[31] Zhang and Yu (2014) argue that the proportion of R&D personnel in the total Population was only 0.1% in China in 2015, and the data is incomplete in some years.

Next, the specific theoretical impacts of education and public health are identified from the discussion and econometric results of previous studies.

3.2 Relationship between Population Quality and Economic Growth

This section discusses the literature underpinning the relationship between population quality and economic growth. It also reviews econometric results that indicate the relationship between population quality and economic growth.

3.2.1 Theoretical Considerations

Controversy still exists about the nature of the relationship between population quality and economic growth, although the majority of studies indicate that population quality has a positive effect on economic growth.

- **Contributions from Countries Other than China**

Romer (1986, 1990) argues that educational attainment is the main aspect of population quality that positively affects economic growth. Endogenous growth theories outline processes that improve the growth of economies by increasing the efficiency of the labour force. These theories emphasize that human capital, accumulated by educated people, is subject to increasing returns and, therefore, may reduce the effect of diminishing returns to physical capital. Romer (1990) also argues that education provides a process that may change production technology and may shift the production function outward, and also improve the efficiency on the job training.

Other studies such as Lucas (1988), Hall (1999), Klenow (1997), Barro (2001), Hanushek (2007) and Jalil (2012) have a similar view to Romer (1986, 1990). Hanushek (2007) argues that a high quality of education can improve labour skill and knowledge that improve the productivity and efficiency of the workforce. He also considers that years of schooling has a major shortcoming as a measure of human capital. Its use implicitly assumes that all skills and human capital formation come from formal schooling, excluding skill training and informal study. Barro (2001) emphasizes that a high level of human capital facilitates the absorption of superior technologies from leading countries, which is likely to be especially important for schooling at the secondary and tertiary levels. Jalil (2012) argues that education quality such as different educational attainment levels represents population quality in a country that has a positive effect on economic growth by capturing the technological impact on economic growth. For example, Jalil (2012) pointed out that educated labour adopts new crop varieties and, therefore, becomes an explanation for higher production in the agriculture sector, which is an important element in the economy of Pakistan.

The impact of different forms of education on economic growth may vary by country; therefore, it is preferable to use the different levels of education in human capital augmented production functions. Lucas (1988) and Romer (1986, 1990) argue that human capital affects growth in at least two ways. Firstly, increases in education and training have the potential to spillover to other individuals, making other workers more productive. Hall (1999) and Klenow (1997) also argue that a further central proposition of endogenous growth models is spillovers between human and physical capital: better-educated and highly skilled workers make better use of firms' capital expenditures to improve the efficiency of capital.

- **Contributions of Studies Focusing on China**

Xu (2005) proposes that population quality consists of two elements: the health level of the population and educational attainment, and that both have a positive effect on economic growth. The health level of the population can be captured by variables such as the infant mortality rate and the number of hospital beds and medical personnel per capita. If a country has a higher population health level, the workforce has a longer working period to create value in society. A healthy population may also spend less money or time to improve their health. The educational level of a population may affect a country's innovation development that improves a country's productivity (Xu, 2005).

Zhao and Wu (2010) argue that a poor level of health in the labour force generates lower working efficiency and so workers need more expenditure on their health. They believe that the educational attainment of the population has a positive effect on economic growth because of the improvement in productivity. Zhou and Zhu (2014) argues that in cities with higher educational attainment, like Beijing and Shanghai, it is easier to find a job that allows the workforce to use the knowledge they have. Conversely, if they find a job in a less developed area they cannot use as much knowledge in their work. He also argues that the gap in educational levels is the main reason for the gap in population quality between the different regions in China.

Jiao (2014) argues that there are three main effects of a skilled labour force on economic growth. Firstly, a skilled labour force can change the main driver of economic growth in a country, for example from capital driven to innovation driven. Second, skilled labour is more important to economic growth in less develoepd areas than developed areas in China. The study argued that less develoepd areas in China have multiple advantage policies to attract expenditure, such as lower taxation of capital and cheaper land. Enterprieses which are located in less developed areas hire local skilled labour and enjoy lower labour costs than developed areas. Third, high-quality labour in China can fully use rich natural resources more efficiently using advanced techniques to improve productivity.

3.2.2 Empirical Evidence

- **Studies Focusing on Countries Other than China**

Barro (2001) uses male secondary and higher education enrolment as a measure of population quality in his model to test the factors affecting economic growth in 100 countries, using data from 1965 to 1995. His results show that population quality has significant and positive effects on economic growth: with the coefficient of 0.004, a weak positive impact of male secondary and higher education schooling years on the economic growth is estimated. However, this study only uses male secondary and higher education enrolment to represent population quality, which not only fails to fully reflect the educational attainment of the population in target countries but also fails to identify population quality completely; other variables which represent population health might also be considered.

Jalil (2012) uses data from Pakistan (1960–2010) and finds that the average educational level, primary, secondary and the tertiary level of education enrolment rates have significant and positive effects on economic growth of Pakistan: respective coefficients of 0.019, 0.024, 0.028 and 0.012 were estimated. He also finds that secondary education is a relatively more important determinant of economic growth compared with the primary and tertiary education in Pakistan. The result is similar to Gemmel (1996), Petrakis and Stamatakis (2002) and Papageorgiou (2003) who all find a positive relationship between post-primary education and economic growth in Pakistan. However, factors such as investment in education which might represent population quality in Pakistan are not included in model.

Based on province-level data for India (1961-2001), Schündeln (2014) finds that average schooling years has positive effects on economic growth using Generalized Method of Moments (GMM) in two models with coefficients of 0.177 and 0.009 respectively; but it has an insignificant effect on economic growth using the fixed effects model, which reflects that average schooling years has an insignificant fixed effect on economic growth in panel data regression. However, the study also found that the effect of government sector size on education's effectiveness in promoting provincial growth was negative, economically large, and statistically significant, which suggests that government absorbed human capital in low productivity activities in India.

Jin (2010) finds that the secondary school enrolment rate (with a coefficient of 0.035) and the number of articles published per person in universities in recent five years (with a coefficient of 0.861) as variables of population quality with positive and significant effects on economic growth using data from 34 developed countries from 1990-2005. University professors' research performance in basic science and engineering had a stronger effect on the growth rate of real GDP than the secondary school enrolment rate which suggests a stronger effect of higher education on economic growth. However, secondary school enrolment rate as the single variable might cannot reflect population quality in multiple countries. Other variables such as educational investment and health should be considered to reflect population quality completely.

Pegkas (2014) uses annual data for Greece (1960-2009) and finds that the higher educational enrolment rate had a positive and significant effect on the economic growth in the long-run with a coefficient of 0.52. The Vector Error Correction Model (VECM) is the technique used in this study which not only finds a positive and significant effect of higher education on economic growth, but also finds an insignificant effect of higher educational enrolment rate on economic growth in the short-run.

Based on the 133 OECD countries and data from 1995-2005, Veeramani (2015) examines knowledge spillovers and economic growth using cross section estimation and GMM models. In this research, the educational attainment of the population (secondary school enrolment) is an important variable and the results show that it has a positive and significant effect on economic growth in a GMM model with a coefficient of 0.023; however, it has an insignificant effect on economic growth in panel estimation.

Based on panel data from 49 African countries from 1996 to 2010, Eggoh, Houeninvo and Sossou (2015) tests the relationship between education, health and economic growth in African countries. This research uses econometric techniques for panel data analysis such as cross-section estimation and system GMM estimation. Variables of education and public health are included in the model to measure their specific effect on economic growth, which are public spending on education as percentage of GDP, health expenditure as percentage of GDP and life expectancy. Public spending on education as percentage of GDP has negative and significant impacts on economic growth in both panel estimation and GMM models, with coefficients of -9.84 and -0.15. Health expenditure as percentage of GDP has significant and negative effects on both panel estimation and GMM model, with coefficients of -3.85 and -0.11. Life expectancy has insignificant effects in all models in this study. The study argues that the results can be explained by the degree of inefficiency with which such expenditures are converted to human capital stock and the low amount of resources devoted to education and health in African countries.

- **Studies that Focus on China**

Xu (2005) finds that the population quality of two Chinese provinces of both Liaoning and Guangdong has a positive and significant effect on economic growth in these areas in the time period of 1981-2000. Specific variables of population quality include the proportions of male and females with higher educational attainment, infant mortality rates (male and female) and illiteracy rates of males and females. These are integrated into one population quality index using common factor analysis (such approaches are discussed in some detail in Chapter Four). Next, a regression model based on the Solow growth model is estimated. Based on the province-level data of Liaoning and Guangdong, population quality indexes have a positive and significant effect on economic growth, with coefficients of 0.352 and 0.890 respectively. The population quality index of Liaoning has a more significant effect than Guangdong. Xu (2005) also finds that Liaoning has higher population quality, and it has a higher coefficient on economic growth compared with Guangdong, even though the level of economic output in Liaoning is much lower than that of Guangdong. The results of Xu (2005) could be more meaningful if the link between related policy and variables are identified.

Lu and He (2008) use annual data from Qingdao city from 1978 to 2004 to test the effect of population quality on economic growth by constructing a population quality index with both education and health indicators. Variables like (1) life expectancy, (2) schooling years and (3) educational expenditure are the detailed variables of population quality. When the population quality index only includes health variables, population quality has a significant and positive effect on economic growth (0.370); if the population quality index only includes the educational variables, population quality has a large positive and strong effect on economic growth (0.406). When the population quality index includes both health and educational variables, the strongest effects on economic growth are observed (0.503). They also find that the effect of capital variables has stronger positive effects on economic growth in all three models than the population quality index (with coefficients of 0.653, 0.618 and 0.574), which reflects the key support of capital to economic growth in Qingdao. However, the value of coefficients of capital decreased with an increase in coefficients of the population quality index.

Chi (2008) found the insignificant or negative impact of education attainment rates in the primary, secondary and tertiary education levels on the real GDP per capita growth rate in China with the coefficients of 0.006, -0.006 and -0.003 respectively, using the 31 provinces data from 1996-2004 using a fixed effects model. System GMM results also indicated a limited impact of education attainment on the change in real GDP per capita, with the coefficients of -0.004, 0.003 and -0.0003.

Yan and Zhong (2009) find that the increase in population quality index, which is calculated by the coefficient of variance method, and includes primary, secondary and higher educational levels enrolment rates and average schooling years, have significant and positive effects on economic growth in Guangdong province based on data from 1982-2005. The population quality index is constructed using the primary, secondary and tertiary enrolment rates and average schooling years. The results show that capital expenditure (0.740) has a stronger positive effect than the population quality (0.249) on economic growth in Guangzhou. Target policy focusing on the education in Guangdong should be identified to help readers understand the results objectively.

Li and Huang (2009) identified positive and significant impacts of education and public health indicators on the real GDP per capita, using the 28 provinces data from 1978-2005. The results indicate that the student/teacher ratio of primary schools has a negative impact on real GDP per capita, with a coefficient of -0.27 respectively; other variables which are the secondary education attainment rate, beds and medical personnel per 10,000 people have positive and significant impacts on the economic output, with the coefficients of 0.82, 0.24 and 0.16 respectively using the fixed effects model. Slightly stronger impacts of both education and health are identified in the developed areas in China.

Zhou, Liu and Zhu (2013) used the fixed and random effects models and panel data of 32 provinces across three geographical areas i.e. the eastern middle and western areas from 1997-2010 to test the effect of population quality on economic growth. They used the variables of birth rate, schooling years, government health expenditure and a Gini educational coefficient to measure population quality in one index using common factor analysis. Results indicate that population quality has positive and significant effects on economic growth in China, with the coefficients of 0.104 and 0.209 respectively using the fixed and random effects models. In three geographical areas in China, the population quality index has a positive and significant effects on economic growth; the strongest effect is observed in the eastern area with the coefficient of 0.489.

Based on data from the Jiangsu province in China, from 1989-2011, Sun (2012) finds that population quality (measured as an index) has a positive and significant effect on economic growth, using OLS estimation and ECM (Error Correction Model) techniques. The population quality index includes the following indicators; the proportion of tertiary employees in total employed population, total number of R&D personnel, new patent application number and university student per 10,000 population, based on common factor analysis. The results indicate that the population quality index coefficient in OLS estimation (0.358) is much higher than the coefficient in ECM technique (0.074), which indicates that population quality has a lower long-term effect on economic growth in Jiangsu once the error correction factor is added in the model. Specific impacts of education and health on economic growth should be identified if two separately indexes are constructed.

Zhang and Yu (2014) find that population quality has a positive and significant effect on economic growth in China using annual data from 2000-2011. Population quality variables include the death rate, infant mortality rate, number of graduates from university, and patent applications per 10,000 people. These variables are combined into an index of population quality using the coefficient of variation method. Based on OLS estimation, the population quality index has a positive and significant effect on economic growth with a coefficient of 0.263. Results based on co-integration and Granger causality tests shows that population quality change cause economic growth, but economic growth does not cause changes in population quality.

Bonnefond (2015) tests the relation between population change and economic growth in China based on province-level data of 29 provinces from 1995 to 2009 using fixed effects and system GMM estimation approaches. the ratio of the number of students enrolled in tertiary education to the number of students enrolled in secondary education is used to represent human capital (education). A positive and significant effect on economic growth is measured in both models, with the coefficients of 0.058 (fixed effects) and 0.032 (GMM). The results indicate a correction of endogeneity problems using system GMM method, which leads to higher coefficient values in the fixed effects estimators, which is similar to Sun (2012).

In summary, most previous studies find a positive and significant effect of population quality on national or regional economic growth. From Table 3.1, most studies which focus on other countries than China use education variables to represent population quality, such as Barro (2001), Jaili (2012), Schündeln (2014) etc.al; only Eggoh, Houeninvo and Sossou (2015) indicates the impacts of health variables on economic growth in the study focusing on African countries. Multiple studies which focus on China prefer to use both education and health variables to represent population quality, such as Xu (2005), Lu and He (2008) et.al. We can conclude that education is the most important factor to represent the population quality in foreign researchers' approaches. Chinese researchers prefer to use both education and health indicators to represent population quality. It seems that public health is applied as a factor of population quality in the studies which focusing on the areas with a weak public health basis, such as African countries and China.

Focusing on the research techniques, we found that studies examining countries other than China use single or few variables in their models - which may not fully reflect population quality. Most studies focusing on China construct one index of quality which uses the indicators of education and public health, based on methods such as common factor analysis and coefficient of variance. Two indexes representing education and public health separately may be useful to identify the specific separate impacts of education and public health.

Previous studies focus on testing the relationship between population quality and economic growth without identifying key policies of government focus. Developments in education and public health in China are a key focus of the Chinese government, which is supported by key policies. China organizes its development periods according to published 'Five-year plans'. The plans include key development policies, such as education and public health. Some policies focus on specific areas or provinces, such as the provinces in Western China, while other policies focus on all regions of China to balance the gap of education and public health development between developed and less-developed areas. Policy analysis offers helpful context to identify how population quality development in China in the past years relates to economic growth. Multiple indicators reflect the effects of key policies of education and public health in China. In the next section, detailed policies about education and public health which are published by the Chinese government are identified.

Table 3.1 outlines the main approaches, measures, data and results found across the studies included in the review of literature conducted for this study.

Table 3.1: Summary of Empirical Literature

Author	Areas/Countries Examined	Measurement of Educational Level	Measurement of Health Level	Empirical Techniques	Results
Barro (2001)	100 countries, 1965-1995	Male secondary and high schooling years	None	Panel regression estimation	Male secondary and high schooling years (0.004)
Xu (2005)	Guangdong and Liaoning province, 1981-2000	Higher educational level population proportions of males and females population over 6 years old, illiteracy rates of male and females over 15-year-old	Infant mortality rates	Common factor analysis, time series regression	Population quality index (0.890 in Guangdong, 0.352 in Liaoning)
Chi (2008)	31 provinces data in China, 1996-2004	Education attainment rates in the primary, secondary and tertiary education levels	None	Fixed effects model and System GMM Model	Fixed effects model: Primary (0.006), Secondary (-0.006), Tertiary (0.003); GMM: Primary (-0.004), Secondary (0.003), Tertiary (-0.0003)
Lu and He (2008)	Qingdao (City), 1988-2004	Schooling years and total educational expenditure	Life expectancy	Coefficient of variation, time series regression	Population quality index (0.370, 0.406 and 0.503)
Li and Huang (2009)	28 provinces in China, 1978-2005	Student/teacher ratio in primary education, secondary education attainment rate	Beds and medical personnel per 10,000 people	Fixed effects model	Student/teacher ratio in primary education (0.27), secondary education

					attainment rate (0.82); Beds (0.24) and medical personnel (0.16) per 10,000 people
Yan and Zhong (2009)	Guangzhou (city), 1990-2000	Primary, secondary and higher educational levels enrolment rates and average schooling years	None	Coefficient of variation, Multiple linear regression and parameter estimation	Population quality index (0.249)
Jin (2010)	34 developed countries, 1975-2003	Secondary school enrolment rate and article publication per person over recent 5 years in universities	None	Panel regression estimation	Secondary school enrolment rate (0.035), publication per person (0.861)
Jalil (2012)	Pakistan, 1960-2010	Average level of education, primary level, secondary level and tertiary level of education enrolment rates.	None	Time series regression with dummy variables	Average level (0.019), primary level (0.024), secondary level (0.028), tertiary level (0.012)
Sun (2012)	Jiangsu Province, 1989-2011	Proportion of the tertiary employees in total employed population, total number of R&D personnel, new patent application number and university student per 10,000 population	None	Common factor analysis, OLS estimation, ECM technique	Population quality index growth rate (0.358, OLS estimation; 0.074 ECM technique)
Zhou, Liu and Zhu (2013)	31 provinces data in China, exclude Hong Kong, Macao	Average schooling years and education Gini coefficient	Birth rate and proportion of public health expenditure as total expenditure	Common factor analysis, Fix and random effect models	Population quality index (fix effect model:0.104, random effect model:

	and Taiwan, 1997-2010				0.209); Eastern: 0.489, Middle:0.231, Western:0.096
Schündeln (2014)	Province level data of India, 1971-2001	Average schooling years	None	Fixed effects model, the random effect model and GMM model	Fixed effects model: insignificant; GMM model: (0.177)
Pegkas (2014)	Greece (1960-2009)	Higher educational enrolment rate	None	VECM	Higher educational enrolment rate (0.52, long-run; insignificant, short-run)
Zhang and Yu (2014)	Annual data of China, 2000-2011	Number of graduates from university and college, patents application number per 10 thousand's people	Death rate, the infant mortality rate	Coefficient of variation method, OLS estimation, Granger causality test	Population quality index (0.263)
Bonnefond (2015)	29 provinces of China, 1995-2009	The ratio of the number of students enrolled in higher education over the number of students enrolled in secondary education is used to represent human capital	None	Fixed effects model and System GMM Estimation	Fixed Effects Model: (0.058), System GMM model (0.032)
Eggoh, Houeninvo and Sossou (2015)	49 African countries, 1996-2010	Public spending on education as percentage of GDP	Health expenditure as percentage of GDP, life expectancy	Cross section regression and GMM system estimation	Cross Section: education spending (-9.839), health spending (-3.851); GMM: education spending (-

					0.146), health spending (-0.112);
Veeramani (2015)	133 OECD countries, 1995-2005	Secondary school enrolment ratio	None	Cross section estimation and GMM model	Cross section: insignificant; GMM: (0.023)

Source: Author’s analysis

3.3 Overview of Key Policy Documents on Improving Education and Health

In the last section, education and public health were identified as key elements of population quality, especially in studies focusing on China. Key policies of education and public health are needed to explain development in the above two areas. This section discusses published policies focusing on improving educational and health levels in China. The detailed data in this section is collected from the Statistical Yearbook of China for 1995 to 2016.

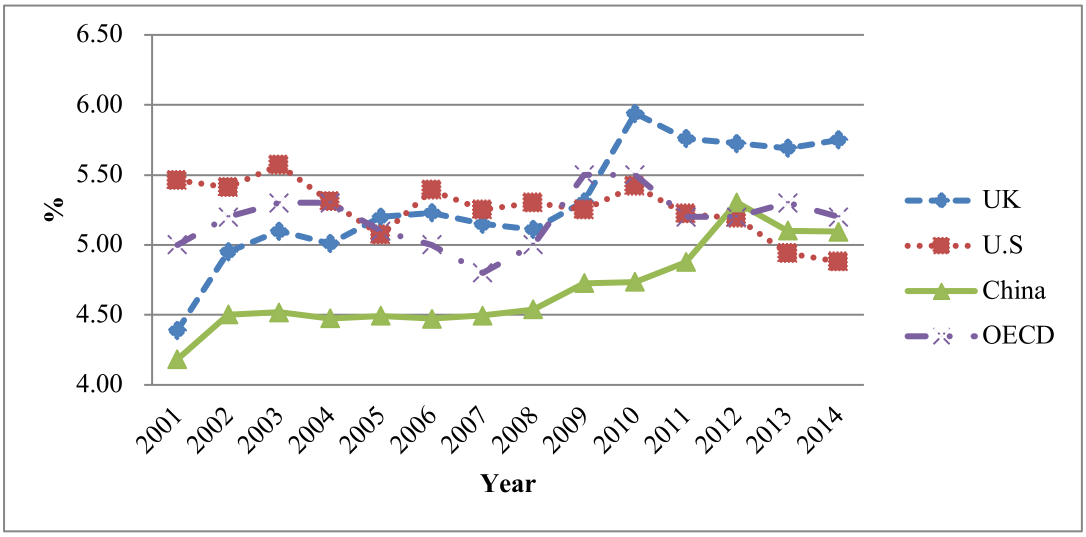
Research by Yuan (2006), Wu and Deng (2011), Qin (2013), Xie (2014) note that government policy in China played an important role in the development of education and public health. Related education and health policies in 'Five-year Plans' as a guide which are published by central government identify the specific targets and objectives for local government. This discussion of policies not only identifies the target and objective of the development in education and public health in China, but also provides context for the changes in specific indicators presented in Chapter 4. This section also identifies the status and problems in education and health in China which can be seen as the reasons behind related policies.

3.3.1 Background to Education Policy

Education in China recovered and developed since the College Entrance Examination began in 1978. Over the past 40 years, expenditure in education in China has narrowed the gap in government expenditure on education as a percentage of total GDP between China and other countries (Yuan 2006, Qin, 2013).

Figure 3.1 shows that government expenditure on education as a percentage of GDP, China had a lower level in 2001 but it grew significantly until 2012 and the gap between China and other developed countries narrowed. In 2012, expenditure in education in China surpassed that of the U.S and the average level of OECD countries but declined after.

Figure 3.1: Government Expenditure on Education as % of GDP, 2001-2014

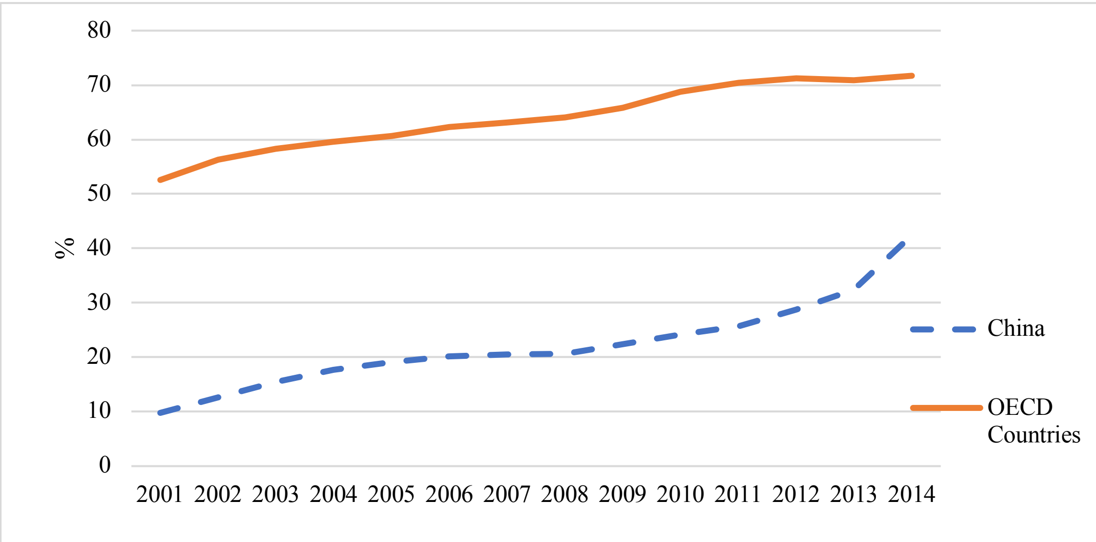


Source: World Bank Database[32]; the Websites of National Bureau of Statistics of China[33]

[32] URL: https://data.worldbank.org/indicator
[33] URL: http://www.stats.gov.cn

Figures 3.2 and 3.3 (see next page) show that enrolment rates in tertiary education and gross education enrolment ratio in China increased from 2001 to 2014, which narrowed the gap between China and OECD countries. However, a significant gap remains.

Figure 3.2: Enrolment Rates[34] in Tertiary Education of China and OECD Countries, 2001-2014

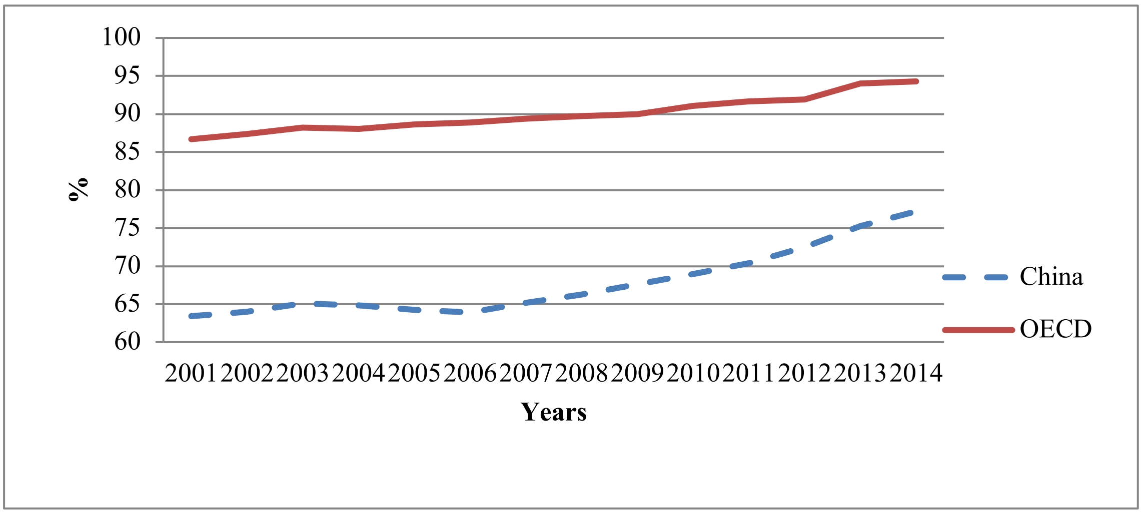


Source: World Bank Database

[34] Enrolment rate is the total enrolment, regardless of age, to the population of the age group that officially corresponds to the level of education shown; Source: https://data.worldbank.org/indicator/SE.TER.ENRR?locations=OE.

Figure 3.3 identifies a higher proportion of students are enrolled in tertiary (relative to primary) across OECD compared to China.

Figure 3.3: Gross Education Enrolment Ratio, Primary to Tertiary of China and OECD Countries, 2001-2014[35]

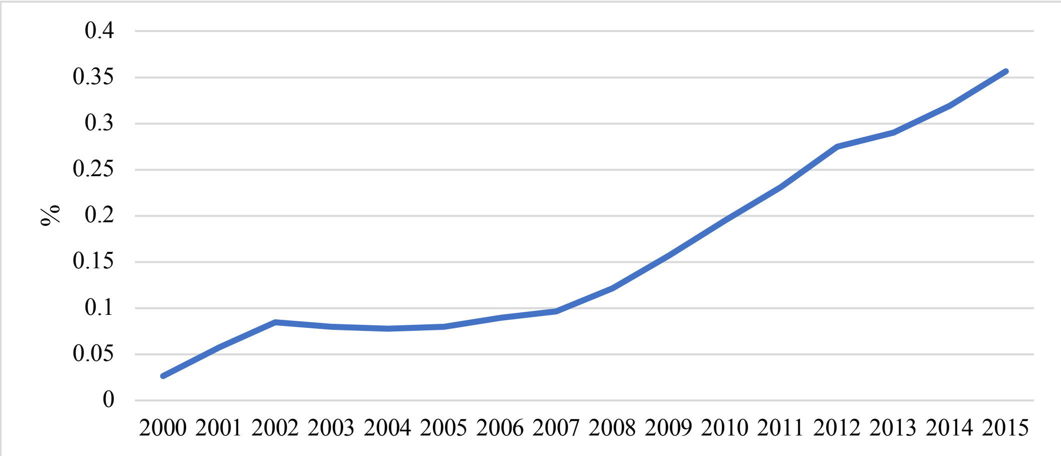


Source: World Bank Database

[35] Total enrolment in primary, secondary and tertiary education, regardless of age, expressed as a percentage of the total population of primary school age, secondary school age, and the five-year age group following on from secondary school leaving. GER can exceed 100% due to the inclusion of over-aged and under-aged students because of early or late school entrance and grade repetition; Source: https://datacatalog.worldbank.org/gross-enrolment-ratio-primary-tertiary-both-sexes.

Although local education saw significant development in China, many students choose to study abroad to access international education and perhaps a better quality of education, which is indicated in Figure 3.4. This is reflected by the rapidly increasing numbers of Chinese students going abroad to study.

Figure 3.4: Proportion of Overseas Chinese Students in Total Student, 2000-2015



Source: the websites of National Bureau of Statistics of China

In general, the above indicators indicate that education in China developed in past years. To identify the reason for education development in China, key policies published by the Chinese government are discussed.

- **Education Imbalance between City and Rural Areas**

Average education expenditure in all urban primary schools in China was 1484 RMB in 2001, and in rural areas it was 784 RMB. Educational expenditure per junior high school student was 146 RMB; the corresponding value in rural areas was only 45 RMB. For educational infrastructure, such as school buildings, which did not reach basic quality standards in 2005 (which is determined by the Ministry of Education in China), 81% of these are the institutions in rural areas and 19% of them in city areas. The gap in educational attainment of teachers between city and rural areas is also significant. For example, in the more developed east region of China, 60% of primary school teachers have a higher educational level[36]while the number is 29% in rural areas.

The imbalance is also reflected in the educational level of the population between city and rural areas. For example, 26% of the population (aged 6 and over) in urban Beijing had an undergraduate qualification in 2015, but the number in rural areas was 5.1%. In the less developed provinces in China such as Gansu, the number of urban residents with an undergraduate degree is 12.4% but only 1.5% for rural residents of Gansu in 2015. Low educational levels in rural areas can be seen as a barrier to developing population quality in China because of the poor educational resources and low income in their families (Yuan, 2006).

- **Education Imbalance between Provinces[37]**

Education imbalance also occurs between different provinces in China. For the educational level of population (aged 6 and over) in Beijing (including city and rural areas), 22% reached undergraduate level but 2% of them have received 'no schooling' in 2015. The comparable indicators in Gansu, which is a less developed province are 6% and 11%. Regarding educational infrastructure, Beijing had 63 higher educational institutions in 1999, which increased to 91 in 2015; Gansu only had 18 in 1999 and 45 in 2015. The educational expenditure per capita (nominal) in Gansu was 212 RMB in 2000 and increased to 2359 RMB in 2015; that of Beijing was 1835 RMB and 5145 RMB in 2015. The above data reflects the gaps in educational output and input between developed and less developed areas in China. The government has identified the need to focus on narrowing the gaps in education input and output between developed and less developed areas.

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[36]Higher educational level in China equal to the Level 8 (honours degree) in Ireland.
[37] Detailed data applied in this section is collected from the database of the National Bureau of Statistics of China, source: http://data.stats.gov.cn.

- **Gap in Education Development and Economic Development**

Yuan (2006) argued that one of the problems of educational development in China is that local government of less developed areas pay more attention to economic growth and ignore education development. This means the less developed areas have a higher growth rate in GDP but low educational input and output. For example, the real GDP per capita growth rate in Lanzhou was 2.1% and the real education expenditure per student growth rate was 1.0% in 1996; the value of GDP growth rate in Lanzhou increased to 8.5% in 2015 and the value of education expenditure growth rate was 19.5%. Yuan (2006) argued government policy such as increasing education expenditure can push less developed area policy makers to focus more on education development.

3.3.2 Background to Education Policies in China

This section outlines policies which focus on the educational development between rich and poor areas, city and rural areas, and public and private education. The educational policies mainly stem from the last three 'Five-Year Plans' of China, implemented from 2001 to 2006, 2006 to 2011 and 2011 to 2016. Some of these policies focus on all provinces in China and others focus on special areas or provinces, such as the Western area. Table 3.2 lists key education policies in China which were published between 2001 and 2016.

The seven main policies are each discussed in turn to identify their focus and main goals.

Table 3.2: Key Education Policies in China

Policy	Introduction Year	Implementing Areas	Contents
1. Nine-year Compulsory Education	2001	Lanzhou, Guiyang, Beijing	Government set 'nine-year compulsory education' as a legal requirement. Government invests 10 billion RMB to support primary and junior high schools to complete the 'nine-year compulsory education', especially in less developed areas and rural areas.
2. Increasing Funding	2001	Lanzhou, Guiyang, Beijing	Government plans to increase the proportion of expenditure in education in total government expenditure from 2001. The proportion of education expenditure in total government expenditure plan to increase 1% every year until 2005, and it should occupy at least 4% of total government expenditure in 2005.
3. Financial Support to Teachers in Less Developed Areas	2006	Lanzhou, Guiyang	Government promotes teachers working in primary and middle schools in areas in China. All lectures can enjoy financial support from central government. The central government plan to invest 10 billion RMB to improve the quality of facilities in less developed area schools, some part of this money used as financial support to these teachers or improve their living facilities.
4. Normal Student Programme	2007	Lanzhou, Guiyang, Beijing	To increase the number of teachers in primary and middle school, the government set a 'free normal student' programme in 6 high-quality normal universities in China. Students who study in this programme do not need to pay fees. After they graduate, they must work for the primary and middle schools arranged by the government. All free normal students must work as a teacher in primary or middle school for at least 10 years.
5. Growing Admission in Higher Education	2008	Lanzhou, Guiyang	The government continues promoting higher education institutions in eastern areas increasing their admission proportion of the middle and western areas student in total admission numbers. The main goal of this policy is to balance the gap between higher education resources of students in developed and less developed areas, and also to improve the educational level of the population in less developed areas.

6.	Teacher Quality Improvement	2010	Beijing, Lanzhou, Guiyang	Government improves the quality education personnel in the primary and middle schools in under-development areas in China by the multiple short-term offline training and long-term online training. High-quality educational personnel from developed areas working for the training to improve the professional skills of the educational personnel in under-development areas to improve the educational quality.
7.	General Development in Higher Education	2012	Lanzhou, Guiyang	Government increases the quality of higher education in the middle and western areas, which focuses on the quality of teaching, human resources of higher education, facilities of higher education, high-quality programmes, Financial supporting and communicating with high-quality universities. Government plans to invest a total of 10 billion RMB until 2015.

Source: Policy documents available from the Website of Ministry of Education of the People's Republic of China; Official Documents of the 10th, 11th and 12th 'Five-Years' Plans.

Educational Policy 1: Nine-year Compulsory Education

The first key education policy was the establishment of ‘nine-year compulsory education’. The main goal of this policy was keeping the basic education attainment to improve the educational level of children in China. The two main objectives of this policy are:

- ensure children in China complete the basic 9 years of primary school and junior middle school; and
- ensure children in China complete 9 years education for free in public primary school and junior middle school without extra payment.

This policy was first mentioned in 1986, adopted in 2001 and became law in 2006. In 2008, the ‘nine-year compulsory education’ policy was fully implemented. This policy mainly focuses on primary school and junior middle schools in China to ensure they complete the obligation to provide educational opportunities to children; public primary schools and junior middle schools should provide education to children for free. Parents’ responsibility is also covered by this policy. Parents cannot, for any reason, stop their child’s education before the compulsory 9 years has been completed. In addition, government educational institutions, such as the Municipal Education Commission and NGOs have the responsibility to supervise the implementation of this policy. This includes reporting and investigating violations of the policy.

Based on Yuan (2006) and the ‘the outline of the 10th 11th and 12th Five-Year’ Plans’, there are three key points of this policy: commonweal, coerciveness, and uniformity. Commonweal refers to public welfare and the ‘nine-year compulsory education’ is mainly funded from government expenditure. Some primary and junior high schools receive a donation from society or NGOs and need to report these to the government. The government not only funds this compulsory education but also guarantees the funding for use by local educational bureaus. Each relevant educational institution or department needs to report their financial records annually to the government Education

Department for auditing.

The second point is coerciveness. Parents cannot stop their children's schooling before they finish ninth grade or they will pay penalties or even face criminal punishment. Schools cannot reject eligible children for any reason. One special case for the 'nine-year compulsory education' is that children can stop studying if they need to join artistic or athletic departments. Once the children and their parents make an agreement with the relevant departments, the children can finish their study. However, some children cannot enjoy further education after they finished 'nine-year compulsory education' because families with significant financial pressure need them to work rather than study (Yuan, 2006).

The third point is uniformity. The same standard of basic education is set for developed and less developed provinces. For example, the 'nine-year compulsory education' policy sets out detailed regulations for educational funding per student, teaching content, construction of schools and teaching materials which standardizes the quality of education in rich and poor provinces. However, most regulations of the 'nine-year compulsory education' are helpful to keep a basic level of population education in China. Educational facilities and rich resources in developed provinces like Beijing promote a higher educational level. People living in less developed provinces like Guizhou and Gansu do not continue to higher education because of the limitations of finance (Wu and Deng, 2011).

Educational Policy 2: Increasing Funding

Increased funding and expenditure in education is the second main educational policy in China and was introduced in 2001. This policy can be seen as a basic policy to increase government expenditure on education in all regions in China. The two goals of this policy are to improve the educational environment and ease the financial burden on students. The objective of this policy was to increase the proportion of total government spending used for education from 2001. The proportion of total government expenditure used for education was planned to increase 1% every year until 2005 and it was expected to reach at least 4% of total expenditure by 2005, and beyond. This policy can be seen as a general policy to increase government expenditure in all kinds of educational institutions in China. This target has been reached until the end of 2005.

Educational Policy 3: Financial Support to Teachers in Less Developed Areas

'Special teacher' was the third education policy published in 2006 to improve education quality in China. The goal of this policy was to improve the basic educational personnel quality in less developed areas in China. To reach this goal, a number of objectives were set as follows:

- Special teachers in different provinces should be employed officially by the local Ministry of Education

The 'special teacher' is a policy or programme set by central government but it is implemented by local government and the Ministry of Education. Local government and the Ministry of Education have the right to select, employ, reward and dismiss special teachers in their provinces.

- Special teachers should enjoy the same or higher levels of basic financial support as teachers working in developed areas

To protect the basic rights of special teachers, the central government decreed that all special teachers in different areas should enjoy the same or higher level of financial support as the average level in developed areas. This acts as an incentive for qualified teachers to join this programme.

- The first stage of financial expenditure for this policy was 10 billion RMB, representing 1.7% of total educational expenditure in 2006.

Finance earmarked to implement this policy is based on the specific programme process and joining teacher numbers.

- Each special teacher should be evaluated each year by examiners from local educational institutions and the Ministry of Education; normally the maximum teaching period for each special teacher is three years.

Evaluating special teachers is important to maintain levels of professionalism and to improve the educational quality in less developed areas of China. A strict evaluation system is set by the local educational institutions and Ministry of Education.

- Special teachers teach in primary schools and junior middle schools.

Based on the educational status of less developed areas in China, the government prioritizes basic education. The special teacher programme is targeted at less developed areas in China.

From 2006-2010, there were over 180,000 special teachers (or 1.4% of total educational personnel in China in 2010) in over 18,000 educational institutions (or 5.2% in total number of educational institutions in China in 2010) in less developed areas. At the same time, financial support to special teachers was also implemented. The average financial support per teacher was 15,000 RMB per year in 2006, and it increased to 18,960 in 2007. It reached 20,540 per year in 2010. Narrowing the education gap between developed and less developed areas in China is a goal for the Chinese government. This is done by sending high-quality educational personnel to less developed areas in China. The policy also addresses the problem of educational personnel employment to encourage them to continue their teaching career after they graduate from school.

Educational Policy 4: Normal Student Programme

Normal Student Programme is the fourth key educational policy which was published in 2007. The main goal of this policy is to increase the educational personnel quantity and quality in primary and middle school in China, especially in less developed areas. To reach this goal, a number of objectives were set as follows:

- Improve the educational personnel quality in the primary and middle schools in less developed areas;
- Develop teaching skills; and
- Provide higher education opportunities with less financial stress on students from poor families.

The policy is set and published by the Ministry of Education; it is implemented by the ministries of education in each province and city. The main content of this policy is to attract high school graduates to continue their undergraduate study in the six normal universities[38] in China by normal majors. Based on the policy, each free normal student signs a contract before they start their study. The contract states that each free normal student must work as a teacher in primary school or middle school in their hometown for at least 10 years (including 2 years working in less developed areas). For each student, the government pays all fees during their undergraduate study and living expenses of 600 RMB per month. In addition, each student can continue their Master's study without an exam[39] in the above six universities after they have worked for one year. Contractually, students need to finish their compulsory teaching work when they finish their Master degree. Students who break the contract not only pay for all the payment from the government during their study (including living expenses) but also incur additional penalties.

Educational Policy 5: Growing Admission in Higher Education

The fifth key educational policy in China, published in 2008, is increasing higher

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[38] The 6 normal universities are Beijing Normal University, East China Normal University, Northeastern Normal University, Central China University, Shanxi Normal University and Southwestern University.
[39]Students in China need to pass an exam for their Master study normally.

education admission numbers in central and western areas. Each higher education institution has different admission numbers in different areas which are planned before admission by the Ministry of Education in China and each university. The main goal of this policy is to balance the gap between higher education resources of students in developed and less developed areas, and also to improve the educational level of the population in less developed areas. The policy is also helpful to enterprises hiring high-quality labour. To reach the above goals, a number of objectives were set as follows:

- Increase admissions of students from less developed areas to higher educational institutions in developed areas based on the original admission plan of each university in developed areas; each university reports the admission plan prior to the Ministry of Education of China to get permission; and
- Ease admission pressure to higher education institutions in less developed areas to increase the total number of the population with higher educational level.

The policy is set and published by the Ministry of Education of China; it is implemented by the ministries of education and universities in certain provinces and cities. There are in total eight less developed provinces covered by this policy; Inner Mongolia, Shanxi, Henan, Guizhou, Gansu, Guangxi, Yunnan, and Anhui. Universities in eleven developed provinces such as Beijing, Tianjin, Liaoning, and Guangdong are expected to increase enrolment of students from the above eight provinces. The first stage of this policy was introduced in 2008-2011. The total increase in enrolment from eight target provinces was 35,000 in 2008, 60,000 in 2009, 120,000 in 2010 and 150,000 in 2011 representing the 1.6%, 1.9%, 2.1%, 2.9% and 3.2% in the total admission number of the above eight provinces.

Educational Policy 6: Teacher Quality Improvement

A national training programme for primary and middle school teachers is the fifth key policy published in 2010. The goal of this policy is to improve the educational quality in less developed areas in China. Policy objectives include:

- Improve the teaching and learning skill of primary and middle school teachers in less developed areas;
- Promoting teaching and learning communication between educational personnel in developed and less developed areas; and
- Narrow the gap of educational personnel quality between developed and less developed areas.

The policy is set and published by the Ministry of Education of China; it is implemented by the ministries of education in each province and city. Two main kinds of training are set by this policy. For most educational personnel in primary and middle schools in less developed areas, online training about teaching skills is used. For more highly qualified educational personnel in primary and middle schools in less developed areas, offline training about teaching skills is used during summer and winter vacations. Nine universities have joined this programme for offline training, namely Peking University, Guangzhou University, Beijing Normal University, East China Normal University, Central China University, Shanxi Normal University, South China Normal University, Jiangxi Normal University, and Shaanxi Normal University. The expenditure for this programme in the first period (2010-2012) was 550 million RMB per annum, representing 0.43%, 0.33% and 0.25% of total educational expenditure of government. The main content of the programme focuses on teaching and learning methods, modern teaching techniques and educational psychology. Target teachers must complete examinations and a thesis about the training during the programme in both short and long-term training.

Educational Policy 7: General Development in Higher Education

The seventh key educational policy in China is general development in higher education in the central and western regions, published in 2012. The main goal of this policy is to improve the standard of higher education in fourteen central and western provinces in of China. To reach this goal, objectives are set as follows:

- Increase expenditure in higher educational institutions in target areas to narrow the expenditure gap;
- Improve teaching and research in the higher educational institutions in target areas;
- Improve facilities of the higher education institutions in target areas; and
- Prioritise high-quality institutions in target areas in the first stage of the plan.

The policy is set and published by the Ministry of Education of China; it is implemented by the ministries of education and universities in certain provinces and cities. This policy is to be implemented from 2012 to 2020 with an expenditure of 10 billion RMB. The first phase of this plan was from 2012 to 2016, when fourteen universities[40] were picked. Other higher educational institutions are also covered by the policy based on the experience of the fourteen target universities. This 10 billion RMB expenditure is to increase the educational expenditure per student, and improve facilities, and hold related conferences to improve educational quality, such as conferences and R&D. The policy promotes high-quality universities in developed areas to share their teaching experience, R&D and management with the target universities.

In summary, the main targets of education policies published by the Chinese government are education equity and quality improvement. Financial support from central government is given to less developed areas by supporting policies. Substantial educational development in provinces such as Gansu and Guizhou can narrow the gap in educational attainment relative to cities like Beijing and Shanghai. For the less developed areas, the government set targets for them over different time periods and also sets supervision for teaching quality and funding use.

The government also attempts to balance educational quality and resources between

[40] The 14 target universities are: Hebei University, Zhengzhou University, Shanxi University, Nanchang University, Yunnan University, Guangxi University, Guizhou University, Hainan University, Inner Mongolia University, Xinjiang University, Qinghai University, Shihezi University, Tibet university and Ningxia University.

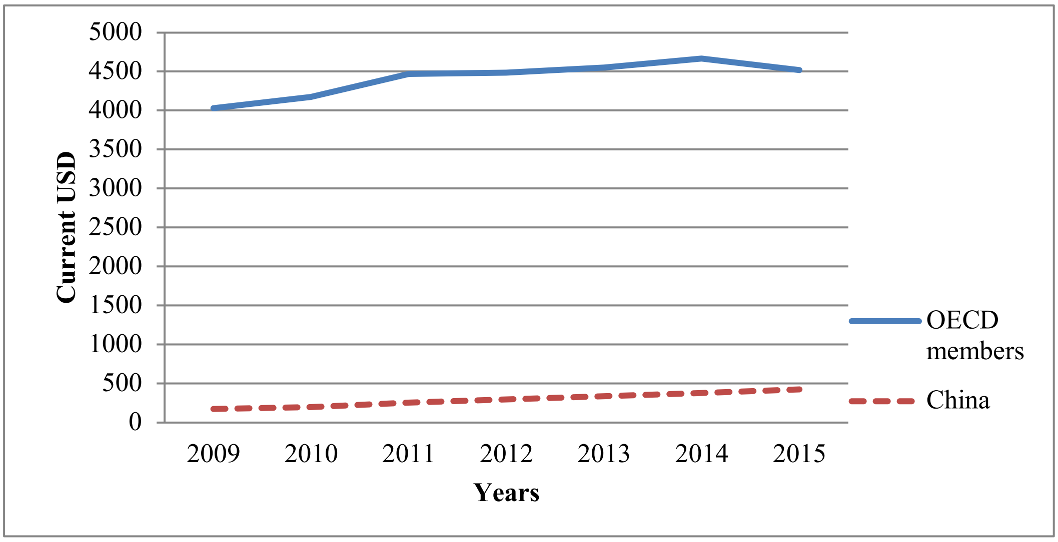
rich and poor provinces in China. More expenditure in education is used not only to renew and improve the infrastructures of educational institutions but also to give economically disadvantaged students an opportunity to improve their education. Supervision from specific departments of government ensures the funding is used appropriately. Attractive policies and better welfare encourage more teachers with professional skills to work in less developed, rural areas. They also narrow the gap in educational quality and improve the educational attainment of the population in poorer provinces (Qin, 2013; Xie, 2014).

3.3.3 Background to Health Policies in China

Public health in China saw limited development in past years, which is reflected in some basic indicators in the following figures. Data for this sub section is collected from the 'China Health Development Plan' as a part of 'Five-Year plans'. Three 'Five-Years plans' are considered, the10th, 11th and 12th Plan published in 2001, 2006 and 2011 respectively.

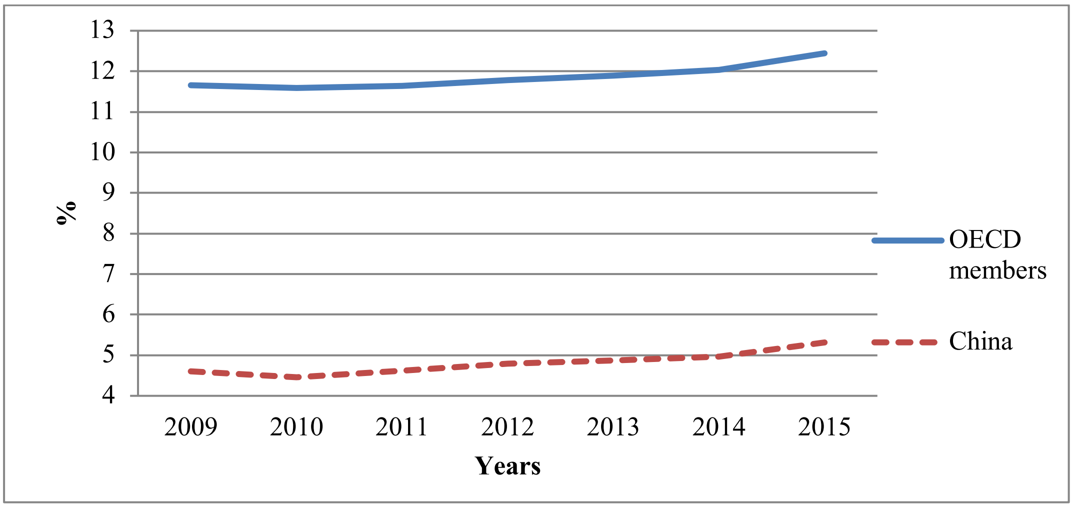
From Figure 3.5 and 3.6, it can be seen that health expenditure in China saw a slight increase from 2009-2015, but a substantial gap still exists between China and OECD countries in both health expenditure per capita and health expenditure as a proportion of GDP.

Figure 3.5: Health Expenditure per capita: China and OECD Countries, 2009-2015



Source: World Bank Database

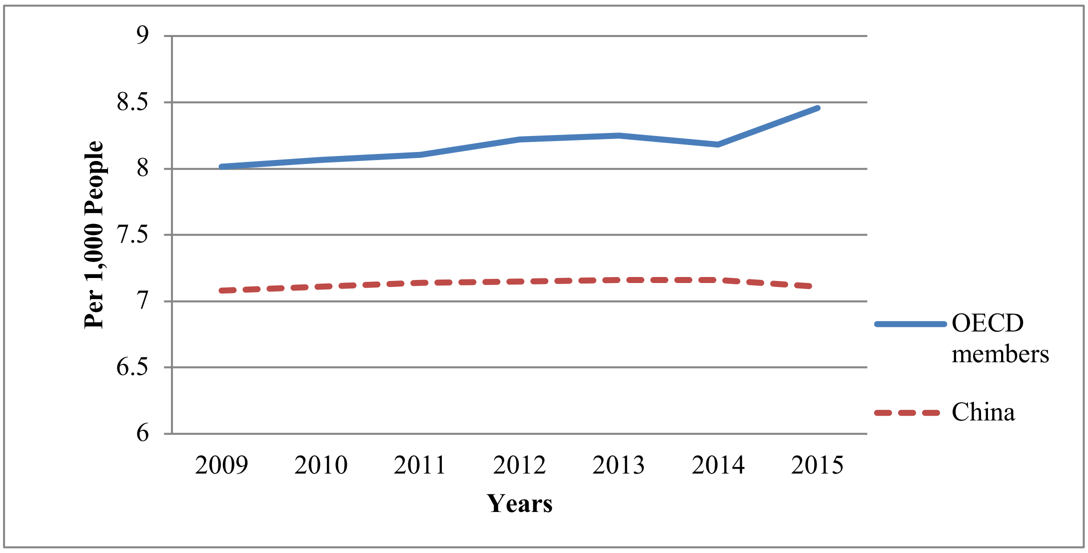
Figure 3.6: Health Expenditure (% of GDP): China and OECD Countries, 2009-2015



Source: World Bank Database

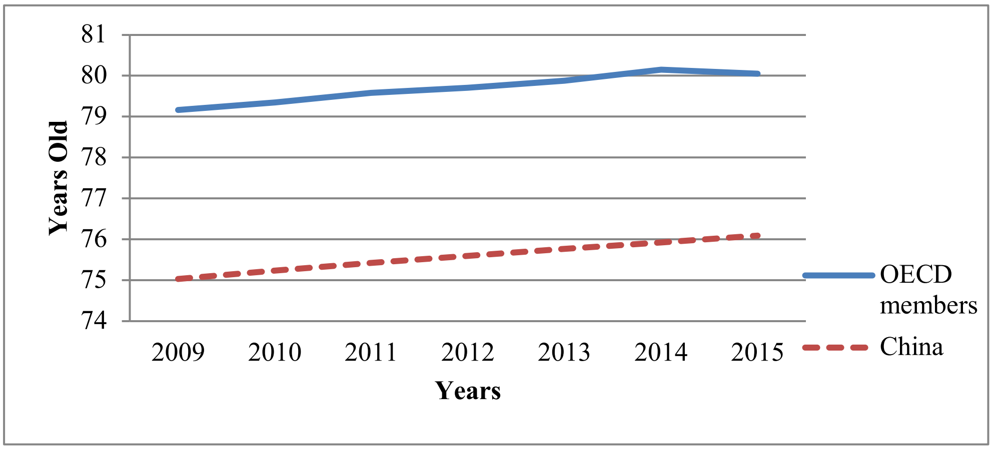
The death rate in China decreased slightly from 2009-2015 and is lower than the OECD countries. For the life expectancy at birth, the gap between China and OECD countries narrowed slightly in the above period.

Figure 3.7: Death Rate in China and OECD Countries, 2009-2015



Source: World Bank Database

Figure 3.8: Life Expectancy at Birth in China and OECD Countries, 2009-2015



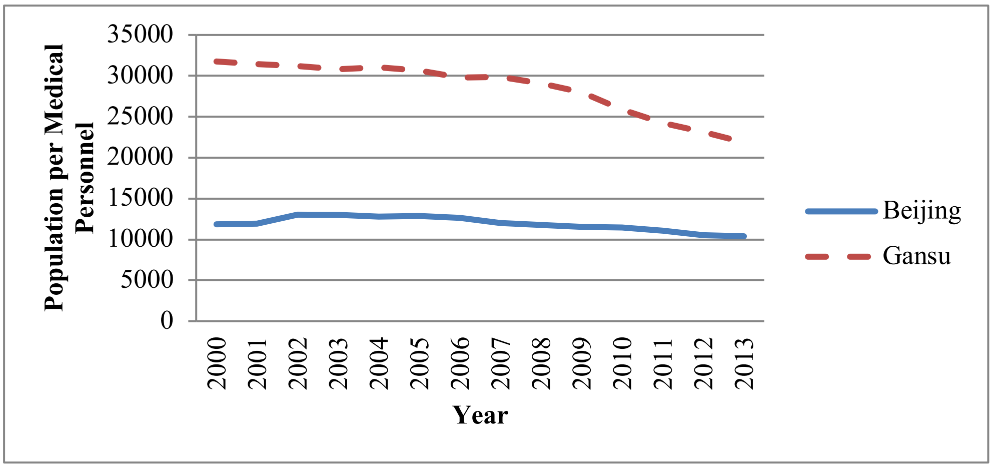
Source: World Bank Database

From the above figures, it can be seen that public health output and expenditure in China have changed but there still exists a significant gap between China and other countries, because of the weak basis of public health in less developed areas, low efficiency of medical system and huge total population (Ren, 2014; Zhang, 2014). The following public health issues which occurred in China in recent years may limit its development.

- **Imbalance in Public Health Resources between Provinces and Areas**

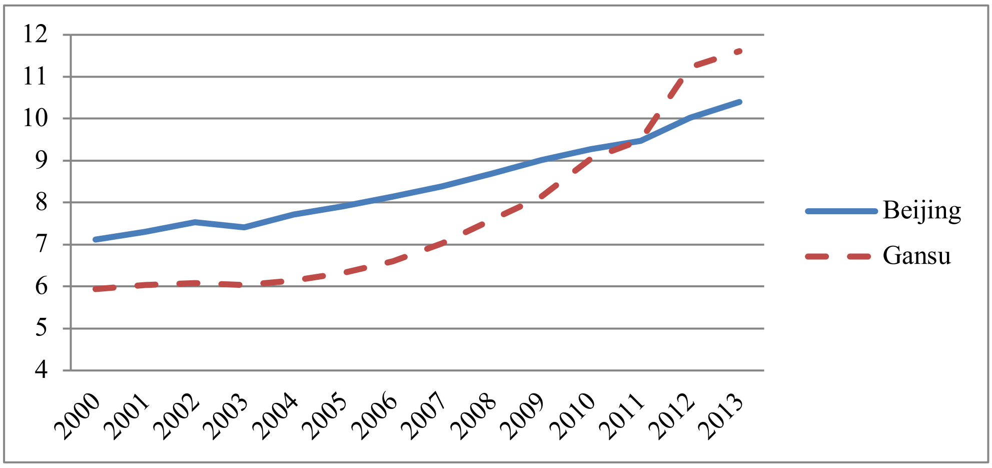
The first challenge affecting population health is the imbalance of public health resources between provinces and regions. Figures 3.9 and 3.10 show the total number of beds per 10,000 people and medical personnel per capita in Gansu and Beijing. This imbalance was most pronounced prior to 2005, but has declined over time. Figure 3.9 shows the gap of population per medical personnel between Gansu and Beijing declined from 269% to 211% Public health expenditure per capita (nominal) in Beijing was 1,529 RMB in 2007 and 1,706 RMB in 2015 (by comparison, Gansu province was 161RMB and 986MB). The gap of number of medical personnel per 10,000 people between Beijing and Gansu narrowed significantly from the year of 2004, the number of Gansu beyonded Beijing from the year of 2011.

Figure 3.9: Population per Medical Personnel between Beijing and Gansu, 2000-2013



Source: Website of National Bureau of Statistics of China

Figure 3.10 Number of Beds of Medical Institutions per 10,000 People in Beijing and Gansu, 2000-2013



Source: the website of National Bureau of Statistics of China

Patients' choices feed further into the imbalance of medical resources. High-income patients living in less developed provinces distrust local medical institutions and they prefer to go to first class hospitals in big cities (Ren, 2014; Zhang, 2014). Local medical institutions cannot fully treat patients with serious diseases, such as cancer so they also need to refer to hospitals in developed areas for advice. Technical limitations and patients' distrust increase the burden on medical institutions in developed areas like

Beijing and Shanghai, and it also aggravates the medical resource imbalance between rich and poor provinces.

- **Incomplete Medical System**

The medical system in China is different to the medical system in Europe as medical institutions and hospitals in China are divided into three levels by the government[41]. The first-class hospitals and medical institutions have the highest level of infrastructure, equipment, personnel, and technology. Different level hospitals and medical institutions in China differ in terms of infrastructure, equipment, personnel, and technology while having the same responsibility and function. Unlike hospitals and medical institutions in Europe, there are very few general practitioners in China and most of them only provide some general medical services for the local elderly (Ren, 2014; Zhang, 2014).

Because of the low numbers and incomplete functional provision by general practitioners, people in China keep their health files in the hospital nearest their home. Chinese people tend to trust public hospitals, considering them to have higher standards. Waiting time before treatment in public hospitals are long (Ren, 2014). The third-class hospitals and health institutions in developed areas are not attractive to both patients and medical personnel. If general practitioners were well established they could share responsibility, that would not only share part non-urgent patients from public hospitals but also balance health resources and ease the financial burden of government. A restructuring of the medical system could increase the efficiency of hospitals and health institutions that improve the health level (Zou, 2006).

Prior to the publication of policies focused on improving health, a number of issues were evident. An imbalance also exists between the rich and poor provinces and regions

[41]Source: The measures for the administration of the hospital grade (1989, 2008 and 2019), published by the National Health Commission and General Office of the State Council of China; http://www.gov.cn/zhengce/content/2019-01/30/content_5362266.htm?_zbs_baidu_bk.

in China. People living in less developed regions cannot pay enough to improve their health and so hospitals cannot earn enough money to adequately invest in their facilities and thus attract the most qualified and experienced medical personnel. The trust that rural inhabitants have for hospitals in urban areas decreases overall efficiency, especially in the most developed cities, like Beijing and Shanghai (Zou, 2006, Zhang, 2014).

3.3.4 Policies Focused on Improving Health[42]

The Chinese government has implemented policies between 2001 and 2015 to increase efficiency in the health system, balance funding and expenditure in rich and poor regions and more stringently supervise the funding and pricing across the health system. Table 3.3 lists the key policies of public health in China.

[42]Policies of this sub section are identified from the China Health Development Plan 10th, 11th and 12th Five-Year Plans.

Table 3.3: Key Policies of Public Health Policies in China

Policy	Introduction Year	Implementing Areas	Contents
1. Modernisation of Public Health System	2001	Lanzhou, Guiyang, Beijing	Build and update 2448 disease prevention and control institutions by investing 10.5 billion RMB; invests 5 billion RMB to the rural area public health centers. This policy mainly focuses on the facilities and institutions in both developed and less developed areas in China.
2. Increasing Financial Supporting	2006	Lanzhou, Guiyang, Beijing	Increasing the public health financial support to people living in rural area. The amount of supporting depends on the income level of the province and different health expenditure amount of people. This policy mainly increases the financial support to the hospitals in rural areas that decrease the cost of medicine and treatment. The medical personnel in rural areas can also enjoy this policy by the increase in their salary. Total expenditure is 47 billion RMB for the facility updating and personnel salary supporting. The expenditure in public health insurance should reach 90 billion RMB in 2012.
3. Breaking Monopoly of Public Medical Institutions	2006	Lanzhou, Guiyang, Beijing	Government eases the limitation of private medical institutions to break the monopoly of a public medical institution that increases the quality and efficiency of public medical institutions.
4. Encourage Medical Personnel Working to Less Developed Areas	2010	Gansu, Guiyang	Government promotes medical personnel to rural areas and the Central or Western area by financial support and priority promotion in their carrier. The government pays 210 million RMB to medical student and personnel in the rural area to improve their skill and experience. The total number of medical personnel in the rural area was over 1.2 million in 2011.

Source: Policy Documents from the Website of National Health Commission of the People's Republic of China, Official Documents of the 10th, 11th and 12th 'Five-Years' Plans.

Health Policy 1: Modernisation of Public Health System

The first key public health policy in China, published in 2001, aimed to complete and modernise the public health system in China. This policy can be seen as a guideline to promote expenditure in public healthcare in both developed and less developed regions. The main goal of this policy is to improve overall public health including facilities, methods, and expertise by increasing expenditure. The objectives are as follows:

- Increase expenditure in public health facilities, such as disease prevention and control, institutions, hospitals, and blood bank to complete the public health network;
- Increase expenditure in professional public health personnel training; and
- Increase expenditure in facilities in less developed and rural areas.

Based on this policy, the Chinese government provides significant support. For example, 2,448 [43] disease prevention and control institution updating programmes, which covered 69% of total number of disease prevention and control institutions were finished in both developed and less developed areas by 2005 with an expenditure of 10.5 billion RMB (as 8% of total public health expenditure of the Chinese government in 2005); 2,668 emergencies public health centers (16% of total number of energencies public health centers in 2005) were established costing 16.4 billion RMB (11% of total public health expenditure of the Chinese government in 2005). From 2003-2005, the central government increased local government spending by 8.3 billion RMB (5% of total public health expenditure of the Chinese government in 2005) to update facilities and train medical workers. A further 2.25 billion RMB (2% of total public health expenditure of the Chinese government in 2005) was invested in the central and western provinces to build 459 blood banks and pay for 1,771 ambulances.

[43] All detailed data applied in Section 3.3.4 are collected from the Website of National Health Commission of the People's Republic of China, Official Documents of the 10th, 11th and 12th 'Five-Years' Plans and the Website of National Bureau of Statistics of China.

Health Policy 2: Increasing Financial Supporting

The second key policy, implemented in 2006, is increased financial support for healthcare in rural areas. The main goal of this policy is to improve public health in less developed and rural areas in China by updating facilities and completing public health insurance. Based on this main goal, the following objectives were set;

- Improve financial support to people living in less developed and rural areas to decrease personal public health expenditure;
- Improve the salaries of public health workers to attract more experienced and qualified personnel to less developed and rural areas;
- Increase the number of clinics and health centers in less developed and rural areas; the basic goal to ensure each village has at least one public clinic; and
- Encourage people living in less developed and rural areas to take out public health insurance which is provided by central government to ease their financial burden in case of medical emergency.

Following the implementation of this policy, 240 million people (as 32.4% of population living in less developed and rural areas) in 678 counties (as 23.7% of total county numbers in 2006) took out public health insurance. The subsequent increase in revenue was used to modernise facilities in target areas and increase financial support (based on income) to people living in these areas. Insurance covers a minimum 50% of medical expenses in these target areas.

Expenditure of 47 billion RMB (24% of the total public health in 2006) was planned to modernise facilities and increase the salary of medical practitioners. Detailed numbers of facilities and salary increased are not indicated in the official document and websites. The government also encouraged higher educational institutions with high quality medical and health programmes to enroll students from less developed and rural areas. The government also provided further training for medical personnel. For example, the government encouraged related graduates working in medical and health institutions in poor areas with better welfare and a shorter term of promotion periods[44]. The government also establishes links between each medical institution in poor areas and large public hospitals in developed areas to share human resource training and expertise. Over 1,100 hospitals in big cities established links with 2,300 hospitals (as 11% of total number of hospitals in China in 2010) in less developed areas before 2010.

Health Policy 3: Breaking Monopoly of Public Medical Institutions

The third key public health policy in China (implemented in 2006) is breaking the monopoly of public medical institutions. One of the reasons for the low efficiency of the Chinese medical system is the monopoly of the public medical institutions. Low numbers of private medical institutions mean that people have to choose public medical institutions, especially in developed areas such as Beijing and Shanghai (Zhang, 2012). The main goal of this policy is to balance the public and private medical resources to improve the efficiency of the medical system. Based on the main goal, the following objectives were set;

- Promote private medical institutions in China, setting a target proportion of private medical institutions at 20% in 2015;
- Increase the supervision by the National Health Commission of China and local Municipal Health Commission of both public and private medical system in three parts: medicine and service price, medical malpractice and financial support; and
- Ease limitations on the private capital to open medical institutions or purchase shares of public medical institutions.

One of the big differences between the medical systems of Europe and China is the general practitioner. The general practitioner acts as the early contract point in European medical systems and eases the burden on the large public hospital that increases the efficiency of the medical system. However, there are few GPs[45] in China

[44]Public health personnel who have working experience in poor areas can take advantage of career promotion.
[45] The total number of hospitals in China was 64,524 and total GP number was 5,968 in 2001.

because of the limited medical personnel training system[46]. To increase the efficiency of the medical system over a short time, the government promotes set medical service centers (private) in cities and rural medical stations (public) in rural areas. The function of these basic medical service institutions is similar to the GP in Europe, i.e. people can enjoy basic medical services near their home. The setting of the basic medical centers also shares some basic medical service functions of large public hospitals that let patients get effective treatment timely. The basic medical services institutions also collect and supervise the health level and data of population in China, i.e. they can warn a higher level of public health institutions about serious diseases (Zou, 2006; Zhang, 2014; Ren 2014).

Supervision from the National Health Commission of China and local Municipal Health Commission to both public and private medical institutions in medicine and service price, medical malpractice and financial support is necessary to ensure the efficiency of the medical system. People can call the supervision department to report any unreasonable use of financial support. The Ministry of the Medical and Public Health in each city also has the authority to check and supervise private and public medical institutions randomly.

Health Policy 4: Encourage Medical Personnel Working in Less Developed Areas

The fourth key policy of public health in China was promoting medical personnel to less developed areas, published in 2010. The main goal of this policy is improving the amount and quality of public health personnel in less developed areas. The government planned to pay 210 million RMB (as 0.04% of total expenditure of public health of Chinese government in 2010) to medical students and personnel in rural areas to improve their skill and experience. The total number of medical personnel in rural areas was over 1.2 million in 2011. Based on the main policy, the objectives were as follows:

[46] Based on Ren (2014), medical personnel training in China mainly focuses on specialist physicians or doctors rather than GPs.

- Establish links between the high-quality medical institutions in developed areas and less developed areas to promote online and offline experience exchange of best practice;
- Attract medical and public health students to work in local medical institutions or in less developed areas;
- Medical personnel who work in the medical institutions in developed areas should have work experience in less developed areas at least one year before their get higher professional qualification; and
- Medical and public health students who choose to work in less developed areas to receive financial support with local living standards. They can also get priority to continue their further professional study in their original schools.

This policy focuses on increasing medical personnel both in quantity and quality in less developed and rural areas in China to improve the local health level. A number of problems create barriers to health level development. The first problem is the shortage of qualified medical personnel in less developed and rural areas. Only 43% medical personnel in total medical personnel in less developed and rural areas are qualified, based on data from 2010. Second, because of the weak medical system and low salaries, medical institutions in less developed and rural areas are not attractive to qualified medical personnel. The third problem is the low quality of medical personnel in less developed and rural areas. Only 23% of total medical personnel in less developed and rural areas have a diploma or higher degree in 2010[47]. Professional medical personnel and students working in less developed and rural areas are necessary to improve the health level in these areas[48].

[47] Source: http://www.alliedphysician.com/News/Articles/Index/1890.
[48] Source: http://www.gov.cn/zwgk/2010-06/08/content_1623025.htm.

3.4 Conclusions

This Chapter is contextual in nature. Its key aim was two-fold: i.e. to identify and explore the concepts underpinning the research and to provide an outline of policies implemented in China from 1995-2015.

Under the first aim the following are the key points of note:

- Studies focusing on countries other than China tend to use just educational indicators to represent population quality;
- Studies focusing on China tend to use two sets of indicators, education and health, to represent population quality;
- Studies focusing on countries other than China tend to employ one single variable (or sometimes a few variables) for population quality in econometric analysis;
- In comparison, studies focusing on China tend to use an index constructed using multiple indicators of education and health, to represent population quality;
- Empirical studies indicate that the education level of population, which is highly correlated with labour skill, should positively affect regional economic growth via knowledge spillovers, productivity improvement and technical progress;
- Further studies on China that include the health level of the population suggest that this factor should positively affect economic growth driven by longer working lives and more productive workers.

Under the second aim key education and health policies outlined in the 10^{th}, 11^{th} and 12^{th} 'Five-year Plans' published by Chinese central government were reviewed at national and regional levels. The key points are as follows:

- Education policies in China have focused on educational development of less-developed areas through financial supports, increases in educational personnel and training programmes to narrow the gap in education levels between the less-developed and developed regions;
- Health policies in China have tended to focus on improving the health system in

less-developed regions through financial supports, increases in medical personnel and training programmes in order to modernize the health care system and improve system efficiency;

Table 3.4: Time of Key Education Policies – Less-Developed and Developed Regions

Policy	**Introduction Year**	**Less-Developed**	**More-Developed**
Ed 1*: Nine-year compulsory education	2001	YES	Yes
Ed 2: Increasing Funding	2001	YES	Yes
Ed 3: Financial Support to Teachers in Less Developed Areas	2006	YES	No
Ed 4: Normal Student Programme	2007	YES	Yes
Ed 5: Growing Admission in Higher Education	2008	YES	No
Ed 6: Teacher Quality Improvement	2010	YES	Yes
Ed 7: General Development in Higher Education	2012	YES	No
H 1**: Modernisation of Public Health System	2001	YES	Yes
H2: Increasing Financial Supporting	2006	YES	Yes
H3: Breaking Monopoly of Public Medical Institutions	2006	YES	Yes
H4: Encourage Medical Personnel Working to Less Developed Areas	2010	YES	No

Notes:
**Ed policies denote each educational policy outlined in Table 3.2.*
***H policies denote each health policy, as outlined in Table 3.3.*
'YES' denotes policies expected to positively impact on economic growth where the expectation is that impacts will be more significant for less-developed relative to developed regions;

The review of policy allows for an organization of the various policies using a time-line to indicate when various policies were introduced and their potential impacts on less-developed regions to be identified, as presented in Table 3.4. In four cases (policies Ed 3, Ed 5, Ed7, and H4) impacts are expected in less-developed regions and not more developed regions. For the remainder of policies, expectations are that would be observed for both regions.

CHAPTER 4: POPULATION QUALITY: DATA DESCRIPTION AND INDEX CONSTRUCTION FOR THREE CHINESE CITIES

The main objectives of this Chapter are three-fold. The first objective is to introduce the three cities selected for analysis. The second objective is to describe the data and present some preliminary descriptive data analysis. The third objective is to outline and apply methods of index construction to produce indexes of population quality for the three selected cities. Two separate indexes are constructed, one for education and another for health drawing on robust data and selecting from the most appropriate techniques. These indexes represent a significant contribution of this research. The index construction underpins the empirical analysis conducted in Chapter Five.

Section 4.1 provides an overview of the rationale for selecting three cities for the analysis and provides background descriptions of these cities. This research chooses Lanzhou, Guiyang and Beijing as the focal cities to identify the impact of population quality on regional economic growth.

Section 4.2 identifies the indicators of education and public health in the three selected cities. Patterns of change and trends are identified over the period 1995-2015.

Section 4.3 introduces the methods used to construct indexes for education and public health, drawing on findings from the relevant literature.

Section 4.4 provides the main conclusions from these sections in terms of empirical analysis and econometric approaches selected for application in Chapters Five and Six.

4.1 Background Information and Rationale for City Selection

This section introduces the basic background of the three cities, namely Lanzhou, Guiyang, and Beijing, and some relevant statistics. Lanzhou and Guiyang are cities in less developed provinces with limited economic growth levels and poor performance in education and public health development: see Figure 4.1 for locations of these cities in China. Studies show that relatively poor performance in education and public health in these two cities limit both population quality and the standard of living; these factors also limit regional economic growth (Xie, 2012; Chen and Yang, et al., 2013). As primary targets of policies detailed in the previous Chapter, education and public health in Lanzhou and Guiyang may be expected to exhibit positive changes. Choosing Lanzhou and Guiyang as target cities for analysis, allows for focus on locations of relevance in the content of China's development policies based on education and health improvement.

Beijing, China's capital city, is a city with more developed education and public health and is used as a comparison with Lanzhou and Guiyang with the aim of examining development in a comparative context. The research also identifies the specific effects of education and public health across the three selected cities to ascertain the nature of effects on both less-developed and developed cities in China.

In the next section, specific indicators of education and public health are identified.

Figure 4.1: Geographic Location of Lanzhou, Guiyang, and Beijing[49]

- **Lanzhou**

Lanzhou is the capital city of Gansu province, a relatively less developed province in the northwest of China. Lanzhou is the main driver of economic growth in Gansu contributing 209.9 billion RMB (31% of Gansu province) of nominal total GDP in 2015, an increase of 9.1% over the previous year[50]. Lanzhou had a population of 3.49 million (13% of Gansu province), 180.3 billion RMB of total fixed asset investment (21% of Gansu province) and an average salary of 58,967 RMB (12% higher than the average salary of Gansu province), as of 2015.

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[49] Source: https://geology.com/world/china-satellite-image.shtml.

[50] All data in this chapter are collected from the Statistical Yearbooks of Lanzhou, Guiyang and Beijing, 1996-2016.

Poor geography and climate are barriers to economic growth in Lanzhou. Mountains have made improvements in transportation infrastructure difficult, limiting local industry and business development (Chen and Yang, 2013). The climate in Lanzhou also has a negative impact on agriculture, its dry climate causing cultivated land to become arid and negatively affecting crop yield. Xie (2012) notes that these conditions negatively affected the flow of expenditure in Lanzhou, compared with other areas of eastern China. An obvious decrease in the growth rate of nominal fixed asset investment[51] reflects the negative status of expenditure in Lanzhou.

Industry structure negatively affects economic development in Lanzhou. Heavy industry, such as petrochemicals, non-ferrous metallurgy, and thermal industry are the main contributors to regional GDP, comprising 37% in 2015. Laws published in 2014 relating to industrial pollutant prevention and treatment negatively impacted heavy industry causing added value growth rate to decrease from 15% in 2011 to 6% in 2015. Tourism, which contributed 14% of total GDP in 2015, was also negatively affected by environmental pollution from heavy industry (Wu, Zou and Du, 1997; Chen and Yang, 2013).

Population quality in Lanzhou compares negatively with that of provinces in the developed areas of China. Lanzhou has a weak basis of economic growth leading to poor regional development, which is unattractive to highly qualified education and public health personnel (Liu, 2010; Xie, 2012).

- **Guiyang**

Guiyang is the capital city of Guizhou province, another less developed province in the Southwest of China. Guiyang comprises 5% of Guizhou's land and 13% of its

[51] The growth rate of nominal fixed asset investment decreased from 42% to 12% between 2011 and 2015; data source: Statistical Yearbooks of Lanzhou, 1996-2016.

population. It contributes 28% of the province's total nominal GDP and 35% of tertiary industry added value in 2015. Guiyang has a population of 4.6 million, total GDP of 289.1 billion RMB, total fixed asset investment of 401.5 billion RMB (37% of Guizhou province) and an average salary of 63,949 RMB (7.1% higher than the average salary of Guizhou province) as of 2015[52].

Industry is one of the main contributors to regional GDP in Guiyang, comprising 38.3% in 2015. The main contributors to industry in Guiyang are tobacco, equipment manufacturing, and coal industries. These are negatively affected by environmental regulations despite causing less environmental pollution[53]. Consequently, there has been a decrease in the growth rate of industry value added in Guiyang decreasing from 22% in 2011 to 20% in 2015. The government is promoting tertiary sectors, such as electronic information technology, tourism, and software with the aim of switching the main drivers of regional economic growth from capital to innovation from 2012. Cooperation with strong Chinese enterprises such as Alibaba and Huawei reflect good potential for Guiyang's development (Wei, 2018).

Education and public health in Guiyang still need to improve to match the demands of regional economic growth. Local educational output cannot cover the demand for skilled labour and increased labour costs. Higher quality of education and health services in other cities are attractive to these skilled workers. As with Lanzhou, the lack of highly skilled educational and medical personnel is one of the main barriers to development (Liu, 2010; Zhang, 2014).

- **Beijing**

Beijing, the capital city of China, is chosen to compare education and public health development with Lanzhou and Guiyang. Beijing is located in the north of China and

[52] Source: Statistical Yearbooks of Guiyang, 1996-2016
[53] Industry added value growth rate decreased from 21.7% in 2011 to 9.7% in 2015.

contributes 2301.4 billion RMB (3.4% of total GDP in China), has a population of 22 million (1.6% of total population in China), 799 billion RMB of fixed asset investment (1.4% of total fixed asset investment in China) and an average salary 97,616 RMB, which is 57% higher than the average salary in China as of 2015. Based on stable economic growth in Beijing, the CPI decreased steadily from 105.6 in 2011 to 101.8 in 2015 and the unemployment rate fluctuated between 1.2% and 1.6% between 2011 and 2015[54].

Tertiary industry contributed a large proportion to Beijing's total GDP increasing from 77% to 80% between 2011 and 2015. The percentage of the workforce employed in tertiary industry increased from 75% to 79% in the same period. The main industrial sectors in Beijing are computer science and software, finance, and real estate, contributing 10%, 17% and 7% to total GDP in 2015, respectively[55].

Highly skilled and qualified workers from all over China live and work in Beijing and the government invests heavily in education and public health to improve the standard of living. In fact, Beijing has been the centre of education in China since the 1900s, which is a good basis for educational development. A good basis and priority of development in education promotes educational development in Beijing (Gao, 1999, 2001). Higher average income in Beijing has also led to greater expenditure on health and child education, furthering development in these areas. Jobs in computer science, software, and finance attract more workers with a higher educational attainment, and in turn further promote local educational development (Gao, 2001; Liu, 2010).

In this research, Lanzhou, Guiyang and Beijing are the three cities selected to investigate the impact of population quality on economic growth. In Chapter three, key education and public health policies between 2001-2015 were outlined, which reflects the attitude of the Chinese government about narrowing the gap in education and public

[54] Source: Statistical Yearbooks of Beijing, 2012-2016.
[55] Source: Statistical Yearbooks of Beijing, 2012-2016

health between less developed and developed areas. Previous studies such as Sun (2012) and Bonnefond (2015) used single province and country-level data respectively, to identify the role of population quality in economic growth in China, but did not focus on the policy aspect. Education and public health development, especially in less developed areas in China are supported by the financial expenditure and other supports of key policies (Liu, 2010; Wu and Deng, 2011). The impact of population quality on economic growth in both developed and less developed cities are identified in this study, which are the key goals of this study with consideration of the policy context.

To identify the effects of policies' implementation, less developed areas are an important focus for research. Trends of detailed indicators reflect differences in population quality development in a context where policies are implemented in the three cities. It is more difficult to get a complete and reliable data for other cities compared with the capital city and so data limitations are identified. Lanzhou and Guiyang, as the capital cities of the provinces of Gansu and Guizhou respectively, are chosen as the target cities. Focus on these two cities, for which complete data is available, is helpful to identify the specific impacts of population quality on economic growth, as examples. The difference between the role and impacts of the same policies can be examined in and between these two less-developed cities, and considered in the context of the impact of developments in Beijing.

Gansu and Guizhou are less developed provinces in China where the real GDP per capita ranked in the bottom three of 28 provinces in 2013[56]. As the capital cities of Gansu and Guizhou, Lanzhou and Guiyang are the main developing targets of local government which are typical to reflect the impacts of key policies (Liu, 2010).

The next section identifies specific indicators of education and public health.

[56] See Table 2.6 in Chapter Two, pp31.

4.2 Population Quality: Education and Public Health Indicators

This section identifies key indicators of education and public health, which are collected from the Statistical Yearbooks of Lanzhou, Guiyang, and Beijing from 1996 to 2016. Basic statistical information such as definition and units of these indicators are also presented here. Trends in the key education and public health indicators are presented in Section 4.2.2.

4.2.1 Definition of Education and Public Health Indicators

This section defines the city level education and public health indicators, including units, and calculation method. For each indicator selected, the main features are outlined below.

- **Educational Indicators**

(1) ***Government expenditure on education per student*** reflects the effects of policies such as increasing educational expenditure on less developed areas. The indicator is calculated as the total government expenditure on education divided by the total number of students each year. This indicator is transformed from nominal to real terms using the CPI of each selected city in each year, and the base year is 1995. The unit of this indicator is RMB.

(2) ***Students per 10,000 people*** reflects the effects of policies related to educational development at different education levels. For example, policies regarding higher education development may lead to an increase in the university student number per 10,000 people. This indicator is divided into three different education levels: primary school students, middle school (including junior and senior middle school, and vocational middle school) students and higher education (including undergraduate, postgraduate and Ph.D. in university, college, and vocational high

schools) students.

(3) ***The number of educational institutions*** reflects the changes in educational provision in selected areas, such as the increase in the number of middle schools and higher educational institutions. Again, this indicator is divided into three different education levels: primary school, middle school (including junior and senior middle school, and vocational middle school) and higher education (including undergraduate, postgraduate and Ph.D. in university, college, and vocational high schools).

(4) ***Number of educational personnel*** reflects an increase in the number of educational personnel reflects development in different education levels that may improve educational attainment. The effect of educational personnel on different education levels is identified using the student-teacher ratio, which is calculated by dividing the number of students by the number of educational personnel. This indicator is expressed at three different education levels: primary school, middle school (including junior and senior middle school, and vocational middle school) and higher education (including undergraduate, postgraduate and Ph.D. in university, college, and vocational high schools).

(5) ***Admission numbers*** is an indicator that may reflect positive educational policies, such as increasing admission numbers in less developed areas and development of higher education. Increasing the admission number, e.g. to higher education, should have a positive effect on the educational attainment of the local population. This indicator is expressed at three different education levels for primary school students, middle school students and higher education students.

(6) ***Average salary of educational personnel*** reflects the effect of implementing policies aimed at improving the standard of living of educational personnel in less developed areas. Higher salaries for educational personnel help attract and maintain

qualified workers and improve the quality of educational personnel. Earnings are transformed into real terms using the CPI of Lanzhou, Guiyang and Beijing, respectively, from 1996 to 2015 and the base year is 1995. The unit of this indicator is RMB.

The above educational indicators are collected from the Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016. Other indicators such as average schooling years and illiteracy rates are generated from demographic data collected every five years in city level databases and it is difficult to estimate missing values for intermediate periods for these variables.

- **Public Health Indicators**

(1) ***Government expenditure on public health per person*** reflects the effectiveness of policies to increase public expenditure on less developed areas. The indicator is calculated by dividing total government expenditure on public health by total population. This indicator is expressed in real terms using the CPI of each selected city in 1996-2015, and the base year is 1995. The unit of this indicator is RMB.

(2) ***The death rate*** reflects the general public health level of the population. It is collected as an indicator of public health in this research even though it cannot reflect the effects of government policies directly (as policy impacts on death rates would take some time to be observed). The death rate is expressed as deaths per thousand per year. The death rate is the only public health *output* indicator in the index. Other public health output indicators such as the infant mortality rate and life expectancy are incomplete in city level databases. These indicators are published in demographic data every five years in city level databases.

(3) ***Number of public health personnel*** is used to track policies implemented to increase the number of medical personnel in less developed areas. Increasing the

number of public health personnel is beneficial in that it improves the efficiency of medical treatment, thus potentially improving the public health level. This figure is calculated by dividing the total number of medical personnel (in general hospitals, disease control and prevention centres, maternal and child health care hospitals and public and private community health centres) by population.

(4) ***Number of beds in public health institutions***. This indicator includes the number of beds in all public health institutions, expressed per thousand people. It is calculated by dividing the total number of beds (in general hospitals, disease control and prevention centres, maternal and child health care hospitals and public and private community health centres) by city population.

(5) ***Average salary of public health personnel*** reflects the effects of policies aimed at improving the standard of living of public health personnel in less developed areas. Higher salaries for educational personnel help attract and maintain qualified workers and improve the quality of medical personnel. It is expressed in real terms using the CPI of Lanzhou, Guiyang and Beijing,1996-2015, and the base year is 1995. The unit of this indicator is RMB.

Given the problem of missing data for some indicators, we focus on collecting those data which are complete for each indicator in each city. Hence, the illiteracy rate and infant mortality rate are excluded from our analyses.

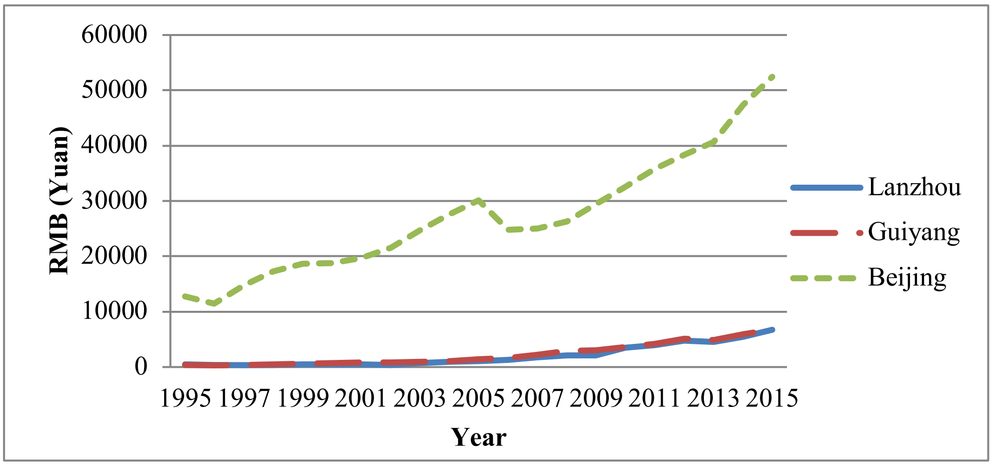
4.2.2 Trends in Key Indicators in the Three Cities

In this section, features and trends of the indicators of education and public health in the three cities are identified. In Chapter three, key policies of education and public health were identified. Detailed indicators which are identified here may reflect the education and public health development of the three cities in previous years.

- **Educational Indicators**

Figure 4.2 shows that real expenditure on education per student in both Lanzhou and Guiyang increased from 2006, reflecting policies implemented to increase educational expenditure on less developed areas.

Figure 4.2: Educational Expenditure per Student in Lanzhou, Guiyang and Beijing, 1995-2015

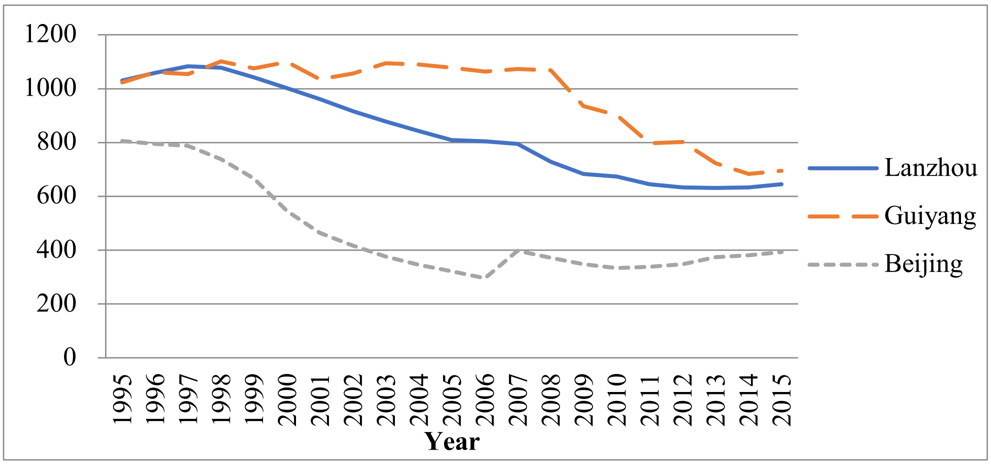


Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

The educational expenditure per student increased from 1995 to 2015 with a slight fall between 2005 and 2006 in Beijing. In the three cities, Lanzhou and Guiyang had the highest growth rate in educational expenditure per student in that period, 1400% and 2120%, respectively. The rate for Beijing was 312%. However, a significant gap between Lanzhou, Guiyang and Beijing exists. Lower amounts of educational institutions in Lanzhou and Guiyang could be a reason for the significant gap in education expenditure; high quality teaching and R&D programmes might improve the education institutions' quality in less developed areas that might attract more expenditure from government (Liu, 2013; Xu, 2014).

Figures 4.3 to 4.5 show statistics for student numbers at different education levels. This reflects the educational attainment of the population as well as development at different levels of education. It is clear that the number of primary students in all three cities decreased from 1995 to 2015.

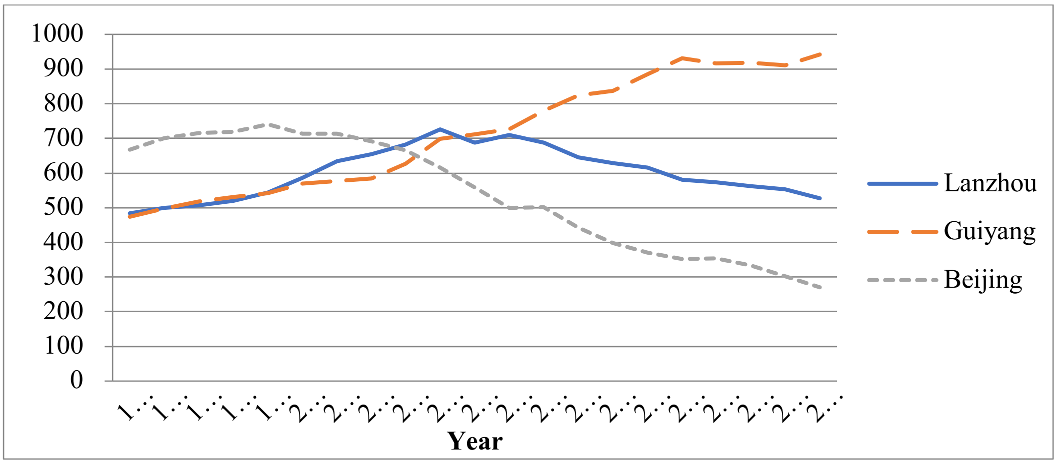
Figure 4.3: Primary School Students per 10,000 People in Lanzhou, Guiyang and Beijing, 1995-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

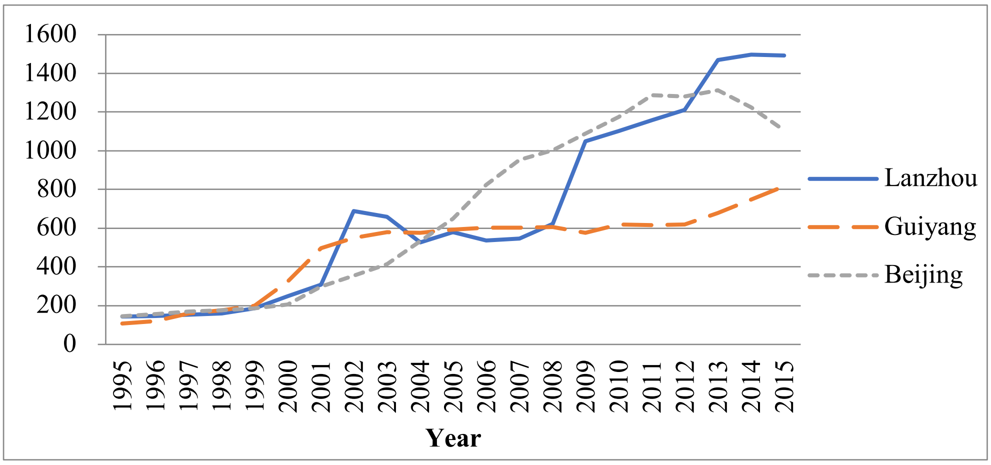
In Lanzhou, the number of middle school students began to decrease after 2004 (see Figure 4.4). The rate in Guiyang, however, rose between 1995 and 2015, reflecting other trends in middle school education in the region. The rate decreased in Beijing after 1999. The number of university and college students per 10,000 increased in all three cities between 1995 and 2015. However, it seems that higher education development in Guiyang began to lag behind that of Lanzhou and Beijing after 2008, based on the lower number of university and college student numbers.

Figure 4.4: Middle School Students per 10,000 People in Lanzhou, Guiyang and Beijing, 1995-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

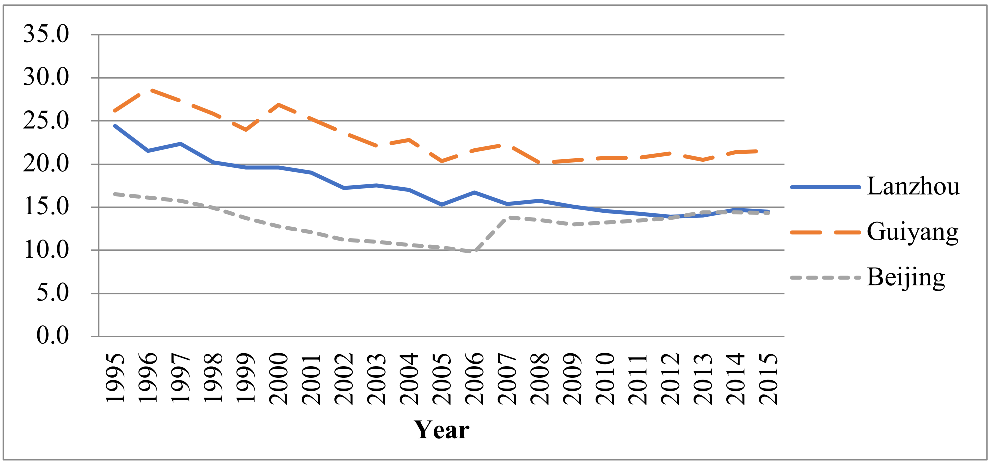
Figure 4.5: University & College Students per 10,000 People in Lanzhou, Guiyang and Beijing, 1995-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

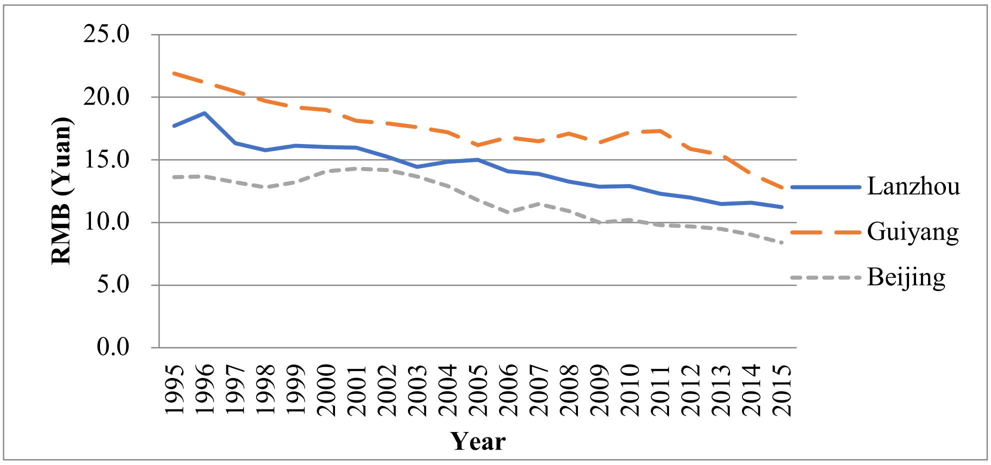
Figures 4.6 to 4.8 show the ratio of students to teachers across different education levels. It is clear that the student to teacher ratio in primary schools decreased in the three cities, due to the decrease in student numbers. The indicator in Beijing had a slight increase from 2006, which has the highest growth rate of 13.3% between 1995 and 2015. The student to teacher ratio in middle school fell consistently in Lanzhou, Guiyang and Beijing; Guiyang has the highest rate of decline between 1995 and 2015, which is -41.6%.

Figure 4.6: Student/Teacher Ratio of Primary Schools in Lanzhou, Guiyang and Beijing, 1995-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

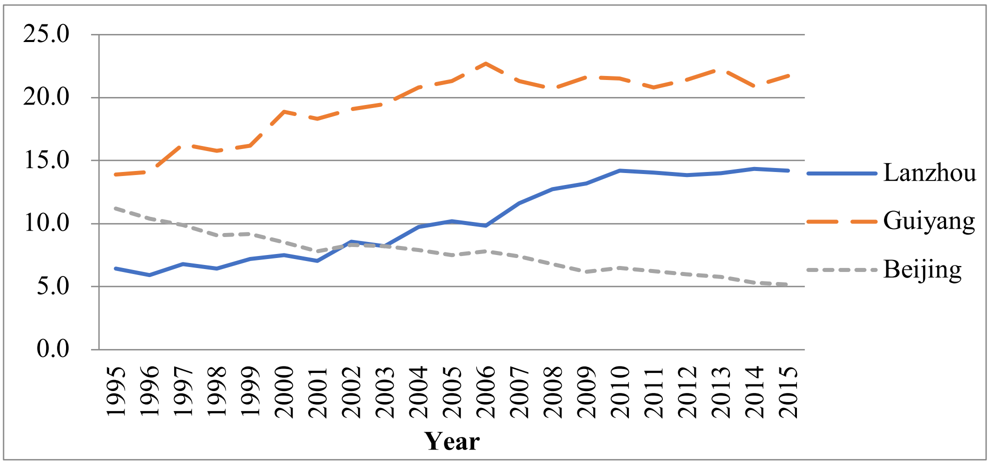
Figure 4.7: Student/Teacher Ratio of Middle Schools in Lanzhou, Guiyang and Beijing, 1995-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

Stable increases in the student/teacher ratio in Lanzhou and Guiyang in higher education show that the number of higher education personnel increased less than the number of students. Compared with Lanzhou and Guiyang, Beijing reveals better levels in higher education.

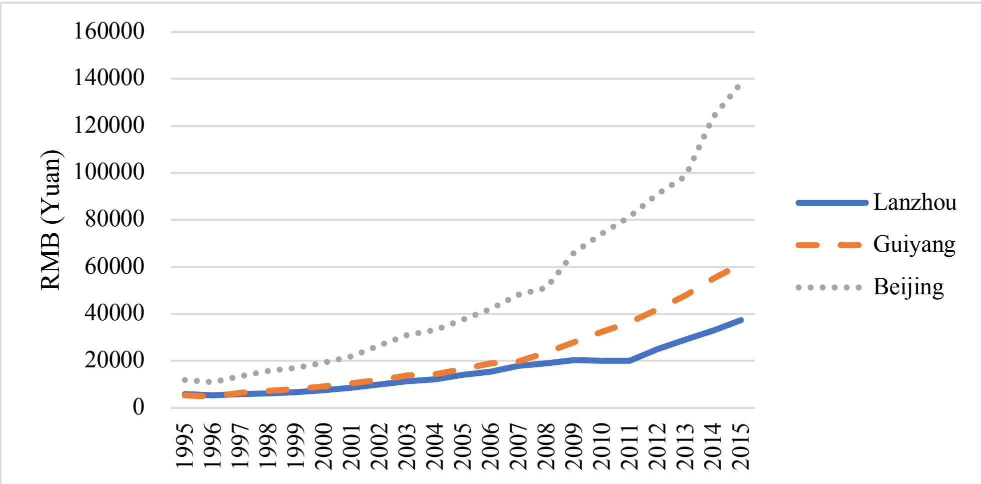
Figure 4.8: Student/Teacher Ratio of University & College in Lanzhou, Guiyang and Beijing, 1995-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

Figure 4.9 shows the average salary of educational personnel. The average salary of educational personnel in these cities increased grew consistently from 1995 to 2015, but the gap between Beijing and the other two cities widened. Although educational policy 2 states that 'special teachers' working in rural areas should have the same salary level as teachers in urban areas in the same region, the salary gap between developed and less developed cities, such as Lanzhou, Guiyang and Beijing still existed.

Figure 4.9: Average Salary of Educational Personnel in Lanzhou, Guiyang and Beijing, 1995-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

Table 4.1 highlights the imbalance in education expenditure between Lanzhou and Guiyang on the one hand, and Beijing on the other. The mean value of real expenditure on education per student in Beijing is ten times that of Lanzhou and Guiyang. The average salary of educational personnel in Beijing is twice that of the other two cities, and reflects the imbalance of income between the regions. The mean figures for primary and middle school students per 10,000 of population and student/teacher ratio are higher than in Beijing, but the number of primary and middle schools is lower. Both the mean figures for university and college students per 10,000 of population and student/teacher ratio are lower than Beijing. In addition, the table reflects an imbalance between the admission numbers and school numbers in the middle schools and universities in Lanzhou and Guiyang. The statistics point to a large gap between

Guiyang and Beijing across all education levels; however, the gap between Lanzhou and Beijing is less pronounced.

Table 4.1: Statistical Analysis of Education Indicators, 1995-2015

Indicators	**Lanzhou**			**Guiyang**			**Beijing**		
	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
1. Educational expenditure per student	2225.74	1912.78	1284.47	2419.87	2086.27	1447.44	27895.97	10240.71	25922.83
2. Average salary of educational personnel	24025.36	16875.42	18075	22198.47	17607.24	14581	41355.19	30364.61	30724
3. Primary school student (per 10,000 population)	836.66	163.51	810	976.48	142.518	1056	468.50	171.58	381
4. Middle school student (per 10,000 population)	600.28	72.01	586	714.43	162.1444	711	539.28	162.21	558
5. University & college student (per 10,000 population)	689.80	464.76	580	494.19	211.086	581	692.95	441.95	649
6. Total number of primary schools	742.33	102.66	751	760.57	128.2633	779	1623.09	641.08	1310
7. Total number of middle schools	183.14	29.42	193	284.42	20.81797	290	952.90	167.82	917
8. Total number of university & colleges	17.14	2.73	18	22.47	7.786552	20	76.47	11.45	79
9. Admission number; primary school	66100.89	19074.35	72588	46005.06	6646.58	43737	113808.71	30828.24	109203
10. Admission number; middle school	51366.59	8540.36	49204	116327.51	28177.05	132042	281804.91	67477.70	271396
11. Admission number; university & college	45612.01	35853.9	39541	52380.19	35494.9	54641	127367.	40302.0	152741

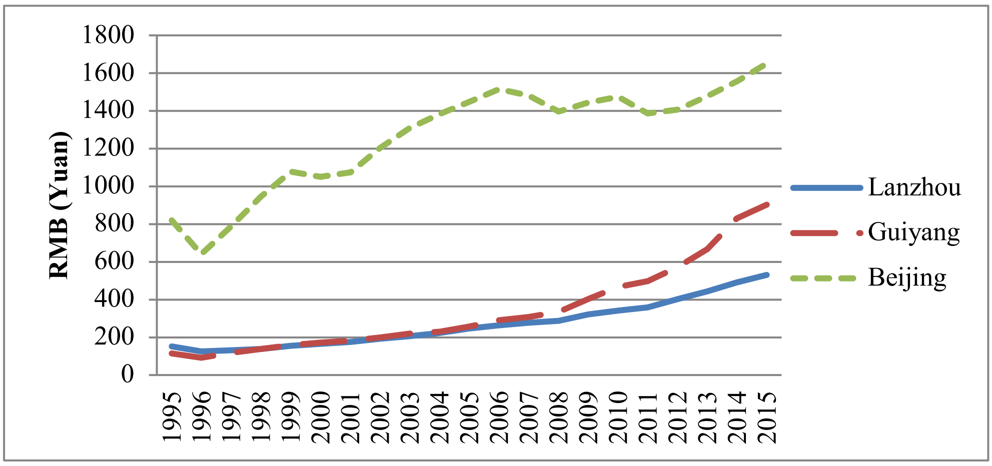
		7			7		50	8	
12. Student / teacher ratio in primary schools	17.26	2.97	16.7	23.01	2.59	22.1	13.25	1.83	13.5
13. Student / teacher ratio in middle schools	14.37	2.04	14.4	17.51	2.17	17.2	11.77	1.88	11.8
14. Student / teacher ratio in university and colleges	10.29	3.08	9.8	19.48	2.63	20.8	7.67	1.62	7.8

Source: Author's analysis, based on data from the Statistical Yearbooks of Lanzhou, Guiyang and Beijing, 1996-2016.

- **Public Health Indicators**

From Figure 4.10, health expenditure per capita in the three cities increased from 1995 to 2015. Expenditure increased more rapidly in both Lanzhou and Guiyang from 2005. The positive effects are evident from higher growth rates in Lanzhou and Guiyang between 1995 and 2015, which are 245% and 705%, and also by the narrowing gap between these cities and Beijing. Policy may have had positive and significant effects in balancing the gap between the three cities.

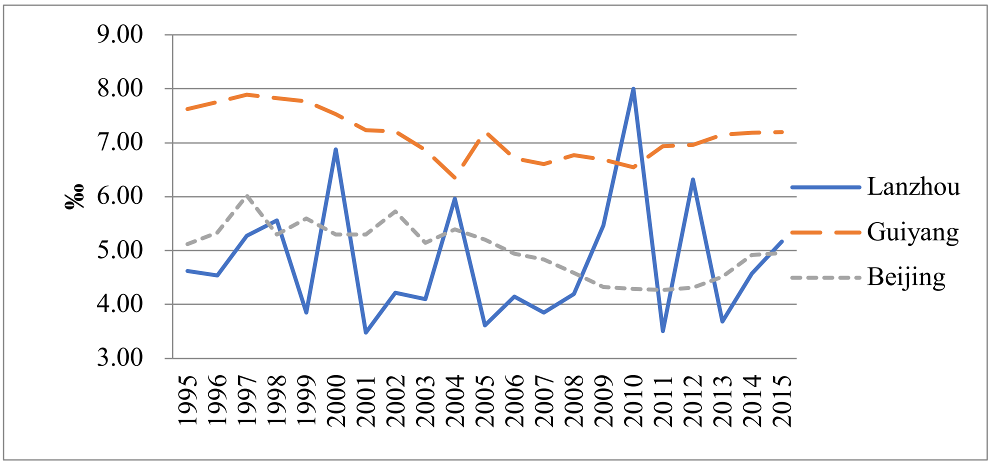
Figure 4.10: Public Health Expenditure per capita in Lanzhou, Guiyang and Beijing, 1995-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

Figure 4.11 shows the death rate in the three cities from 1995 to 2015. The death rate in Beijing and Guiyang is stable compared with that of Lanzhou. The death rate in Guiyang is the highest among the three cities and can be viewed as a negative population health level outcome. Geographical disasters based on the weak environment and poor medical treatment, especially in rural areas, might be the main reasons for the high-level death rate in Guiyang between 1995 and 2015 (Zhang, 2014).

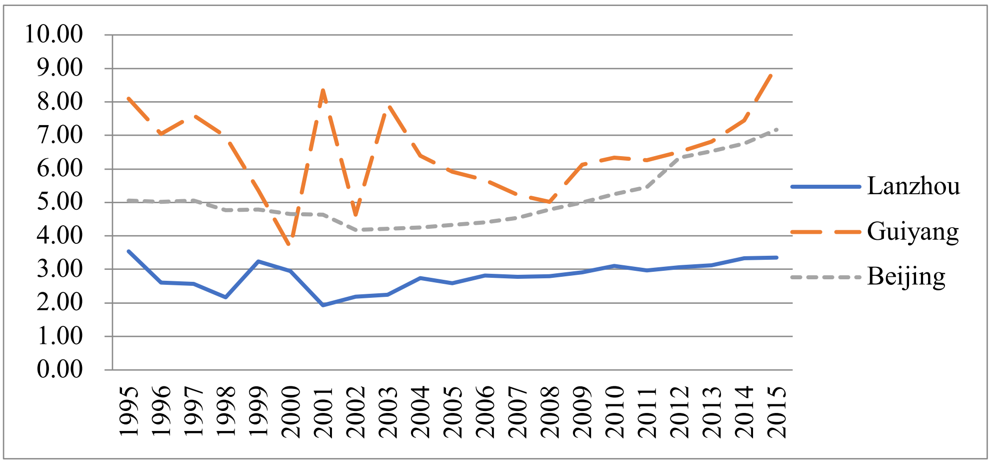
Figure 4.11: Death Rate in Lanzhou, Guiyang and Beijing, 1995-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

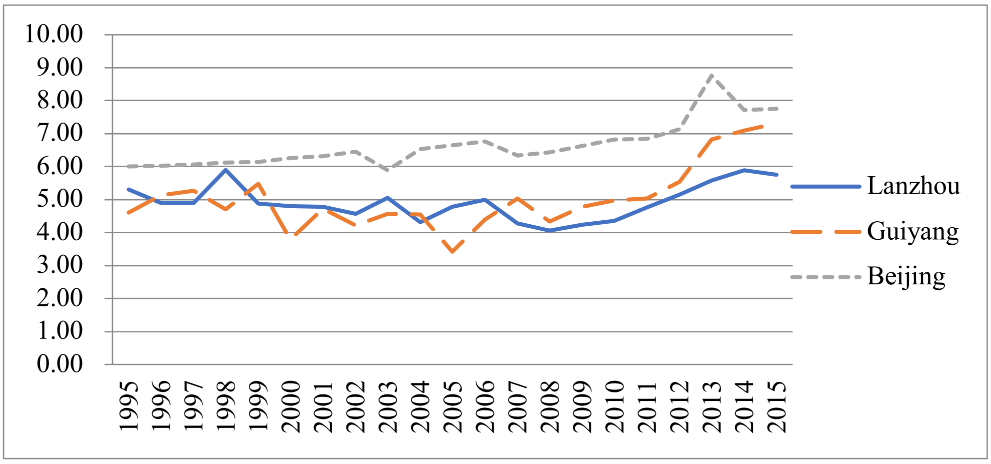
Figures 4.12 and 4.13 show trends in public health personnel and facilities across the three cities between 1995 and 2015. The number of medical personnel and number of beds in public health institutions increased in all three cities after 2008 (see Figure 4.13). Guiyang maintains the highest number of medical personnel per 1,000 people, and Lanzhou the lowest. Beijing has the highest number of beds in public institutions per 1,000 people, Lanzhou fares worst here, too.

Figure 4.12: Number of Medical Personnel per Thousand People in Lanzhou, Guiyang and Beijing, 1995-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

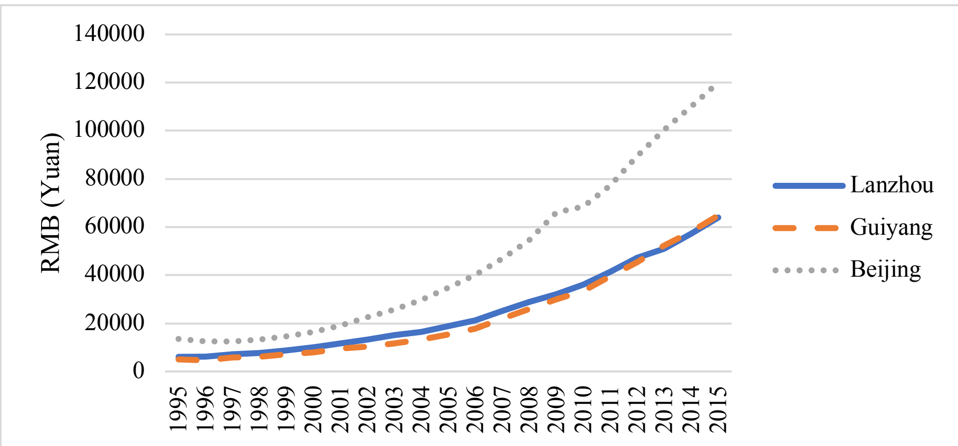
Figure 4.13: Number of Beds in Public Health Institutions per Thousand People in Lanzhou, Guiyang and Beijing, 1995-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

Figure 4.14 shows the average salary of public health personnel. The salary gap between health personnel in Lanzhou and Guiyang and those in Beijing increased, although Guiyang has the highest growth rate of 1172% in the three cities. Lower average salaries make it difficult to attract high quality medical personnel to poorer areas from developed areas, despite the average salary of public health personnel being higher than the local average salary (Ren, 2014; Zhang, 2014).

Figure 4.14: Average Salary of Public Health Personnel in Lanzhou, Guiyang and Beijing, 1995-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

A number of observations can be made from Table 4.2. The mean increases in salary for Beijing's public health and real public health expenditure per capita is, respectively, double and triple that of Guizhou and Lanzhou. The mean value of medical personnel per thousand people in Guiyang is significantly higher than Lanzhou and Beijing, but the death rate is higher than the other two cities. The mean value of medical personnel in Lanzhou is lower than the other two cities. It is interesting that the average death rate in Guiyang is higher than Lanzhou and Beijing, even though it has improving medical resources, such as medical personnel and beds in public health institutions, while the average values indicating slight gaps between Lanzhou, Guiyang and Beijing.

Table 4.2: Statistical Analysis of Public Health Indicators, 1995-2015

Indicators	Lanzhou			Guiyang			Beijing		
	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
1. Public health expenditure per capita	416.08	246.35	331.51	358.95	241.63	268.62	1326.34	265.32	1481.98
2. Average salary of public health personnel	25054.41	17597.98	18849.50	23211.84	18411.57	15247.16	46933.17	34459.21	34867.98
3. Death rate	4.81	1.18	4.54	7.14	0.44	7.18	5.02	0.49	5.12
4. Number of public health personnel per thousand population	2.81	0.42	2.82	6.50	1.30	6.40	5.10	0.85	4.79
5. Number of beds in public health institutions per thousand population	4.92	0.52	4.88	5.04	0.97	4.78	6.65	0.69	6.46

Source: Author's analysis, Data from the Statistical Yearbooks of Lanzhou, Guiyang and Beijing, 1996-2016.

It is difficult to conclude on the impact of policies on the education and public health levels of population in Lanzhou, Guiyang and Beijing based on the figures and tables in this section. To investigate these relationships more comprehensively, two indexes are constructed to identify the changes in population quality, i.e. education and public health levels, in the three cities. Detailed methods about constructing indexes based on education and public health indicators are introduced in the next section.

4.3 Methods to Measure Quality: Constructing Education and Health Indexes

Detailed indicators of education and public health were identified in the last section. To identify changes in population quality, index construction is used to quantify the education and public health levels of population and their changes over time in selected cities. This section details the steps in constructing the education and health indexes.

- **Rationale for Using Indexes**

Indexes are used to reflect a relationship between two indicators, or to measure the comprehensive impact of multiple indicators which come from single or multiple data sets (Schilderinck, 1977; Everitt,1998; Jia, 2009 and Yao, 2015). Indexes not only may reflect the relationship between two indicators but also can reflect macro impacts of multiple indicators. An index may be constructed using multiple indicators with the same or different weights over time, instead of using complicated sets of single indicators. There are two main kinds of indexes: simple and aggregated. A simple index is an index calculated using indicators with simple mathematical methods without weights, such as the BMI[57]. An aggregated index is calculated using different indicators with the same or different weights, such as PQLI[58].

[57]BMI: Body Mass Index simply reflects body quality by height and weight, which is calculated by the weight value divided by the height square value (Liu, 2009).

[58]PQLI: Physical Quality Life Index is calculated using three indicators with same weights, which are infant mortality rate, average life of population and literacy rate of population over 15 years old (Liang, 1994).

There are three major advantages in using an index rather than using single or multiple indicators in this research. First, an index displays an overall status of an area that single indicators cannot reflect. For example, the PQLI reflects population quality based on three indicators: life expectancy of the population, infant mortality rate and the literacy rate of the population over 15 years old. Any single indicator cannot comprehensively reflect population life and quality. The indicators in the above index include data of multiple areas that provide a more complete method for reflecting the quality of life of the population. Second, an index is a convenient method to help understand statistical information. For example, the effects that indicators such as average life expectancy, literacy rate and infant mortality rate have on the quality of life can be identified clearly using PQLI. Third, an index can be rationally used in econometric work. A large number of indicators cannot be added to econometric models as independent variables because of the risk of auto-correlation, multicollinearity, and degrees of freedom problems (Schilderinck, 1977; Gorsuch, 1983; Everitt,1998; Jia, 2009 and Yao, 2015).

Many studies use indexes to represent statistics in different areas. Courtault (2010) uses the ‘h-index’ to examine research excellence and achievement. Bei and Chung (2013) use a brand power index to evaluate the strength of television and mobile phone brands in Taiwan. Stern (2017) uses a Social Progress Index which includes human needs, foundations of wellbeing and opportunities to show opportunities for social progress in a large sample of countries. In Chinese studies, Yang (2014) uses an index including average income, total population, and total GDP growth to show the imbalanced economic growth in Shaanxi province, China. Zhang (2014) constructs an index of agricultural development to examine the development of agriculture in BRICS (Brazil, Russia, India, China, and South Africa) countries. Yang (2016) calculates coordinated development in Hangzhou, China, using indicators of population, environment, natural resources, and regional economic development.

Indexes used in previous studies focusing on population quality are mentioned in Chapter Three. Researchers such as Xu (2005), Lu and He (2008), Yan and Zhong

(2009), Sun (2012), Zhou, Liu and Zhu (2013), Zhang and Yu (2014) used indexes constructed from multiple indicators in their studies to reflect population quality in different areas.

4.3.1 Index Construction Methods

According to Schilderinck, (1977), Gorsuch (1983), Jia (2006) and Yao et al., (2015) there are two main kinds methods to create an index. The first kind method is a subjective method, which gives different weights to indicators based on subjective opinion, such as the analytic hierarchy process (AHP). Factor analysis and coefficient of variation methods are objective, which use statistical techniques to give weights to different indicators of the index. For the purpose of this research, subjective methods to create indicators of education and public health are not used due to the lack of rational subjective standards or weights to create them. Therefore, the objective method is used to construct education and public health indexes (Everitt,1998; Jia, 2009 and Yao, 2015).

Three objective methods have been widely used in studies to construct indexes. These are factor analysis, the entropy method and coefficient of variation method. Each is considered.

- **Factor Analysis**

Factor analysis is a method used to construct an index based on the common factors between multiple indicators. The method focuses on the internal relationship between original indicators to generate indicators to replace original indicators based on identified common factors. Common factors cannot be identified directly from the original indicators but they have a close relationship to multiple original indicators. Based on the common factor, each indicator can be described using the following equation (Schilderinck, 1977; Everitt, 1998; Gorsuch 1983; Jia, 2009; Yao, 2015).

$X_i = a_{i1}F_1 + a_{i2}F_2 + a_{i3}F_3 + a_{im}F_m + \varepsilon_m \ (i = 1,2,\dots,p)$ (4.1)

In the above equation, F are the common factors, ε is the special factor of indicator X_i which is the difference of the indicator between common factors (can be understood as the error term); a is the number of common factors and p is the number of indicators; the matrix of equation (4.1) is shown in equation (4.2) as follows (Everitt, 1998; Gorsuch 1983; Jia, 2009; Yao, 2015).

$\mathrm{X} = \mathrm{AF} + \varepsilon$ (4.2)

In the above two equations, the number of common factors is less than the indicators; and each common factor (F) and special factor (ε) are independent. The covariance between X and F is provided in equation (4.3).

$\mathrm{Cov}(X_i, F_j) = \mathrm{Cov}(\sum_{k=1}^{m} a_{ik}F_k + \varepsilon_i, F_j = a_{ij}$(4.3)

a_{ij} in the above equation is the correlation factor between X and F; a higher value of a_{ij} means a close relationship between X and F that should be given a higher weight in the index; a lower value of a_{ij} indicates a weak relationship between X and F that should be given a lower weight in the index (Schilderinck, 1977; Jia, 2006; Pan, 2011).

Principal Component Analysis (PCA) identifies the correlation structure by the correlated number of p variables with the uncorrelated number of q variables ($\mathrm{p} > q$) to calculate new independent measures that represent different linear combinations of variables. To find the linear combinations of the variables in the data matrix, eigenvalues and eigenvectors of the covariation or correlation matrices are used. The covariation matrix is given by $\sum$ and ρ is the correlation matrix of the random vector, $[x_1, x_2, \dots x_p]$ where latent root $\gamma_1 \geq \gamma_2 \geq \cdots \geq \gamma_p$. $l_1, l_2, \dots l_p$ are the corresponding orthogonal eigenvectors of the correlation matrix. $PC_i = l_i'X$ (i =

$1,2, \ldots p$) is the linear combination of the variables and the explanation of the ratio of the total variation of the kth PC can be described as $\frac{\gamma_k}{\gamma_1 + \cdots + \gamma_p}$; each indicator is ranked according to values of PC (Jia, 2006 Bei and Cheng 2013). Studies including Tang and Yang (2003), Zhu, Hu and Sun (2012), Bei and Cheng (2013), Ford, Apputhurai and Meyer (2017) and Johnson et al, (2018) use factor analysis or PCA as the main research method.

- **Entropy Method**

The entropy method involves constructing an index based on the dispersion and extreme values of the data. Higher degrees of dispersion and extreme values of indicators reflect key information, which are given a higher weight in the index. Entropy means the uncertainty level, which is reflected by the dispersion degree. A higher value of entropy means more information is reflected by the data (Everitt, 1998; Golan, 2008; Jia, 2009). Studies including Esposito (2013), Yonamoto (2013), Zou, Xu and Yang (2013), Wang (2015), Levy (2016) and Hu et al, (2016) applied the entropy method as the main methods in studies.

The first step of the entropy method is calculating the weight of a single unit indicator P_{ij} as in equation (4.4).

$$P_{ij} = \frac{x_{ij}}{\sum_{i-1}^{n} x_{ij}} \quad i = 1,2 \ldots n; j = 1,2 \ldots m \quad (4.4)$$

The entropy value of the indicator is calculated as outlined in the following equation (4.5)

$$e_j = -k * \sum_{i=1}^{n} P_{ij} \log P_{ij}, k = 1/\ln(n) \quad (4.5)$$

In equation (4.5), the total sample amount $k = \frac{1}{\ln n}$.

The coefficient of entropy can then be calculated following equation (4.6).

$$g_j = 1 - e_j (4.6)$$

The weighs of the indicators are calculated following equation (4.7).

$$W_j = \frac{g_j}{\sum_{j=1}^{m} g_j} \ (4.7)$$

From the above, a limitation of the entropy method is the impact of extreme values on the weights of the index. Based on equations (4.4) to (4.7), an extreme value of the data generates a large weight for a single unit indicator P_{ij} at first; then the entropy value e_j and coefficient of entropy g_j are affected by the large weight that leads a large value of the indicator W_j in the index. In equation (4.4), there is no other factor, such as the mean value of indicator to control the effect of an extreme value of indicator. Sometimes an extreme value in economic data is meaningless, and highlights potential limitations of the method (Everitt, 1998; Golan, 2008; Jia, 2009; Yao, 2015).

- **Coefficient of Variation Method**

The Coefficient of Variation method is used to construct indexes which focus on data changes over a certain time period. It is similar to the entropy method in that data or indicators with higher levels of dispersion have more information and these data or indicators are given a higher weight in the index. The main difference between the coefficient of variation method and the entropy method is the method of identifying the dispersion degree. The entropy method uses entropy to value the dispersion degree; the coefficient of variation method uses the coefficient of variation, which is constructed by the means and variations of each indicator (Everitt, 1998; Brown, 1998; Reed, 2002; Jia, 2009; Yao, 2015).

As a first step, the data are normalized. Because of the different value scales of each indicator, a data standardization method, based on the maximum and minimum value of each indicator, as presented in equation (4.8) is used transform the original value of each indicator to a value between 0 and 1.

$$Z_{ij} = \frac{X_{ij} - X_{ij}(A)}{X_{ij}MAX - X_{ij}MIN} \quad (4.8)$$

X_{ij} denotes the detailed indicator i in time j; $X_{ij}(A)$ is the maximum or minimum value of indicator X_i in the dataset. If indicator X_i is a positive value indicator, such as real educational expenditure per student, $X_{ij}(A)$ should be the minimum value of the real educational expenditure per student in the dataset; if the indicator X_i is a negative value indicator, such as death rate, $X_{ij}(A)$ should be the maximum value of the death rate in dataset. $X_{ij}MAX$ means the maximum value of the indicator X_i and $X_{ij}MIN$ means the minimum value of the indicator X_i in the dataset. The coefficient of variation method can be used to construct index (Brown, 1998; Reed, 2002; Jia, 2009; Yao, 2015).

A series of steps can be followed.

1. Calculate the sum, mean and standard deviation of each indicator;
2. Calculate the ratio between the standard deviation and mean of each indicator, which is the coefficient of variation (CV) following equation (4.9).

$$CV\ X_i = {Standard\ Deviation\ X_i}/{Mean\ X_i} \qquad (4.9)$$

3. Compute the sum of the coefficient of variation, and then, get the weight of each indicator in the sum of the coefficient of variation of all indicators as in equation (4.10).

$$\text{Weight } X_i = \frac{CV\ X_i}{\sum_{i=1}^{n} CV\ X_i} \quad (4.10)$$

Given the above, in this research, the coefficient of variation method is selected as the appropriate approach in constructing the indexes of educational quality and public health quality, similar to Zhang and Yu (2013). The method is suitable to construct an index from measurable indicators, such as the number of primary schools and the enrolment in universities. The key point of this method is the variations between different indicators. If one indicator has a higher degree of variation compared with other indicators, that means the sample value of the indicator has a significant change during the selected time period; so, the indicator has a higher weight in the index. If an indicator has a lower value of variation compared with other indicators it means it exhibits a slight change and the indicator would have a lower weight in the index (Brown, 1998; Yao, 2015).

Methods such as factor analysis and PCA based on the statistical relationship between indicators do not reflect the changes in each individual indicator. Factor analysis and PCA use weights that are derived by common factors rather than each indicator. Indicators with a lower correlation with common factors may be removed by the method, and PCA is not suitable to use if sample indicators have low levels of correlation. Important indicators affected by key policies with a lower common level with others may be removed by factor analysis and PCA. Compared with factor analysis and PCA, the coefficient of variation method keeps all detailed indicators in the index by applying rational weights based on coefficients of variation. The method reflects the original information and changes in each indicator, rather than finding a statistical relationship between them (Jia, 2009; Yao, 2015).

The entropy method depends critically on the value of entropy that is sensitive to extreme values. The method focuses on the uncertainty and degree of dispersion but has less control on the impacts of extreme values. This method is more suitable for data where the random extreme value has a strong impact on the index, such as stock prices (Everitt, 1998; Reed, 2002; Jia, 2009; Yao, 2015).

In addition, the coefficient of variation method is widely used in the research of population quality and regional economic growth. Chen and Yang (2013) used the coefficient of variation method in their research on population quality development in Gansu. Zhang and Yu (2014) also used coefficient of variation method to create an index of population quality, using this method. Other studies include Zhu and Li (2005) constructing an index of income by this method in a study of income imbalance in China. Yang (2014) used the coefficient of variation method in research on regional economic growth imbalance in Shaanxi province in China. Ma and Yang (2014) used this method in research on measurement and evaluation of tourism competitiveness of five north-western provinces in China. Studies which focus on other areas also applied the coefficient of variation method, such as Faber and Korn (1991), Eldridge, Ashby and Kerry (2006), Banik, Kibria and Sharma (2012) and Ormi, Mabrouk and Sassi-Tmar et al, (2015).

To construct the education and public health indexes, data must be normalized first, and then, the standard deviation and mean value of each indicator should be calculated, as shown in Table 4.3. Next, the coefficient of variation of each indicator can be calculated as in equation (4.9). Finally, we can compute the sum of coefficients of variation.

Table 4.3 shows the details of the education indicators in education index based on normalized data. In Lanzhou, indicators such as the student & teacher ratio of university & college, primary school student per 10,000 population and total number of university & colleges have higher standard deviations, which reflect a significant change in the value of the above indicators between 1995-2015 The total number of primary schools, middle schools and the university & college have a higher mean in all education indicators in Lanzhou. However, high mean values lead to lower values of the coefficients of variation, such as the student & teacher ratio of university & college. For the values of coefficient of variation, real education expenditure per student, the real average salary of education personnel and admission number students of university & college have a higher level than other indicators.

Table 4.3: Details of Educational Indicators in the Population Education Index

Education Indicators	Lanzhou			Guiyang			Beijing		
	Standard Deviation	Mean	Coefficient of variation	Standard Deviation	Mean	Coefficient of variation	Standard Deviation	Mean	Coefficient of variation
Real education expenditure per student	0.31	0.28	1.09	0.31	0.30	1.01	0.32	0.33	0.95
Average salary of educational personnel	0.30	0.33	0.93	0.32	0.32	0.99	0.26	0.38	0.67
Primary school student per 10,000 population	0.36	0.46	0.80	0.34	0.70	0.49	0.34	0.34	0.99
Middle school student per 10,000 population	0.30	0.48	0.62	0.35	0.51	0.67	0.35	0.57	0.60
University & college student per 10,000 population	0.34	0.40	0.85	0.30	0.54	0.55	0.38	0.47	0.81
Total number of primary schools	0.29	0.62	0.47	0.32	0.52	0.61	0.34	0.34	1.02
Total number of middle schools	0.29	0.64	0.45	0.32	0.67	0.47	0.39	0.45	0.86
Total number of university & colleges	0.34	0.64	0.53	0.34	0.46	0.74	0.36	0.55	0.66
Admission number students of primary school	0.32	0.51	0.63	0.30	0.32	0.95	0.31	0.44	0.72
Admission number students of middle school	0.29	0.35	0.84	0.39	0.51	0.75	0.20	0.28	0.71

Admission number students of university & college	0.30	0.35	0.87	0.31	0.42	0.75	0.37	0.68	0.54
Student & teacher ratio of primary school	0.28	0.68	0.42	0.30	0.66	0.46	0.27	0.49	0.56
Student & teacher ratio of middle school	0.27	0.58	0.47	0.22	0.54	0.40	0.32	0.48	0.66
Student & teacher ratio of university & college	0.37	0.48	0.76	0.29	0.34	0.84	0.26	0.60	0.44
	Sum of coefficients of variation: 9.74			Sum of coefficients of variation: 9.70			Sum of coefficients of variation: 10.19		

Source: Author's analysis, Data from the Statistical Yearbooks of Lanzhou, Guiyang and Beijing, 1996-2016.

For Guiyang, the admission numbers of middle schools, total number of university and college and primary school students (per 10,000 population) have higher standard deviations, which reflect significant changes in the level of these indicators from 1995 to 2015. Primary school students (per 10,000 population), total number of middle schools and the student-teacher ratio of primary schools exhibit high mean values. For Lanzhou, real education expenditure per student, real average salary of education personnel and admission number students of primary school have higher measured coefficients of variation.

For the indicators of Beijing, higher standards deviation of the total number of middle schools, university and college student (per 10,000 population) and total number of university & colleges reflect a significant change in the values of above indicators. Admission numbers of university & college students, student-teacher ratio of university & college and the middle school student (per 10,000 population) have higher means. The number of primary schools, education expenditure per student, and the primary school enrolment have higher coefficients of variations than other indicators.

The weight of each indicator is calculated following equation (4.10) in Table 4.4.

Table 4.4: Weights of Education Indicators in Population Education Index

Indicators	**ED Index Lanzhou**	**ED Index Guiyang**	**ED Index Beijing**
Real education expenditure per student	0.11	0.10	0.09
Real average salary of educational personnel	0.10	0.10	0.07
Primary school student per 10,000 population	0.08	0.05	0.10
Middle school student per 10,000 population	0.06	0.07	0.06
University & college student per 10,000 population	0.09	0.06	0.08
Total number of primary schools	0.05	0.06	0.10
Total number of middle schools	0.05	0.05	0.08
Total number of university & college	0.05	0.08	0.06
Admission number students of primary school	0.06	0.10	0.07
Admission number students of middle school	0.09	0.08	0.07
Admission number students of university & college	0.09	0.08	0.05
Student & teacher ratio of primary school	0.04	0.05	0.05
Student & teacher ratio of middle school	0.05	0.04	0.07
Student-teacher ratio of university & college	0.08	0.09	0.04

Source: Author's analysis, Data from the Statistical Yearbooks of Lanzhou, Guiyang and Beijing, 1996-2016

In Table 4.4, the different weights of indicators reflect differences in each indicator across the three cities between 1995 and 2015. For Lanzhou, real education expenditure per student and the real average salary of education personnel are weighted highest in the education index. For Guiyang, education expenditure, average salary and admission number of primary schools are the three indicators with the greatest weights. Unlike

Lanzhou and Guiyang, the number of primary schools, expenditure per student, and primary school enrolment are weighted highest in Beijing.

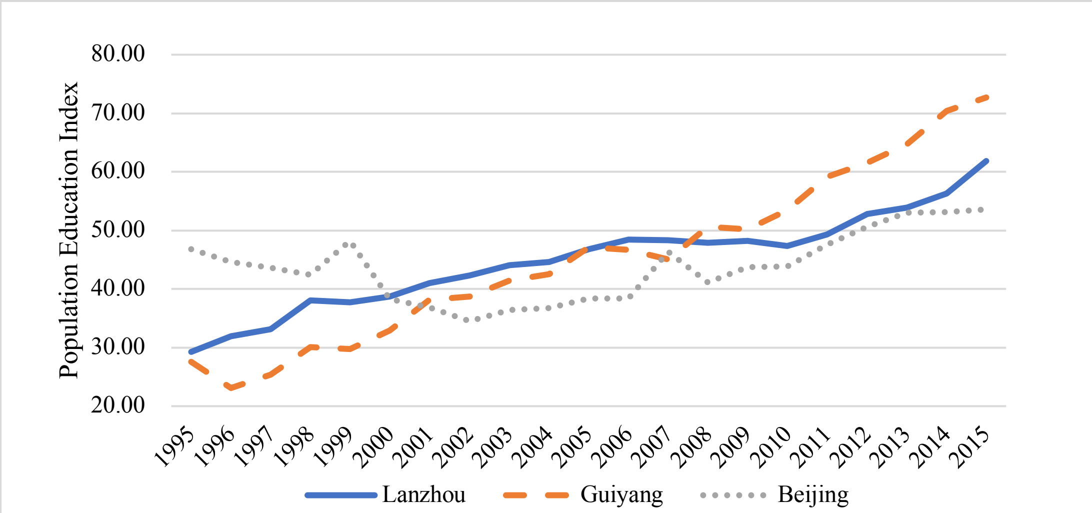
Based on the coefficient of variation method, indicators with a higher level of coefficient of variation have a higher weight in the index, such as the real educational expenditure per student in the three cities. Indicators such as the total number of university and colleges and the university & college student (per 10,000 population) in Lanzhou have the same standard deviation of 0.34 with the different weights in the education index (0.05 and 0.09), which is generated by the different means (0.64 and 0.40). As the discussions in Jia (2006) and Pan et al. (2011) show, the value of variation, which decides the weight of indicator in the index, is highly related to the values of standard deviation and mean values to control the impact of extreme values on the weight of each indicator in the index.

Comparing the weights of indicators across three cities, expenditure on education as the indicator has higher weights in all three cities, especially in Lanzhou and Guiyang. The average salary of educational personnel has higher weights only in Lanzhou and Guiyang. Compared with other kinds of indicators, financial indicators seem to be more important to the education index across the three cities.

For other indicators, higher education-related indicators such as the admission number students of university and college and the student-teacher ratio of university and college students also has a higher weight in Lanzhou and Guiyang, which indicates that the higher education development is important to the education level index in two less developed cities. Unlike Lanzhou and Guiyang, primary education related indicators for Beijing, such as the number of primary schools and the primary school enrolment, are important to the education level index and are given higher weights.

The education index in the three selected cities improved from 1995 to 2015, especially in the two less developed cities. Beijing's education index shows the least growth in the same period of 20% despite its higher level in 1995. Guiyang had the highest growth rate between 1995 and 2015 of 163%. The results indicate that the education level of population in Lanzhou and Guiyang improved significantly between 1995-2015, especially in Guiyang which began the period at the lowest level and exceeded the level of both other cities since 2008.

Figure 4.15: Education Index of Lanzhou, Guiyang and Beijing, 1995-2015



Source: Author's analysis

For the public health index, the same method of construction was used. Details of the health index are shown in Table 4.5.

In Table 4.5, financial indicators, which are represented as the real public health expenditure per capita and the real average salary of medical personnel, have higher standard deviations than other health indicators across all three cities. The death rate has the highest mean value in Lanzhou, Guiyang and Beijing. For the values of the coefficients of variation, real public health expenditure per capita and the real average salary of medical personnel have been higher in both Lanzhou and Guiyang. The real average salary of medical personnel has a higher coefficient of variation in Beijing, but the value of the real public health expenditure in Beijing is low. Medical facilities indicators, such as the beds and medical personnel, in Beijing have higher values - but not in Lanzhou and Guiyang.

Table 4.5: Details of indicators in Health Index									
Health Indicators		**Lanzhou**			**Guiyang**			**Beijing**	
	Standard Deviation	Mean	Coefficient of variation	Standard Deviation	Mean	Coefficient of variation	Standard Deviation	Mean	Coefficient of variation
Death rate	0.26	0.71	0.37	0.29	0.53	0.55	0.27	0.60	0.45
Number of public health personnel per thousand population	0.26	0.55	0.47	0.24	0.52	0.46	0.28	0.31	0.92
Number of beds in public institutions per thousand population Lanzhou	0.28	0.47	0.61	0.25	0.42	0.60	0.24	0.27	0.90
Real Average salary of medical personnel	0.30	0.33	0.93	0.31	0.30	1.01	0.32	0.33	0.95
Real public health expenditure per capita	0.30	0.32	0.96	0.31	0.33	0.93	0.29	0.58	0.49
	Sum of coefficients of variation: 3.35			Sum of coefficients of variation: 3.55			Sum of coefficients of variation: 3.72		

Source: Author’s analysis, based on data from the Statistical Yearbooks of Lanzhou, Guiyang and Beijing, 1996-2016

Table 4.6 shows the different weights of public health indicators in the health index for the three cities. Similar to the education index, real expenditure (on public health per capita) and the average salary (of public health personnel) have higher weights than other indicators in the two less developed cities, Lanzhou and Guiyang. Public health facilities, such as beds in public health institutions and public health personnel, play more important roles than expenditure on public health in Beijing in the index. The average salary of public health personnel has a higher weight relative to other indicators in Beijing. As for the discussion on the education index, indicators with a higher level of the coefficient of variation are given higher weights in the index, caused by the higher or similar standard deviation than mean value. Higher weights of the financial indicators in Lanzhou and Guiyang not only reflect the importance of these indicators in the health index, but also indicates the significant change in its value from 1995 to 2015. Compared with two less developed cities, public health facilities seem to be more important in Beijing to health level development.

Table 4.6: Weight of Public Health Indicators in Population Health Index

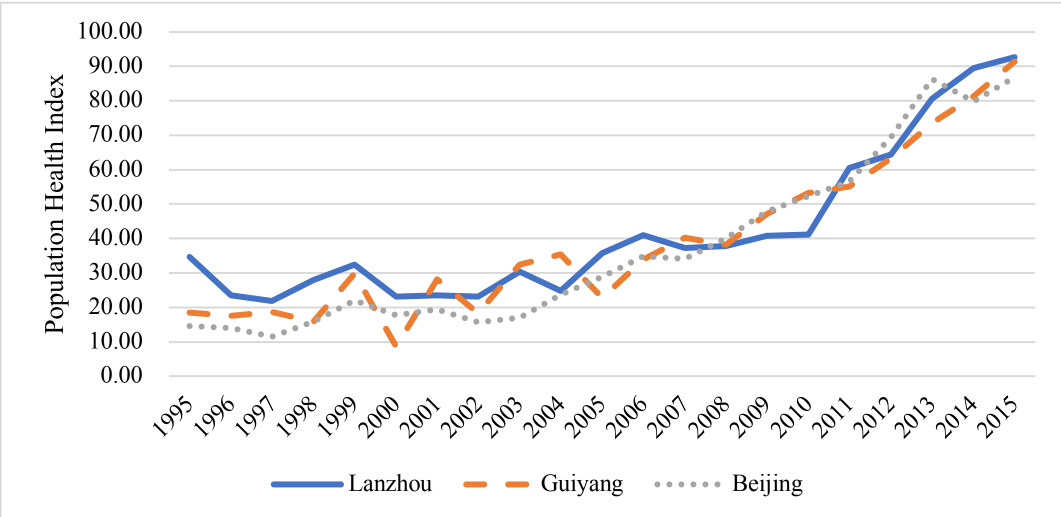
Indicators	**HE Index Lanzhou**	**HE Index Guiyang**	**HE Index Beijing**
Real public health expenditure per capita	0.29	0.29	0.13
Real average salary of public health personnel	0.28	0.26	0.26
Death rate	0.11	0.15	0.12
Number of public health personnel per thousand population	0.14	0.13	0.25
Number of beds in public health institutions per thousand population	0.18	0.17	0.24

(Source: Author's analysis)

Figure 4.16 shows that population health indexes in the three cities have quite similar trends, with a significant increase evident from 2005, and also with similar trends across the three cities compared with their original levels in 1995. The highest growth rate of health index between 1995 and 2015 was 500% in Beijing and the value in Lanzhou and Guiyang were 166% and 396% respectively.

The figure implies limited impacts of public health policies on narrowing the gap between less developed and developed areas. Beijing has the lowest level of health index for most of this period.

Figure 4.16: Population Health Index: Lanzhou, Guiyang and Beijing, 1995-2015



Source: Author’s analysis

4.4 Conclusion

In this chapter, the rationale for selecting Lanzhou, Guiyang and Beijing was outlined. It was noted that Lanzhou and Guiyang are located in less developed regions with a lower baseline of education and public health. It was also observed that economic growth patterns are different across these cities. Beijing as the capital city of China has a strong baseline of education and public health, and hence is chosen as the main comparative developed city.

Index construction is selected as the primary means to reflect population quality, i.e. the education and public health status, of three cities, Lanzhou, Guiyang and Beijing between 1995-2015. Several methods were considered and the Coefficient of Variation was chosen as the most appropriate way to proceed to ensure the most relevant indicators would be selected for inclusion in the analysis. This method also has the benefit of removing the negative impacts of any extreme values in the data.

Based on Tables 4.3, 4.4, 4.5, some features of the details of indicators of both education and public health in Lanzhou, Guiyang and Beijing were identified. For the standard deviations and means of health indicators, financial indicators, such as the average salary of medical personnel and the health expenditure per capita had higher standard deviations across all three cities which reflects a more significant change in the health financial indicators than observed for other indicators from 1995 to 2015. The death rate is the indicator with the highest mean value across all three cities. Compared with health indicators, no significant features are observed in the standard deviations and mean values of the education indicators across the three cities.

The coefficient of variation of indicators determines their weights in the index. To remove the impact of extreme values on the weight of indicator, mean values are used in the weight calculation. From Tables 4.3, 4.4, 4.5 and 4.6, indicators with a higher or similar standard deviation with its mean value have a higher level of coefficient of variation, and were given a higher weight in the index, such as the expenditure on education and public health per capita in Lanzhou, Guiyang and Beijing. Indicators such as primary school students in Guiyang and real public health expenditure per capita of Beijing with high standard deviations and mean values have lower weights in the education and health indexes.

For the weights of indicators in the education index, financial indicators have higher weights than other indicators in Lanzhou, Guiyang and Beijing, which indicates that the financial support to education plays an important role in the education level in the three cities. The weights of financial indicators in the education indexes of Lanzhou and Guiyang are higher than Beijing, which indicates the higher importance of financial variables in less developed areas. Only the average salary of education personnel of Beijing as a financial indicator has a lower weight in the education index. Higher education also plays a more important role in the education index in Lanzhou and Guiyang, which is indicated by the higher weights of related indicators in the education index. In contrast with Lanzhou and Guiyang, primary education indicators, such as primary school students and the total number of primary schools are important to the education index in Beijing, as indicated by the higher weights in the index.

Similar features are also identified in the weights of health indicators. The average salary of medical personnel has a higher weight in the health indexes across all three cities; but health expenditure per capita is only weighted higher in Lanzhou and Guiyang. Financial support to public health appears more important in indexes for Lanzhou and Guiyang. Health facilities indicators, such as the medical personnel and beds per 10,000 people are more important to the health level index in Beijing, relative to Lanzhou and Guiyang.

On the basis of the considerations and analysis conducted in this Chapter, we may expect that education and public health plays different roles in economic growth in the three different cities. Chapter Five reports on investigation of these issues at city level.

CHAPTER 5: EFFECTS OF POPULATION QUALITY ON ECONOMIC GROWTH: EMPIRICAL ANALYSIS FROM THREE CHINESE CITIES

This chapter presents the key empirical results of the research on its reference both. Using up-to-date econometric techniques, the effects of population quality on economic growth, building reference on the themes of education and health presented in earlier chapters, are estimated. It is anticipated, based on previous studies and a review of policies in China, that education and public health may have different impacts on economic growth in the three cities, including two from less-developed regions.

The structure of the chapter reflects the aim to provide a step-by-step consideration of what can be considered robust and reliable results.

In Section 5.1 the model is introduced which is applied to identify the effects of population quality on economic growth in three cities. Data sources are identified and descriptive statistics are provided for the variables included in estimations. The analysis proceeds as follows: five separate models are estimated for each city, each model adding one additional explanatory variable to identify separate effects of different variables across the models. Section 5.2 outlines the econometric techniques employed in this research, including a range of tests to ensure the reliability of the results. Section 5.3 presents the results of the estimations to identify the effect of population quality on city-level economic growth. These results are also set against those found in previous studies for the purpose of comparison. Section 5.4 sets out the main conclusions of the Chapter.

5.1 Empirical Models and Data

The model which identifies the relationship between population quality and regional economic growth is based on the Solow Growth model. The basic model is shown in Equation 5.1 as follows.

$$\Delta Y = a_0 + a_1 \Delta POP + a_2 \Delta POQ + \Delta Z + \varepsilon \quad (5.1)$$

where
Y: Real GDP per capita
POP: Total Population
POQ: Education and Health Indexes
Z: Real Fixed Investment per capita, Real R&D Expenditure per capita
And delta (insert the symbol) denotes annual change

This empirical model is similar with the literature on the population quality and economic growth, such as Eggoh, Houeninvo and Sossou (2015), Bonnefond (2015), Zhang and Yu (2014), Yao, Kinugasa and Hamori (2013), and Sun et al. (2012). In this chapter, Y denotes the economic growth in Beijing, Lanzhou, and Guiyang, represented by real GDP per capita growth rate from 1996-2015. City-level CPI indexes are used to remove price effects for the three cities, following the method employed previously for data used in Chapter two. The base year for real GDP per capita growth rate is 1995. POP represents the variable of population quantity, which is measured as growth rate of the total population in three cities from 1996-2015. POQ represents the change in population quality, which is the growth rates of population education index and population health indexes, as identified in the previous Chapter. Z denotes a set of control variables, which include real fixed asset investment per capita and real R&D expenditure per capita; inflation effects in these two variables are removed by the fixed asset investment index and CPI of three cities, respectively, in 1995-2015; ε is the error term.

Based on equation (5.1), five models are used to identify the specific impacts of population quality on economic growth as presented in equations (5.2) to (5.6)[59].

Model (1) $\Delta Y = a_0 + a_1 \Delta POP + \varepsilon$ (5.2)

Model (2) $\Delta Y = a_0 + a_1 \Delta POP + \Delta Z + \varepsilon$ (5.3)

Model (3) $\Delta Y = a_0 + a_1 \Delta POP + a_2 \Delta EDU + \Delta Z + \varepsilon$ (5.4)

Model (4) $\Delta Y = a_0 + a_1 \Delta POP + a_2 \Delta HEL + \Delta Z + \varepsilon$ (5.5)

Model (5) $\Delta Y = a_0 + a_1 \Delta POP + a_2 \Delta EDU + a_3 \Delta HEL + \Delta Z + \varepsilon$ (5.6)

The above five models are constructed by gradually adding variables, following to Yao, Kinugasa and Hamori (2013). The model construction method of Yao, Kinugasa and Hamori (2013) provides a clear approach to examine the different impacts of key variables. Yao, Kinugasa and Hamori (2013) use Model (1) a basic regression between population growth (quantity) and economic growth. Two variables which represent the impact of capital investment and technological advance are added to generate Model (2) to simulate the basic Solow Growth Model to examine the impact of population quantity, capital and technological advancement on economic growth.

In subsequent Models (3), (4) and (5), population quality variables are introduced. From Chapters Three and Four, it is expected that education and public health, which are the two main elements of population quality, might have different effects on economic growth across three cities. The extent to which education and health impacts differently on growth in each city individually is also concerned. To identify the different impacts of these two factors, education and public health indexes are used separately in the models, and then are introduced jointly into the Models (3), (4) and (5) respectively.

[59] Variables in the equation (5.2)-(5.6) are the same as in equation (5.1).

Data for this research is collected from the Statistical Yearbooks of Lanzhou, Guiyang and Beijing, 1996-2016. The real GDP per capita growth rate is the dependent variable to represent city-level economic growth. Nominal GDP is transformed into real terms using the CPI of each selected city in each year, and the base year is 1995. For the independent variables, the total population growth rate represents the change in population quantity in the model. The education index growth rate and health index growth rate are included to measure these elements of change in population quality in each of the three cities. The education index and health index are constructed as outlined in Chapter 4. Real fixed investment per capita is included to represent the impact of increasing capital investment on economic growth. Nominal fixed investment is transformed into real terms using the CPI of each city in each year, and the base year is 1995. To examine the impact of technological progress on economic growth, the real R&D expenditure growth rate is used and again the inflation effect is removed by applying CPI of each selected city in each year, with a base year of 1995. Detailed data for both the GDP inflator and CPI for each selected city in each year are collected from the Statistical Yearbooks of Lanzhou, Guiyang and Beijing, 1996-2016.

Basic descriptive statistics for the data are shown in Table 5.1.

For four of the six variables provided in Table 5.1, Guiyang has the highest mean of growth rates across the three cities, i.e. for Real GDP, Population education, Population health and Real R&D expenditure. In the case of Population growth, Beijing has the highest average growth of the three cities. This might be explained by the migration of population from other areas, because of the quality of its education and medical services (Liu, 2010; Zhang, 2014). It is notable that significant population growth in Beijing promotes demand for both facilities and personnel across education and public health (Liu, 2010).

Table 5.1: Descriptive Statistics of Variables[60]

Variables	Lanzhou			Guiyang			Beijing		
All in growth rates (per capita)	Mean	SD	Med	Mean	SD	Med	Mean	SD	Med
1. Real GDP	7.34 (3)	7.43	9.45	10.94 (1)	6.94	10.86	7.77 (2)	6.51	8.68
2. Total population	0.89 (3)	0.72	1.15	1.24 (2)	0.65	1.13	2.75 (1)	2.17	2.49
3. Population education index	3.89 (2)	3.98	3.60	5.24 (1)	7.58	5.81	1.05 (3)	8.56	5.63
4. Population health index	7.12 (3)	20.84	5.04	20.11 (1)	58.76	11.55	10.87 (2)	17.87	9.55
5. Real fixed asset investment	12.77 (2)	9.11	11.08	18.62 (1)	13.38	17.08	5.25 (3)	9.95	3.66
6. Real expenditure in R&D	15.48 (1)	17.93	15.33	7.29 (3)	6.34	9.06	13.55 (2)	15.76	7.97

Notes: 'SD' denotes standard deviation; 'Med' denotes median; '(1)' denotes the highest mean across three cities; (2) denotes the middle mean across three cities; '(3)' denotes the lowest mean across the three cities.

Source: Author's Analysis, Data from the Statistical Yearbooks of Lanzhou, Guiyang and Beijing, 1996-2016.

For the final variable, R&D expenditure, the growth rate is highest in Lanzhou. The mean growth rate is more than double that observed for Guiyang and almost two percentage points higher than for Beijing.

[60] See Appendix A for the figures of real GDP per capita growth rate, population growth rate, education index growth rate, health index growth rate, real fixed investment per capita growth rate and real R&D expenditure per capita growth rate across the three cities over the period.

Table 5.2 shows the Pearson's correlation coefficients between variables in level. The real GDP per capita displays a strong and positive correlation with real expenditure in R&D per capita; it also has medium and positive correlations with education level index, health level index and real fixed asset investment per capita but has a medium and negative correlation with the total population.

Table 5.2: Pearson's Correlation Coefficient

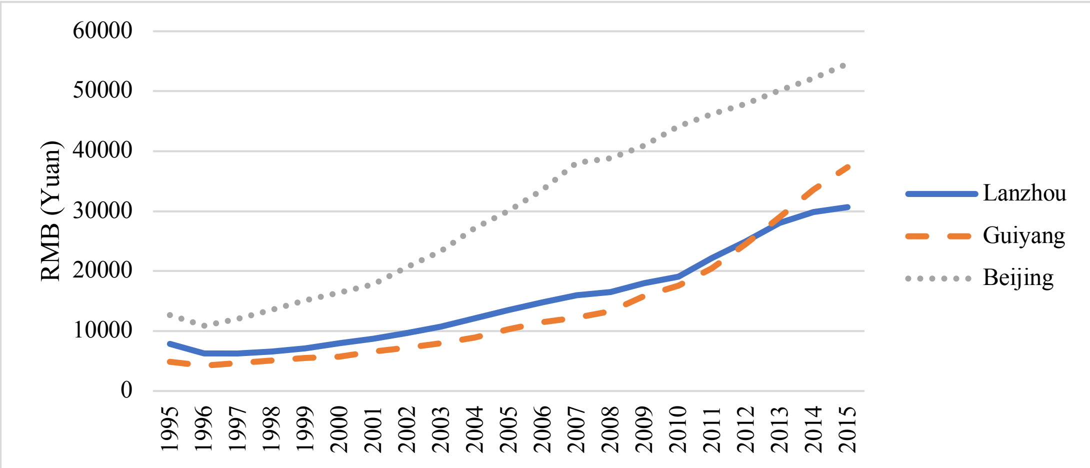
Variables (All in growth levels; per capita)	**Real GDP**	**Total Population**	**Education Level Index**	**Health Level Index**	**Real fixed asset investment**	**Real Expenditure in R&D**
Real GDP	1					
Total Population	-0.63	1				
Education Level Index	0.54	0.02	1			
Health Level Index	0.62	0.12	0.68	1		
Real fixed asset investment	0.54	0.11	0.76	0.72	1	
Real Expenditure in R&D	0.74	0.63	0.08	0.32	0.20	1

Source: Author's Analysis, Data from the Statistical Yearbooks of Lanzhou, Guiyang and Beijing, 1996-2016.

For the correlations between total population and other variables, it has positive but very weak correlations with the education level index, health level index and real fixed asset investment per capita; it has a medium and positive correlation with real expenditure in R&D per capita. The education level index has a medium and positive correlation with the health level index; it has a strong and positive correlation with the real fixed asset investment per capita and also has a positive but very weak correlation with the real expenditure in R&D per capita. The health level index has a strong and positive correlation with the real fixed asset investment per capita, but also has a weak and positive correlation with the real expenditure in R&D per capita. A positive and weak correlation is identified between the real expenditure in R&D per capita and real fixed asset investment per capita. Expressing variables in growth rates are applied to the econometric analysis to avoid the high correlation between independent variables.

Figure 5.1 to 5.3 shows the trends of real GDP per capita, real fixed asset investment per capita and real expenditure per capita in R&D.

Figure 5.1: Real GDP per capita in Lanzhou, Guiyang and Beijing, 1995-2015

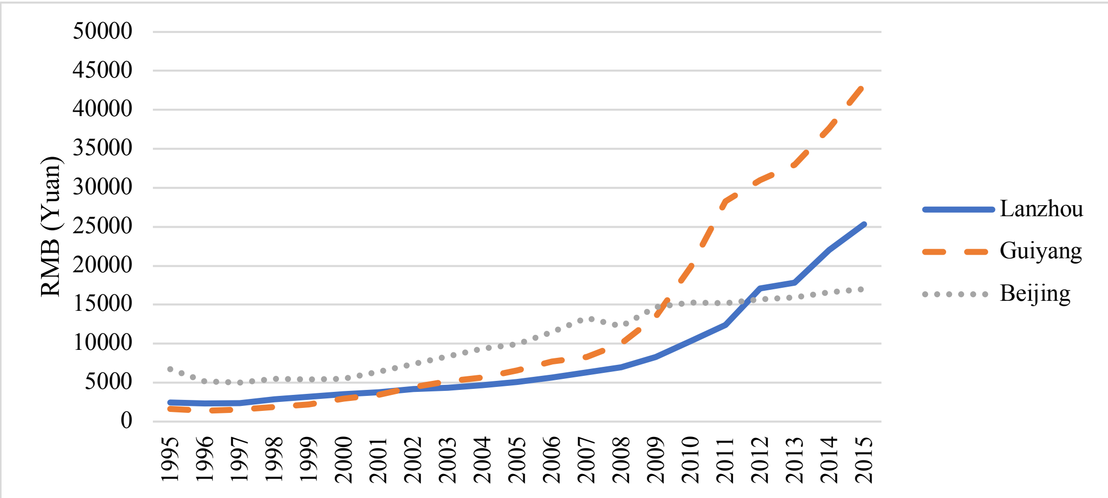


Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

From the above figure, real GDP per capita kept increasing in Lanzhou, Guiyang and Beijing during 1995-2015. The gap of real GDP per capita between Guiyang and Beijing narrowed significantly since the year of 2008. The gap between Lanzhou and Beijing seems slightly narrowed since the year of 2010.

Figure 5.2 shows the real fixed asset investment per capita in Lanzhou, Guiyang and Beijing from 1995 to 2015. Real fixed asset investment per capita in Lanzhou and Guiyang have significant growth since 2008, and the values over Beijing since the year of 2010 and 2012. Higher population growth than Lanzhou and Guiyang might be a key reason of slight increasing in fixed asset investment per capita in Beijing. Regional supporting policies such as the 'Great Western Development' strategy, which has been launched in 2000 might explain the growth in Lanzhou and Guiyang (Bonnefond, 2015). Development in the industries such as electronic information technology and software might be a reason about the growth in fixed asset investment in Guiyang (Wei, 2018).

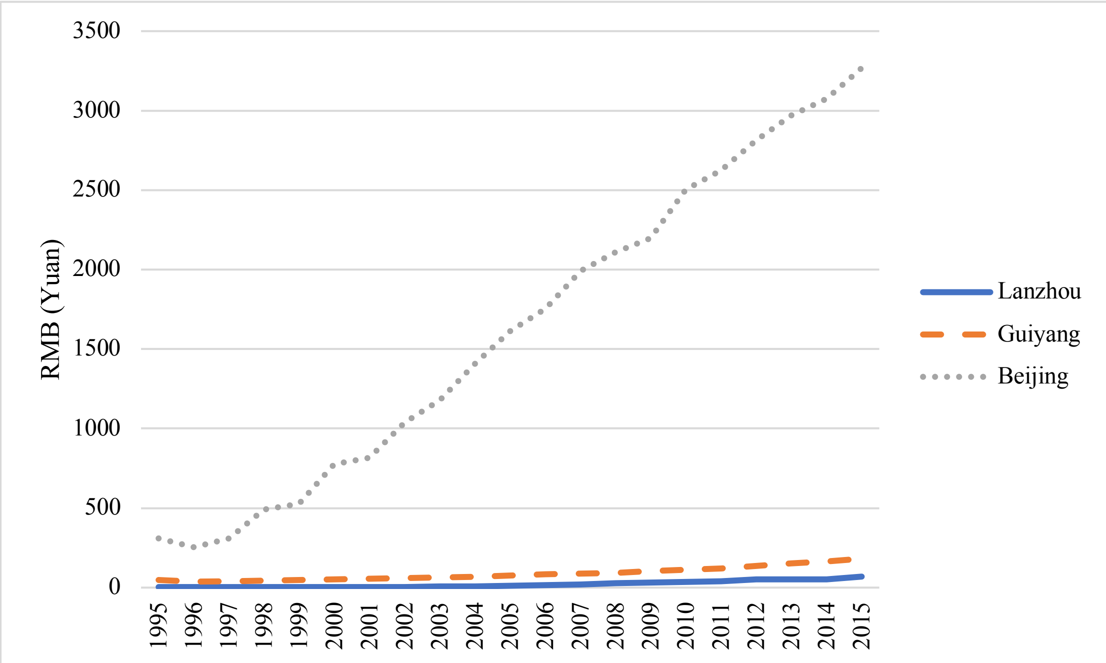
Figure 5.2: Real fixed asset investment per capita in Lanzhou, Guiyang and Beijing, 1995-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

A stable and significant growth of the real R&D expenditure per capita in Beijing from 1995 to 2015 is identified in Figure 5.3. The huge gaps of the real R&D expenditure per capita between Lanzhou, Guiyang and Beijing are larger, even though the R&D expenditure had 1378% and 393% growth in Lanzhou and Guiyang between 1995 and 2015. Lanzhou only has the highest average value in the real R&D expenditure per capita (see Table 5.1), which might be due to its poor level of R&D and should be interpreted in that context.

Figure 5.3: Real R&D expenditure per capita in Lanzhou, Guiyang and Beijing, 1995-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

5.2 Techniques to Identify the Impacts of Population Quality on Economic Growth

In this section, techniques used to test the impacts of population quality on economic growth in three cities are identified and explained.

- **Time Series Analysis**

Techniques of time series analysis are used to identify the impact of population quality on economic growth in Lanzhou, Guiyang and Beijing. This is different to the methods used earlier in Chapter two. The choice of time series methods is more appropriate here.

Different data is the first reason for the choice of time series analysis. In Chapter two, 28 provinces' data were collected to identify the relationship between the population quantity and economic growth. In this Chapter, city level data with large numbers of indicators is used[61]. Using time series analysis for each city is helpful to compare the difference impacts of population quality on economic growth between three cities.

Education and public health as the two main factors of population quality feature in government policies in China. Policies, identified in Chapter Three, focus on narrowing the gaps in education and public health development between less developed and developed areas in China. Based on the different development status and backgrounds, different impacts of education and public health on three cities may be expected. Using time series analysis in each city, rather than one panel analysis across all three cities, may identify the different roles of education and public health across the three cities. Coefficients of the same variable between different cities might reflect different impacts which is meaningful to discuss. This city level analysis is identified as an important contribution of this research. Studies by Xu (2005), Jalil (2012), Sun et al., (2012) used time series analysis to identify the specific impact of population quality on economic

[61] Choice of cities was guided based on the following criteria: (1) policy coverage; (2) education and health quality; (3) data availability from 1995-2015.

growth in Guangdong, Liaoning, Jiangsu provinces in China and in Pakistan. Studies by Jalil (2012) and Sun (2012) focus on population quality in a single country or provinces within a country using multiple indicators or a single population index in the time series estimation, which is different to this study.

Based on the population index to both education and health indicators, Xu (2005) applied time series estimation separately for Liaoning and Guangdong provinces that found a stronger positive effect of population quality on economic growth in Guangdong. The results of Xu (2005) indicate that the different impacts of key independent variables between research areas could be identified by time series analysis.

- **Reliability and Time Series Analysis**

A number of tests need to be applied prior to regression estimation to ensure the results are reliable.

Before the time series analysis, two main tests need to be completed; unit-root tests and co-integration tests.

Augmented Dickey-Fuller Test (ADF) Test

For the time series analysis, unit root tests should be applied at first to ensure the data is stationary. The ADF test is a basic and important test for time series data stationarity. Non-stationary data with a unit root leads to unreliable regression results. Stationarity implies the statistical properties of time series do not change over time, i.e. the process generating series. The ADF test is used to test the stationary of each variable. (Dicky, 1979; Fuller, 1996; Jia 2009; Wei, 2010).

A random variable Y in the time period T can be expressed as $\{Y_t, t \in T\}$. Stationary of Y means the change in Y is not correlated with the time change T, representing random change. A unit root is a feature of some stochastic processes that can cause statistical problems involving time series models. A linear stochastic process has a unit root, if 1 is a root of the process's characteristic equation. Such a process is non-stationary but does not always have a trend. If the other roots of the characteristic equation lie inside the unit circle, which have a modulus (absolute value) less than one, then the first difference of the process will be stationary; otherwise, the process will need to be differenced multiple times to become stationary (Nielsen, 2005) However, Wei (2010) argued that some data, such as the GDP growth rate are non-stationary. So, the stationary test (unit root test) is necessary before estimating any regression.

In short, a non-stationary variable with a unit root means the trend of the variable is generated by external factors across the whole time period, which also means that external factors have long-term impacts on the variable's trend. A stationary variable without unit root can be seen as a variable for which the long-term impact of external factors is removed (Dicky, 1979; Fuller, 1996; Jia 2009; Wei, 2010).

For variable Y, its random generation is shown in equation (5.7): μ_t denotes the white noise error term (Dicky, 1979; Fuller, 1996; Jia, 2009; Wei, 2010).

$Y_t = Y_{t-1} + \mu_t$ ... (5.7)

If the random variable Y is representable to equation (5.8) that means the variable is non-stationary or it has a unit root.

$Y_t = \mu + Y_{t-1} + \mu_t$ ... (5.8)

For the ADF test, the basic equation (5.7) is transformed to equation (5.9)

$\Delta Y_t = \delta Y_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta Y_{t-j} + \mu_t$ ... (5.9)

The T-test magnitude of δ can be calculated by the OLS estimation of equation (5.9), which is t_δ, then comparing the t_δ with the critical value τ. If $t_\delta < \tau$, the null hypothesis of ADF test, $\delta = 0$ is rejected, implying the variable is stationary with no unit root; if $t_\delta < \tau$, the null hypothesis cannot be rejected that implying the variable is non-stationary with a unit root (Dicky, 1979; Fuller, 1996; Jia ,2009; Wei, 2010).

Vector Auto Regressive (VAR) and Vector Error Correction Models (VECM)

A Vector Error Correction Model (VECM) is a key econometric model for this research A VECM identifies both stable long-term and short-term relationship between variables. The VECM can be seen as a modification of the Vector Autoregression (VAR) model.

Based on Hamilton (1994), Watson (1994), Johansen (1995), Lutkepohl (2005) and Yao, Kinugasa and Hamori (2013), a basic VECM can be used beginning with a VAR as seen in equation (5.10). The following outline is provided on Dicky, (1979); Fuller, (1996); Jia, (2009) and Wei, (2010).

$$\alpha y_t = \gamma_0 + \gamma_1 y_{t-1} + \gamma_2 y_{t-2} + \cdots + \gamma_p y_{t-p} + \mu_t \quad (5.10)$$

In the above equation, $y_t = [1, y_{1t} \ldots y_{nt}]', \gamma_0 = [\gamma_{10}, \gamma_{20} \ldots \gamma_{n0}]'$ and an $n \times n$ matrix $a, \gamma_0, \gamma_1 \ldots \gamma_p$ is used for each term, $\mu_t = [\mu_{1t}, \mu_{2t} \ldots \mu_{nt}]'$.

If we divide both sides of (5.10) by α, it yields equation (5.11) as follows:

$$y_t = \alpha^{-1} y_0 + a^{-1}\gamma_1 y_{t-1} + a^{-1}\gamma_2 y_{t-2} + \cdots + a^{-1}\gamma_p y_{t-p} + a^{-1}\mu_t \quad (5.11)$$

Use $J_0 = \alpha^{-1} y_0, J_1 = a^{-1}\gamma_1 \ldots J_p = a^{-1}\gamma_p$ and $v_t = a^{-1}\mu_t$ modifies equation (5.11) to equation (5.12)

$$y_t = J_0 + J_1 y_{t-1} + J_2 y_{t-2} + \cdots + J_p y_{t-p} + v_t \quad (5.12)$$

Hamilton (1994), Yao, Kinugasa and Hamori et., al (2013) argued that a VAR model cannot be used for equation (5.10) if the data has a unit root. Johansen (1995) argued that if the original data has a unit root but is stationary in the same order level, a co-integration test should be used for the original data that leads to an over-differencing of the data. Over-differencing data may negatively affect the long run relationship between variables (Hamilton, 1994; Watson, 1994; Johansen, 1995; Lutkepohl 2005; and Yao, Kinugasa and Hamori, 2013).

A VECM can be used for the original data if they exhibit co-integrating relationships. The co-integration tests via the maximum likelihood method can be used. Equation (5.12) can be modified to equation (5.13) as follows:

$$\Delta y_t = J_0 + \left(J_1 + J_2 + \cdots + J_{p-I}\right) y_{t-1} + J_1 \Delta y_{t-1} + J_2 \Delta y_{t-2} + \cdots + J_{p-1} \Delta y_{t-p+1} + v_t$$

(5.13)

The above equation can be also written as equation (5.14)

$$\Delta y_t = J_0 + (\textstyle\sum_{i=1}^{p} J_i - I) y_{t-1} + \sum_{i=1}^{p-1} \delta_i \Delta y_{t-i} + v_t,\ \ \delta_t = -\sum_{j=i+1}^{-p} J_i \quad (5.14)$$

If $(\sum_{i=1}^{p} J_i - I) y_{t-1}$ =0, this means there is a co-integrating relationship between variables, and both sides of the above equation are equal to $I(0)$ procenes. Based on the VECM, equation (5.19) can be transformed to equation (5.15) as follows:

$$\Delta y_t = J_0 + AB' y_{t-1} + \textstyle\sum_{i=1}^{p-1} \delta_i \Delta y_{t-i} + v_t \quad (5.15)$$

$(\sum_{i=1}^{p} J_i - I) = AB'$ yields, and setting rank(A) = rank(B) = r, so, Δy_t can be separated into the impacts of divergence in a long-term equilibrium at t-1, which is $B' y_{t-1}$ and the short-term changes are $\sum_{i=1}^{p-1} \delta_i \Delta y_{t-i}$. The long-run equilibrium relationships among variables can be confirmed from the co-integrating vector B', and A is the adjustment coefficient vector to adjust the value of $B' y_{t-1}$ to its mean value in the long run by the positive or negative value of A, which is called the process of error correction in the model (Hamilton, 1994; Watson, 1994; Johansen, 1995; Lutkepohl 2005; and Yao, Kinugasa and Hamori 2013).

For the research model (as equation 5.1) in this study, it can be expressed in VECM form, as in the following equations based on equation (5.15). where

$$\Delta Y_t = J_1 + A_1 B' Y_{t-1} + \sum_{i=1}^{p-1} \delta_{1i} \Delta Y_{t-i} + \sum_{i=1}^{p-1} \gamma_{1i} \Delta POP_{t-i} +$$

$$\sum_{i=1}^{p-1} \theta_{1i} \Delta EDI_{t-i} + \sum_{i=1}^{p-1} \zeta_{1i} \Delta HEI_{t-i} + \sum_{i=1}^{p-1} \eta_{1i} \Delta FAI_{t-i} + \sum_{i=1}^{p-1} \lambda_{1i} \Delta R\&D_{t-i} + v_{1t}$$

(5.16)

$$\Delta POP_t = J_2 + A_2 B' POP_{t-1} + \sum_{i=1}^{p-1} \delta_{2i} \Delta Y_{t-i} + \sum_{i=1}^{p-1} \gamma_{2i} \Delta POP_{t-i} +$$

$$\sum_{i=1}^{p-1} \theta_{2i} \Delta EDI_{t-i} + \sum_{i=1}^{p-1} \zeta_{2i} \Delta HEI_{t-i} + \sum_{i=1}^{p-1} \eta_{2i} \Delta FAI_{t-i} + \sum_{i=1}^{p-1} \lambda_{2i} \Delta R\&D_{t-i} + v_{2t}$$

(5.17)

$$\Delta EDI_t = J_3 + A_3 B' EDI_{t-1} + \sum_{i=1}^{p-1} \delta_{3i} \Delta Y_{t-i} + \sum_{i=1}^{p-1} \gamma_{3i} \Delta POP_{t-i} +$$

$$\sum_{i=1}^{p-1} \theta_{3i} \Delta EDI_{t-i} + \sum_{i=1}^{p-1} \zeta_{3i} \Delta HEI_{t-i} + \sum_{i=1}^{p-1} \eta_{3i} \Delta FAI_{t-i} + \sum_{i=1}^{p-1} \lambda_{3i} \Delta R\&D_{t-i} + v_{3t}$$

(5.18)

$$\Delta HEI_t = J_4 + A_4 B' HEI_{t-1} + \sum_{i=1}^{p-1} \delta_{4i} \Delta Y_{t-i} + \sum_{i=1}^{p-1} \gamma_{4i} \Delta POP_{t-i} +$$

$$\sum_{i=1}^{p-1} \theta_{4i} \Delta EDI_{t-i} + \sum_{i=1}^{p-1} \zeta_{4i} \Delta HEI_{t-i} + \sum_{i=1}^{p-1} \eta_{4i} \Delta FAI_{t-i} + \sum_{i=1}^{p-1} \lambda_{4i} \Delta R\&D_{t-i} + v_{4t}$$

(5.19)

$$\Delta FAI_t = J_5 + A_5 B' FAI_{t-1} + \sum_{i=1}^{p-1} \delta_{5i} \Delta Y_{t-i} + \sum_{i=1}^{p-1} \gamma_{5i} \Delta POP_{t-i} +$$

$$\sum_{i=1}^{p-1} \theta_{5i} \Delta EDI_{t-i} + \sum_{i=1}^{p-1} \zeta_{5i} \Delta HEI_{t-i} + \sum_{i=1}^{p-1} \eta_{5i} \Delta FAI_{t-i} + \sum_{i=1}^{p-1} \lambda_{5i} \Delta R\&D_{t-i} + v_{5t}$$

(5.20)

$$\Delta R\&D_t = J_6 + A_6 B' R\&D_{t-1} + \sum_{i=1}^{p-1} \delta_{6i} \Delta Y_{t-i} + \sum_{i=1}^{p-1} \gamma_{6i} \Delta POP_{t-i} +$$

$$\sum_{i=1}^{p-1} \delta\theta_{6i} \Delta EDI_{t-i} + \sum_{i=1}^{p-1} \zeta_{6i} \Delta HEI_{t-i} + \sum_{i=1}^{p-1} \eta_{6i} \Delta FAI_{t-i} + \sum_{i=1}^{p-1} \lambda_{6i} \Delta R\&D_{t-i} + v_{6t}$$

(5.21)

Y denotes Real GDP per capita

POP denotes Total Population

EDI denotes Education Index

HEI: denotes Health Index

FAI: denotes Real Fixed Investment per capita

RAI: denotes Real R&D Investment per capita

In the above equations, $A_1, A_2 \ldots A_6$ are the adjustment coefficients to construct a long run equilibrium relation between variables. In addition, $\delta, \gamma, \theta, \zeta, \eta, \lambda$ are the parameters to explain the short run effects of the variables; $p-1$ denotes the best lagged periods of independent variables, which can be determined by the Akaike Information Criterion (AIC), Hannan–Quinn Information Criterion (HQIC) and Schwarz Bayesian information criterion (SBIC).

The results of the VECM generates a long run equilibrium equation with adjustment coefficients as follows:

$$A_1Y + A_2POP + A_3EDI + A_4HEI + A_5FAI + A_6R\&D + \varepsilon = 0 \quad (5.22)$$

$$A_1Y = (-A_2POP) + (-A_3EDI) + (-A_4HEI) + (-A_5FAI) + (-A_6R\&D) + (-\varepsilon)$$
(5.23)

Normally the adjustment coefficient value of the dependent variable A_1 is set equal to 1, and equation (5.22) can be transformed to equation (5.23), which explain the negative sign of adjustment coefficients in Stata results and the long run equilibrium equation (Engle and Granger, 1987; Nielsen, 2001; Yao, Kinugasa and Hamori, 2013).

Cointegration in Vector Error Correction Model (VECM)

Cointegration tests are a key step in the Vector Error Correction Model (VECM) and is well documented in e.g. Hamilton (1994), Watson (1994), Johansen (1995), and Becketti (2013). If the data is stationary, the VAR can be used directly. Once the original data is not stationary but it is stationary in a certain order of difference, the cointegration tests should be applied to identify whether a cointegration relationship exists.

If there is no cointegration relationship between the variables, the VECM cannot be used to estimate the long run equilibrium equation and then, stationary data in a certain order of difference should be used for VAR estimation. Variables are required to be covariance stationary in the standard regression techniques, such as OLS estimation. A variable is covariance stationary if its mean and all its autocovariances are finite and do not change over time. Cointegration analysis provides a framework for estimation, inference, and interpretation when the variables are not covariance stationary (Hamilton 1994; Watson 1994; Johansen 1995; Becketti 2013).

Many economic time series appear to be 'first-difference stationary' which means that the level of a time series is not stationary but its first difference is. First-difference stationary processes are also known as integrated processes of order 1, or I(1) processes. Covariance-stationary processes are I(0). For equation (5.10), we maintain the assumption that $E[\mu_t = 0]$,

$y_t = a + bx_t + \mu_t$ (5.24)

In this equation, μ_t must also be covariance stationary if both y_t and x_t are covariance-stationary processes. When $E[x_t\mu_t = 0]$ the parameters a and b can be consistently estimated using OLS. Furthermore, the distribution of the OLS estimator converges to a normal distribution centered at the true value as the sample size grows (Hamilton 1994; Watson 1994; Johansen 1995; Becketti 2013).

If y_t and x_t are random and b = 0, there is no relationship between y_t and x_t, this is called a spurious regression. Granger and Newbold (1974) performed Monte Carlo experiments and showed that the usual t-statistics from OLS regression can almost always reject the null hypothesis of the test that b = 0 even though b is in fact zero, if a large enough dataset can be applied. Here the OLS estimator does not converge to any well-defined population parameter (Hamilton 1994; Watson 1994; Johansen 1995; Becketti 2013).

Granger (1981) pointed out that it is impossible for y_t to be a random walk and x_t and μ_t to be covariance stationary because a random walk cannot be equal to a covariance-stationary process, the equation does not 'balance'. An equation balances when the processes on each side of the equal sign are of the same order of integration.

Based on Engle and Granger (1987),

$y_t + \beta x_t = \epsilon_t, (\epsilon_t = \epsilon_{t-1} + \xi_t)$ (5.25)

$y_t + \alpha x_t = v_t, (v_t = \rho v_{t-1} + \zeta_t)$ (5.26)

where ξ_t and ζ_t are the disturbances over time that are correlated with each other. Because both y_t and x_t are I(1). The condition that $|\rho| < 1$ implies that v_t and $y_t + \alpha x_t$ are I(0). Thus y_t and x_t cointegrate, and (1, α) is the cointegrating vector (Granger, 1981; Engle and Granger, 1987).

Transforming the equation (5.25) and (5.26) to (5.27) and (5.28) as follows:

$\Delta y_t = \beta\delta z_t + \eta_{1t}$ (5.27)

$\Delta x_t = -\delta z_{t-1} + \eta_{2t}$ (5.28)

where $\delta = \frac{1-\rho}{\alpha-\beta}, z_t = y_t + a x_t$, and η_{1t} and η_{2t} are distinct, stationary, linear combinations of ξ_t and ζ_t, this is known as the Vector Error-Correction model (VECM). The point at which y_t and x_t are in equilibrium at $z_t = 0$. The coefficients on z_{t-1} describe how y_t and x_t adjust to z_{t-1} being nonzero, or out of equilibrium. The "error" in the system is z_t, and (5.27) and (5.28) describe the process by which the system adjusts or corrects back to the equilibrium. As $\rho \to 1$, the system degenerates into a pair of correlated random walks. The VECM parameterization highlights this point, because $\delta \to 0$ as $\rho \to 1$. The definition of a bivariate cointegrating relation requires simply that there exists a linear combination of the I(1) variables that is I(0). If y_t and x_t are I(1) and there are two finite real numbers $\alpha \neq 0$ and $\beta \neq 0$, such that $\alpha y_t + \beta x_t$ is I(0), then y_t and x_t are cointegrated (Granger, 1981; Engle and Granger, 1987).

Based on the above discussion, tests such as ADF tests and co-integration tests are applied to ensure the reliability of the subsequent econometric results. The unit root test for the original data is the first step in the time series analysis. If the original data is stationary without unit roots, the VAR can be used directly. If the original data is non-stationary with unit roots, the data in a certain order of difference (to be identified) should be tested for stationary. After that, co-integration tests should be used to test whether the co-integration relationship exist between variables. The VECM can be used for data with a co-integration relationship. If there is no co-integration relationship between data, a VAR should be used for the stationary data.

Detailed econometric results are provided in the next section.

5.3 Initial Tests and Empirical Results

Several tests were applied before using the VECM. Firstly, an Augmented Dickey–Fuller (ADF Test) unit root test is used to test the stationary of each variable. Because the raw data has unit roots, each variable in first-difference order is used for the ADF tests and the results are shown in Table 5.3. Lower ADF test statistics than the critical value means the data is stationary without unit roots. From Table 5.3, the ADF test statistic values of the first-difference order variables are lower than the 5% critical value that means all first-difference order variables are stationary and co-integration tests may be conducted.

Table 5.3: Results of Augmented Dickey–Fuller Tests

Variable (First Difference)	**Lanzhou**		**Guiyang**		**Beijing**	
	ADF Test Statistic	5% Critical Value	ADF Test Statistic	5% Critical Value	ADF Test Statistic	5% Critical Value
Real GDP per capita growth rate	-6.72	-3.00	-3.36	-3.00	-4.10	-3.00
Total population growth rate	-6.05	-3.00	-5.45	-3.00	-4.30	-3.00
EDI growth rate	-5.95	-3.00	-4.17	-3.00	-3.71	-3.00
HEI growth rate	-8.58	-3.00	-4.06	-3.00	-4.87	-3.00
Real fixed asset investment per capita growth rate	-3.78	-3.00	-3.89	-3.00	-6.44	-3.00
Real R&D expenditure per capita growth rate	-3.36	-3.00	-8.38	-3.00	-4.49	-3.00

Source: Author’s Analysis

Cointegration tests are conducted to determine whether there is a stable relationship between population growth and economic growth. The VECM may be used if a co-integration relationship exists between the variables. Assuming the existence of such a relationship, it is necessary to determine the appropriate number of lags of each model before cointegration tests are performed. The results of tests for appropriate numbers of lags are shown in Table 5.4.

Table 5.4: Results of Lags Test for VECM

	Lags	LR	FPE	AIC	HQ	SBIC
Model (1) Lanzhou	1	13.99	4.80	7.43	7.45	7.72
Model (2) Lanzhou	2	53.35	5.6e-12	-25.97	-24.84	-23.91
Model (3) Lanzhou	2	68.87	2.2e+06	-29.86	-29.84	-29.71
Model (4) Lanzhou	2	72.91	3.5e+08	-29.64	-29.42	-28.97
Model (5) Lanzhou	3	99.13	1.3e-14	-79.26	-76.89	-72.91
Model (1) Guiyang	1	15.17	3.18	6.83	6.86	6.92
Model (2) Guiyang	2	39.45	3.8e-13	-19.83	-19.70	-17.32
Model (3) Guiyang	2	87.41	1.7e-11	21.70	21.83	24.35
Model (4) Guiyang	2	79.01	9.2e+06	-67.02	-65.04	-64.39
Model (5) Guiyang	3	85.47	3.8e-21	-99.73	-99.67	-95.10
Model (1) Beijing	1	9.75	37.84	9.31	9.32	9.41
Model (2) Beijing	2	81.67	2.1e-09	-29.10	-28.94	-26.01
Model (3) Beijing	2	95.20	2.0e+08	-87.72	-87.52	-83.85
Model (4) Beijing	2	57.27	1.5e+06	-94.09	-93.89	-90.23
Model (5) Beijing	3	176.27	7.7e-38	-157.42	-157.18	-152.78

Notes: LR denotes Likelihood Ratio; FPE denotes Final Prediction Error; AIC denotes Akaike Information Criterion; HQ denotes Hannan–Quinn Information Criterion; SBIC denotes Schwarz Bayesian information criterion.

Source: Author's Analysis

Table 5.4 indicates the most suitable lags for each model based on the values of LR, FPE, AIC, HQ and BIC. Based on the above table, one year lag is applied for Model (1); two years lags are applied for Model (2), (3) and (4); three years lags are applied for Model (5) of the three cities.

Once the lagged value of each model is determined, cointegration tests (trace and max-eigenvalue test) can be conducted. The results reflect that co-integrating relationships were detected. In Table 5.5, the maximum ranks reflect the maximum numbers of the co-integration relationships between variables. It thus follows that a co-integrating long-term relationship is identified between population quality and economic growth for each city. Then, the VECM may be applied to identify both the long-run and short-run relationships between variables.

Table 5.5: Results of Co-integration Test for VECM

	Lags	Maximum Ranks	Trace Statistic	5% Critical Value
Model (1) Lanzhou	1	1	2.52	3.76
Model (2) Lanzhou	2	1	26.02	29.68
Model (3) Lanzhou	2	2	21.94	29.68
Model (4) Lanzhou	2	1	42.35	47.21
Model (5) Lanzhou	3	4	12.73	15.41
Model (1) Guiyang	1	1	2.98	3.76
Model (2) Guiyang	2	1	21.78	29.68
Model (3) Guiyang	2	2	20.03	29.68
Model (4) Guiyang	2	1	42.28	47.21
Model (5) Guiyang	3	2	46.17	47.21
Model (1) Beijing	1	1	2.33	3.76
Model (2) Beijing	2	2	15.29	15.41
Model (3) Beijing	2	2	26.59	29.68
Model (4) Beijing	2	2	26.52	29.68
Model (5) Beijing	3	3	24.50	29.68

Notes: ‘Maximum ranks’ denotes the maximum co-integration relationships between variables; ‘Trace Statistics’ denotes the values of co-integration tests; the null hypotheses can be rejected once the effective trace statistics are lower than the 5% critical values.

Source: Author’s Analysis

In this case, the VECM may be applied to identify both the long-run and short-run relationships between variables.

A long-term stable relationship between variables is identified by the VECM model, as shown in Tables 5.6 to 5.8

- **Lanzhou**

In Table 5.6, results of Model (1) indicate that total population growth negatively affects GDP per capita growth in Lanzhou from 1996-2015, with a coefficient of -3.72. This result is generally similar to previous studies, such as Yao, Kinugasa and Hamori (2013) and the results in Chapter Two A less negative coefficient is identified in Lanzhou compared to that found in Yao, Kinugasa and Hamori (2013) with the coefficient of -4.39. A longer time period was used in Yao, Kinugasa and Hamori (2013), and their research was based on country level data: a higher population growth rate in early years in China e.g. before 1978 could explain more negative impacts of total population growth on economic growth.

Results for Model (2) indicate that negative impact of population growth is strengthened by including variables for capital investment (FAI) and technological advance (R&D) for Lanzhou, with the coefficient reduced to -4.39 and remaining significant. Two variables, real fixed asset investment per capita and real R&D expenditure per capita, positively affect real GDP per capita growth in the long term in Lanzhou, with significant coefficients of 0.76 and 0.23 respectively. The extent of heavy industry (as the basis for the industry structure) may explain the stronger impact of capital relative to technological progress on economic growth in Lanzhou. The results of Models (1) and (2) are in line with the pessimistic views of the effect of population growth on economic growth.

Indexes which represent population education and health levels are added in the Models (3) to (5). Population Quality, measured with an index of education is added in Model (3). The results indicate a positive impact of the education index on GDP per capita growth in Lanzhou between 1996 and 2015, with a coefficient of 0.98. Coefficients on both capital and technology increased slightly in Model (3) (0.79 and 0.28).

Table 5.6: Results of VECM in Lanzhou

Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
ΔPOP	-3.72*** (1.84)	-4.39*** (1.42)	-2.24*** (0.38)	-4.46*** (1.63)	-8.33*** (2.19)
ΔEDI			0.98*** (0.09)		1.23*** (0.47)
ΔHEI				0.45*** (0.06)	0.27** (0.12)
ΔFAI		0.76*** (0.14)	0.79*** (0.13)	0.38*** (0.16)	0.74*** (0.19)
ΔR&D		0.23*** (0.04)	0.28*** (0.03)	0.29*** (0.05)	0.02 (0.08)
Constant	4.20	9.74	8.49	4.89	7.52
P>$\mathbf{Chi^2}$	0.004	0.000	0.001	0.001	0.000
Log Likelihood	-38.66	-170.90	-209.25	-233.60	-363.03
Trace test and max-eigenvalue test	Yes	Yes	Yes	Yes	Yes

Notes: SEs are presented in brackets; 'No' means no serial correlation in the residuals, 'Yes' means that trace and max-eigenvalue tests reject the null hypothesis of no co-integration vector at a significance level of 0.05, the results of the test are shown in Table 5.4.

Source: Author's Analysis

Total population growth in Model (3) still negatively affects real GDP per capita growth rate with a significant coefficient of -2.24. While still statistically significant, inclusion of the education index substantially reduces the negative impact of population on economic growth. Compared with the coefficients of variables in previous studies (which used educational variables only to represent population quality), the coefficient of the education level of population in Model (3) is higher than the coefficients in previous studies such as those by Pegkas (2014), Yan and Zhong (2009) and Bonnefond et.al, (2015) with the coefficients of 0.52, 0.25 and 0.06 respectively. The index of education level in this study is constructed using multiple educational indicators which comprehensively reflects the level of education. For example, in Pegkas (2014) only the higher educational enrolment rate in Greece was used to represent the population quality and a coefficient of 0.52 was reported. Yan and Zhong (2009) constructed an index of education by the indicators of the primary, secondary, tertiary educational levels enrolment rates and average schooling years from 1990-2000 and a coefficient of 0.25 was reported.

The health level index is added in Model (4). A positive impact of the health measure of population quality on economic growth is estimated for Lanzhou, with a significant coefficient of 0.45. This result follows the approach of Chinese studies which add health indicators in index construction. It is observed that the negative impact of population growth on economic growth is strengthened in Model (4) with a significant coefficient of -4.46. The impact of capital (FAI) remains positive but with a weaker effect on economic growth in this model. The coefficient on technological progress is basically unchanged compared to Model (3).

In Model (5), both education and health level variables of population quality are added on the analysis. Both are estimated to positively affect economic growth in Lanzhou with significant coefficients of 1.23 and 0.27 respectively. The positive impact of education is strengthened relative to Model (3). Total population growth as a barrier to economic growth in Lanzhou, still negatively affects the economic growth and with a substantially larger coefficient of -8.33, which is similar with the coefficient of Yao, Kinugasa and Hamori, (2013), with a coefficient of -7.27 respectively in its Model (2). The variable representing capital investment has a positive impact on economic growth, with coefficient of 0.74, similar to Models (2) and (3). Of the four models that include R&D, this model indicates no significant impact on economic growth. In all five models, Model (5) has the lowest value of $\boldsymbol{P>Chi^2}$ and the highest value of log likelihood indicating that Model (5) for Lanzhou might be the best long-term estimation model compared with the other four models[62].

[62] As the explanation of Jia, (2009) and Wei (2010), a larger log likelihood value means the independent variables are explained better by the model.

- **Guiyang**

In Table 5.7, results of Model (1) indicate that the population growth negatively affects GDP per capita in Guiyang from 1996-2015, with a significant coefficient of -2.81. This result is consistent with previous empirical results such as in Yao, Kinugasa and Hamori (2013) and results in Chapter two. The coefficient on population growth in Model (1) for Guiyang is lower than the coefficient of Yao, Kinugasa and Hamori (2013).

Table 5.7: Results of VECM in Guiyang

Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
ΔPOP	-2.81*** (1.09)	-8.08*** (1.16)	6.68** (3.25)	-9.66*** (1.23)	6.20*** (2.20)
ΔEDI			1.52*** (0.37)	-	0.93*** (0.31)
ΔHEI				0.19*** (0.04)	-0.27 (0.22)
ΔFAI		1.88*** (0.65)	0.68*** (0.13)	0.33*** (0.11)	0.30*** (0.07)
ΔR&D		0.37*** (0.08)	0.98*** (0.40)	0.05 (0.08)	0.22*** (0.03)
Constant	6.61	13.78	3.86	4.93	7.22
P>**Chi^2**	0.010	0.000	0.000	0.000	0.000
Log Likelihood	-65.22	-154.42	-197.44	-231.69	545.24
Trace test and max-eigenvalue test	Yes	Yes	Yes	Yes	Yes

Notes: SEs are presented in brackets; 'No' means no serial correlation in the residuals, 'Yes' means that trace and max-eigenvalue tests reject the null hypothesis of no co-integration vector at a significance level of 0.05, the results of the test are shown in Table 5.4.

Source: Author's Analysis

Results of Model (2) are similar to Lanzhou i.e. the negative impact of total population growth is stronger with the inclusion of capital investment and technological progress, with significant positive coefficients of 1.88 and 0.37 respectively. No significantly different results are detected from Model (1) and (2) results between Lanzhou and Guiyang. The results also indicate that the impact of population growth on economic growth in Guiyang is larger than Lanzhou. Further, the impacts of capital and technological progress on economic growth in Guiyang are larger than Lanzhou.

Results in Model (3) are different to all previous estimations since a significant and positive impact of total population growth with a coefficient of 6.68 is measured in Model (3), which adds the education index. The education index positively affects economic growth in Guiyang, with a coefficient of 1.52, which is higher than many previous studies (Yan and Zhong, 2009; Schündeln, 2014; Pegkas et.al, 2014). This result might be explained by the method of index construction (see Chapter four, Section 4.3). The positive and significant impact of real fixed asset investment per capita is weakened slightly relative to Model (2), but the impact of technological progress is stronger in Model (3). Considering high-tech industry is important for Guiyang (insert ref), real R&D expenditure per capita would, arguably, benefit from higher population quality.

In Model (4), population quality as measured using the health index has a positive but weak impact on economic growth in Guiyang with a coefficient of 0.19. The relatively weak health system in Guiyang might explain a weak impact on economic growth because substantial financial support from government is needed to improve the health level of the population. A negative and significant impact of total population growth is estimated is Model (4), with a coefficient of -9.66: the largest estimated effect in all five models. The positive and significant coefficient of the variables of capital (0.33) is weakened when health level is included in Model (4) compared to Model (3). Technological advancement has an insignificant impact on economic growth in Model (4). It may be explained (as in Eggoh, Houeninvo and Sossou, 2015) that inefficient investment from government in public health might be substituted for investment in other factors, which might be expressed by the weaker coefficients of other control variables.

A positive and significant impact of education on economic growth is estimated in

Model (5) with a significant coefficient of 0.93. An insignificant impact of health on economic growth in Guiyang is identified, similar to results in Eggoh, Houeninvo and Sossou (2015). Institutional factors (such as the public-private mix of health facilities) might have an insignificant, even negative effect on the less developed areas' government with financial pressure that leads an insignificant impact of health on economic growth (Eggoh, Houeninvo and Sossou, 2015). A positive and significant effect of total population growth on economic growth is identified in this model for Guiyang, with a coefficient of 6.20. Positive and significant impacts are identified with the coefficients of 0.30 and 0.22 respectively, for real fixed investment growth and real R&D expenditure on economic growth. The lowest value of $\boldsymbol{P{>}Chi^2}$ and the highest log likelihood value are seen in the results for Model (5) for Guiyang, suggesting it might be the best long-term estimation model.

- **Beijing**

Generally for Beijing, estimated coefficients are lower for population quantity effects on economic growth relative to the other two cities. All coefficients with significant impacts on economic growth are positive. The population growth rate has a positive impact on regional economic growth in Beijing with coefficients of 0.43 and 0.65 in Models (1) and (2) in Table 5.8. As the capital of China with relatively high living standards, Beijing is attractive to high quality labour to contribute to economic growth. Significant and positive long-term impacts of capital investment and technological progress (0.19 and 0.29 respectively) also strengthen the positive impacts of total population growth in Model (2) compared to Model (1).

When the education variable is introduced in Model (3), it has a long-term positive impact on economic growth in Beijing, as observed for Lanzhou and Guiyang: the coefficient here is 0.63, substantially lower than for the first two cities. The positive impact of total population growth is slightly lower than Model (2) with a significant coefficient of 0.54. For capital and technological progress, both effects remain positive and significant and while the coefficient on capital increases, relative to Model (2), that for technological progress slightly declines.

Table 5.8: Results of VECM in Beijing

Variables	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)
ΔPOP	0.43*** (0.22)	0.65*** (0.20)	0.54** (0.14)	0.65*** (0.09)	1.02*** (0.40)
ΔEDI			0.63*** (0.06)		0.61** (0.13)
ΔHEI				0.14*** (0.02)	-0.10 (0.15)
ΔFAI		0.19*** (0.05)	0.51*** (0.04)	0.11** (0.03)	0.77*** (0.10)
ΔR&D		0.29*** (0.05)	0.23*** (0.02)	0.09*** (0.02)	0.47*** (0.06)
Constant	2.77	1.55	7.20	7.80	6.73
P>$\mathbf{Chi^2}$	0.047	0.000	0.000	0.001	0.000
Log Likelihood	-80.02	-200.21	-223.26	-254.41	547.10
Trace test and max-eigenvalue test	Yes	Yes	Yes	Yes	Yes

Notes: SEs are presented in brackets; 'No' means no serial correlation in the residuals, 'Yes' means that trace and max-eigenvalue tests reject the null hypothesis of no co-integration vector at a significance level of 0.05, the results of the test are shown in Table 5.4.

Source: Author's Analysis

A positive and significant impact of health is identified in Model (4) with a coefficient of 0.14. Positive impacts of total capital and technological progress on economic growth are lowest in this model (with coefficients of 0.14 and 0.11 respectively), relative to all other models. A stronger positive impact of total population growth is also identified in Model (4) compared with Model (3), with a coefficient of 0.65 respectively.

The impact of health is insignificant in Model (5) when the education variable is included also. The long-term impact of labour quality on economic growth remains significant and positive, but is only reflected in education with a similar coefficient to that observed in Model (3). Positive impacts on economic growth are identified for population, capital and technological progress in the long-term, with significant coefficients of 1.02, 0.77 and 0.47 respectively, and all these coefficients are higher than the coefficients in Model (3) and indeed across the five models estimated. The above results also indicate that the Model (5) may be the best model of the long-term estimation for Beijing based on the lowest value of $\boldsymbol{P{>}Chi^2}$ and the highest log likelihood value.

Comparing the coefficient values of education and health with other variables in the three cities, the education index exhibits stronger long-term impacts on economic growth in Lanzhou and Guiyang than Beijing. The health demonstrates stronger long-term impacts in Lanzhou and Guiyang than Beijing. We can conclude that improving population quality might have more significant impacts on regional economic growth in less developed cities in China. The negative impacts of total population growth are weakened with the inclusion of education in the models in Guiyang and Beijing, but not for Lanzhou.

Considering that R-squared for the short-term regression in each selected city is the highest for Model (5) compared with Model (3) and (4) in all three cities[63]; all the variables are added in Model (5) and most of them significantly affect the dependent variables. Model (5) might be the best specification for short-term estimation.

The short-term effect of each of the independent variables in Model (5) are also identified by the VECM, as presented in Table 5.9. The purpose here is to discuss the effects of as many explanatory variables as possible, hence the focus on the results of Model (5). Lags of two years for real GDP per capita (only) have a significant and positive impact on economic growth in Lanzhou, which indicates a positive short-term influence of past real GDP per capita growth rates. The coefficient of one-year lagged

[63] Short-term estimation results for all models (3) and (4) are shown in Appendix B.

total population growth is estimated to be negative in Guiyang only, which indicates that growth in population reduces growth in GDP per capita in the short run, similar to results found by Yao, Kinugasa and Hamori (2013).

Table 5.9: Short-term Dynamics of Real GDP per capita Growth Rate by VECM

Variables	Model (5) Lanzhou	Model (5) Guiyang	Model (5) Beijing
$\mathbf{B'y_{t-1}}$	-0.05** (0.02)	-0.07** (0.01)	-0.04*** (0.01)
Δ**RGDPPC**(-1)	0.21(0.38)	0.07 (0.85)	0.66 (0.49)
Δ**RGDPPC**(-2)	0.33* (0.05)	0.63 (0.85)	0.19 (0.38)
Δ**POP**(-1)	0.78 (0.84)	-0.02* (0.01)	-0.83 (0.61)
Δ**POP**(-2)	0.52 (0.37)	-0.34 (0.44)	-0.03 (0.38)
ΔEDI(-1)	0.04** (0.01)	0.04 (0.52)	0.17 (0.16)
ΔEDI(-2)	0.55 (0.43)	0.05** (0.02)	0.09***(0.01)
ΔHEI(-1)	-0.01** (0.01)	0.02 (0.05)	-0.01 (0.05)
ΔHEI(-2)	0.18 (0.13)	0.04 (0.03)	0.11** (0.02)
Δ**FAI**(-1)	0.13** (0.03)	-0.09 (0.20)	-0.18*(0.10)
Δ**FAI**(-2)	0.28 (0.24)	0.18 (0.12)	-0.19** (0.09)
Δ**R&D**(-1)	0.03 (0.06)	0.37 (0.56)	0.09*** (0.02)
Δ**R&D**(-2)	0.22 (0.19)	-0.03 (0.22)	0.38*** (0.11)
Constant	1.67*** (0.43)	0.64***(0.06)	0.43* (0.25)
R-square	0.87	0.73	0.81

Notes: Standard errors into brackets. Level of statistical significance: 1 %***, 5 %**, and 10 %*.

Source: author's analysis

One-year lagged education index has positive and significant impacts on economic growth in Lanzhou; and two-years lagged education index growth has positive and significant impacts in Guiyang and Beijing. One-year lagged health index growth has a negative and significant impact on economic growth in Lanzhou. Two-years lagged health index growth has a positive and significant impact in Beijing. For the variables of capital and technological progress in Model (5), one-year lagged capital investment has a positive and significant impact in Lanzhou but it is insignificant in Guiyang. Both one-year and two years lagged capital investment negatively affect economic growth in Beijing. It seems that the significant short-term impact of capital stock might be detected in areas where traditional industry plays an important role, such as Lanzhou. The results in Table 5.9 also indicate that technological progress, which is represented by one-year and two-years lagged real R&D expenditure per capita growth, has positive and significant effects on economic growth in Beijing only: no such short-run influences are evident on economic growth in Lanzhou and Guiyang.

The adjustment coefficients $\boldsymbol{B'y_{t-1}}$ for Lanzhou and Guiyang and Beijing are negative in three cities, which imply that the adjustment process to the short-run equilibrium economic growth works well. The economic growth in three cities is higher than the level of equilibrium and so the adjustment coefficients $\boldsymbol{B'y_{t-1}}$ adjusts the higher growth down in the next period to bringing the system back to equilibrium. Comparing the values of adjustment coefficients in the three cities, economic growth in Lanzhou and Guiyang seems to have the slightly better performance relative to Beijing based on the lower negative values of the adjustment coefficients.

In addition, the Lagrange-Multiplier test for serial correlation in the residuals and the Jarque-Bera test for normal distribution of errors are applied in all models for the three cities. For the Lagrange-Multiplier test, all p values in the Lagrange-Multiplier test results are over 0.05 that the null hypotheses ‘H0: no correlation at lag order in residuals’ cannot be rejected. This means no serial correlation was identified in all models for the three cities. For the results of Jarque-Bera test, all p values are higher than 0.05 that the null hypothesis ‘H0: the errors are normally distributed’ cannot be rejected. This means the errors of all models are normally distributed. The results of these tests are shown in the appendix.

In the next section, conclusions are set out.

5.4 Conclusion and Discussion of the Econometric Results

- **Key Results for Education**

The results from the estimations in this Chapter suggest that education, measured as an index of indicators, has a positive long-run impact on economic growth in Lanzhou, Guiyang and Beijing. A positive short-run impact of education on economic growth is identified only in Lanzhou. These results are in line with some empirical studies that analyze relationship between population quality and economic growth using education indicators, such as Barro (2001), Hanushek and Kimbo (2007), Yan and Zhong (2009), Pegkas (2014), Sun et al. (2012). Detailed indicators of the education index are the targets of the key policies discussed in Chapter 3. Positive and significant impacts of the education index on economic growth may indicate positive impacts of these key policies. Comparing the coefficients on the education index with previous studies, the coefficients in Beijing are similar to studies such as Pegkas (2014), Yan and Zhong (2009), Sun (2012). Higher coefficients of education are estimated for Lanzhou and Guiyang, which may be explained by their status as less developed and with potential to benefit more as a result, perhaps indicating some convergence effects.

The education index in this study is constructed using multiple indicators including the input, output and attainment indicators that more completely reflect the education level of the population in specific areas. Using single or few indicators does not fully represent the education level that might generate lower coefficients, as previous studies. A negative short-run impact of the education level on economic growth in Lanzhou and Guiyang is also identified in this study.

A significant and positive short-run impact of education on economic growth is detected in Lanzhou, Guiyang and Beijing. The findings of a positive impact of education on economic growth differs to the results found by Kumar (2006), Chi (2008), Eggoh, Houeninvo and Sossou et al. (2015), who find a negative relationship between economic growth and education in countries which might neglect their human resource by devoting inadequate attention and expenditure to education.

In this study, education is measured by an index, including indicators of both government expenditure (as investment in education) and attainment, rather than solely investment in education. A stable political and development environment of China might weaken any potential negative impacts of ‘institutional factors’ on the relationship between education and economic growth. Policies published by central government tend to be strictly supervised, and this potentially improves the efficiency of implementation, especially in less developed cities in China. Impacts of education on economic growth are identified in studies in China, but not at detailed city level as in this study. Hence, it is difficult to draw comparisons with other results. It is worth noting that government expenditure on education has a relatively high weight in the index constructed in this research.

- **Key Results for Health**

A key finding in this study is the positive long-run impact of health on economic growth in Lanzhou only (Model 5). This could suggest there are positive impacts of public health policies on economic growth in this location, following findings on the relationship between health and economic growth, such as in Li and Huang (2009), Eggoh, Houeninvo and Sossou et al. (2015). As identified earlier in the literature, such positive impacts of health on economic growth may be explained in terms of human capital formation permitting longer working lives of and/or better quality of working lives leading to greater productivity.

The insignificant long-run impact of health on growth in Guiyang and Beijing is a noteworthy finding. Eggoh, Houeninvo and Sossou (2015) provides a possible explanation for this finding. It is argued that the efficiency of the health system is weak in Lanzhou and Guiyang, since investments to date have not been significant enough to generate any measurable impacts on economic growth. It may well be the case that further investment is required and/or the earlier investment will take some time to have a longer-term effect. Clearly, further research will shed light on these issues. The insignificant short-run impacts of health on economic growth in Guiyang, and the negative impact of one-year lagged health on growth in Lanzhou can be also explained as above. Beijing has a better health system than Lanzhou and Guiyang but the health growth still has an insignificant long-term impact on growth. Considering the less health indicators for the index construction than education might not measure the health quality completely because of the data limitation, further research will consider to shed light on the measurement to measure health quality completely.

- **Other Key Findings**

As the discussion in Section 5.3 shows, Model (5) may be the best specification compared with the Model (3) and (4). From the results of Model (5) in the three cities, education (and also health only in Lanzhou) have stronger long-term impacts on economic growth in the two less developed cities Lanzhou and Guiyang than Beijing. It seems that improving population quality might have more significant long-term impacts on regional economic growth in less developed cities (such as Lanzhou) in China, especially in education. This finding differs to the results found by Xu (2005), which found a more significant impact of population quality on economic growth in developed provinces than less developed provinces. More comprehensive detailed indicators of both education and public health for the indexes' construction are applied by this research than Xu (2005). Considering the times of policy publication and the target provinces, different time periods and research targets might explain the different findings between Xu (2005) and this research. In addition, stronger short-term impacts of both education and health are identified in Beijing than Lanzhou and Guiyang (see Table 5.8), which might be explained as the weak basis of the education and health in less developed cities such as Lanzhou and Guiyang.

Higher coefficients of education than health indicates a stronger impact of education than health for three cities in both long-run and short-run estimations. It seems that education plays a more important role in economic growth in Lanzhou, Guiyang and Beijing, similar to findings of Li and Huang (2009). In light of the theoretical relationship between the education and economic growth, and detailed and focused policies of education suggest this finding is reasonable.

Technological advance has a positive impact on economic growth in Guiyang in Model (5), which is different results with Chapter Two. Technological advance supporting policies in Guiyang[64] might be the main reason of this result, despite the different variables are selected to represent technological advance between Chapter Two and Five (Wei, 2018).

[64] See details in Chapter Four, pp142.

CHAPTER 6: CONCLUSION

The main objectives of this chapter are to summarise the key findings of the research and propose recommendations that may be considered relevant by policy makers. The recommendations arise primarily from the econometric results derived from Chapters Two and Five.

Section 6.1 outlines the main findings of each chapter. Section 6.2 sets out recommendations with respect to population policy, which is an important contribution of this research. Section 6.3 concludes with a discussion of the limitations of the research and suggestions for further work.

6.1 Key Findings of Each Chapter

The main objectives of this thesis were to explore the concept of labour from perspectives both of population quantity and quality change, and to identify the impacts of population quantity and quality change in China on economic growth over the recent period. This was operationalized through analyses across different spatial scales i.e. provincial (Chapter Two) and city levels (Chapter Five).

The research contributes to existing literature by providing a detailed review of the relationship between population quantity and economic growth and the measurement of population quality change, within a general Solow-growth model approach. A second key contribution to existing studies is the construction of two indexes, of education and health, and their incorporation into the estimation of population quality impact on economic growth. This approach has not been undertaken in many studies, and in particular, such research for China is not available. Third, the quantitative analysis and techniques employed provide reliable econometric evidence of the relationship between population quantity and quality change and economic growth.

Rapid economic growth in China is evident in the last several years (Feng and Zhang, 2018; Yao, Kinugasa and Hamori, 2013). High population growth in China has played an important role in China's experience of economic growth, and this has drawn interest from many researchers. For example, Yao, Kinugasa and Hamori (2013) and Bonnefond et al., (2015) argue that abundant labour, labour-intensive production and high fixed-capital investment feature prominently in explaining economic growth in China.

However, as highlighted in Barro (2001), Zhang (2006), Konig et al., (2015) high population levels might provide a limit to improvements in population quality, which may lead to an *imbalance* between population quantity and population quality and a challenge for related policies. Considering the various empirical evidence on the relationship between the population quantity and quality change and economic growth, this research provides further China-focused analyses that contribute to this debate. Exploring both population quantity and quality as two important factors for economic growth in China, this research focuses on estimating empirical relationships between population change – both quantity and quality - and economic growth.

The first empirical chapter (Chapter Two) identifies the impact of population quantity change on economic growth. The main objective is to estimate the relationship between population growth and economic growth based on data across 29 Chinese provinces from 1985-2013. Appropriate and recent techniques of panel data modelling are used. The fixed effects model, random effects model and dynamic panel data model (System GMM estimation) are employed.

The empirical investigations conducted as part of Chapter Two indicate that the determinants of provincial economic growth in China are as follows.

- Total population growth has a strong and statistically significant negative effect on economic growth, with the coefficients of -0.44 and -1.44 in the random effects and system GMM estimations; the coefficient of system GMM estimation is similar to that found in Barlow (1994) and Bonnefond (2015) but higher than in Creshaw (1997), Yao, Kinugasa and Hamori (2013) and lower than in Yamaguchi (1973), Lai (2006) and Zhang et al., (2006). The coefficient generated from fixed effects estimation is similar to the long-term coefficients in Zhang (2006) and Banerjee (2012).

- Growth in real fixed asset investment (per capita) has a positive effect on economic growth, with coefficients of 0.19 and 0.26 from random effects and System GMM estimations, which are similar in size with the coefficients in Bonnefond (2015).
- Growth in the dependency ratio (with coefficients of -0.12 and -0.34) exhibits a weak negative impact of the decreasing working-age population proportion. Non-agricultural population (only significant in the system GMM estimation with the coefficient of 0.20) exhibits a positive but weaker effect on economic growth compared with the effect of total population growth.
- Growth in innovation (measured as new patent applications per 10,000 people) has an insignificant effect on economic growth.
- Considering the different geographical areas in China, total population growth has stronger negative impacts on economic growth in the Eastern (-0.49, -1.25) and Western areas (-0.65, -1.10) based on both models. The dependency ratio growth has a negative and significant impact only in the Western area (-0.16, -0.27). The non-agricultural population ratio growth has a positive and significant impact only in the Middle area (0.21, 0.22) based on both models.
- Considering the different development level areas (measured as average real GDP per capita) in China, total population growth has stronger negative impacts on economic growth in the less-developed area with coefficients of -1.58 and -2.49 respectively. Growth in the dependency ratio has negative and significant impacts in the developed (-0.23, -0.44) and less-developed areas (-0.18, -0.16) based on both models. Growth in the non-agricultural population ratio has negative and significant impact only in the developing area (0.17, 0.26) based on both models.
- Growth in innovation has weak positive impacts in the Eastern area (0.07, 0.03) and developed area (0.02, 0.06), but is not as significant in other areas.

In brief, the results indicate that growth in total population served as a significant drag on economic growth in China across its provinces over the period considered.

In the context of findings from Chapter Two, Chapter Three sets out two main aims, i.e. to further explore the concepts underpinning the research and to provide an outline of population-related policies implemented in China from 1995-2015. These concepts and contexts serve to improve understanding of the policy background that is relevant to measurement of population quality conducted subsequently in Chapter Four and in Chapter Five's estimations of the relationship between population quality and economic growth for three selected cities.

Under the first aim the following are the key points of note:

- Studies focusing on countries other than China tend to use just educational indicators to represent population quality.
- Studies focusing on China tend to use two sets of indicators - education and health - to represent population quality.
- Studies focusing on countries other than China tend to employ one single variable (or sometimes a few variables) for population quality in econometric analysis.
- In comparison, studies focusing on China tend to use an index constructed using multiple indicators of education and health, to represent population quality.
- Empirical studies indicate that the education level of the population, which is highly correlated with labour skill, should positively affect regional economic growth via knowledge spillovers, productivity improvement and technical progress.
- Further studies on China that include the health level of the population suggest that this factor should positively affect economic growth driven both by longer working lives and more productive workers.

To address the second aim, key education and health policies outlined in the 10th, 11th and 12th 'Five-year Plans' published by Chinese central government were reviewed at national and regional levels. The key points are as follows.

- Education policies in China have focused on educational development of less-developed areas through financial supports, increases in educational personnel and training programmes to narrow the gap in education levels between the less-developed and developed regions.
- Health policies in China have tended to focus on improving the health system in less-developed regions through financial supports, increases in medical personnel and training programmes in order to modernize the health care system and improve system efficiency.

Chapter Four further builds on the research goals first by providing the rationale for selecting the cities of Lanzhou, Guiyang and Beijing to estimate the relationship between population quality change and economic growth. Education and public health development, especially in less-developed areas in China, are supported by the financial expenditure and other supports of key policies (Liu, 2013; Xu, 2015). The impact of population quality on economic growth in both developed and less-developed cities are identified in this research to link the key goals of this study with consideration of the policy context. From a policy perspective, the selection of cities is appropriate as these operate as administrative units with authority for decision making and specific policy implementation and allocation of financial budgets.

Furthermore, Chapter Four presents outlines of trends of detailed indicators reflecting differences in population quality development in a context where policies are implemented by different administrations in the three cities. It was noted that Lanzhou and Guiyang are located in less-developed regions with lower baselines of educational attainment and public health status. It was also observed that economic growth patterns are different across these cities. Beijing as the capital city of China has strong baselines of education and public health, and hence is chosen as the main comparative developed city.

Index construction is selected as the primary means to reflect the education and public health status of three cities, Lanzhou, Guiyang and Beijing, between 1995-2015. Several methods were discussed and the Coefficient of Variation was chosen as the most appropriate way to proceed to ensure all relevant indicators would be included in the analysis. This Chapter sets out both the method and outcome of index construction for population quality using a range of education and health indicators.

In Chapter Five, the main estimation results of the relationship between population quality and economic growth in Lanzhou, Guiyang and Beijing are identified, using city level data of the three selected cities, 1995-2015. The estimation approach selected uses a VECM technique appropriate to time-series analysis in order to identify both long-term and short-term impacts of population quality on economic growth.

The empirical investigations from Chapter Four indicate that the determinants of economic growth in the selected cities are as follows.

- Increases in the education level have a positive long-run impact on economic growth in Lanzhou, Guiyang and Beijing with the coefficients of 1.23, 0.93 and 0.61. Such results are in line with those of Barro (2001), Hanushek and Kimbo (2000), Yan and Zhong (2009), Pegkas (2014), Sun et al., (2012). The coefficients for Beijing are similar to studies such as Pegkas (2014), Li and Huang (2009), Xu (2005); coefficients in Lanzhou and Guiyang are higher than in the above studies i.e. the impacts are larger.
- Increases in the population health level has a positive long-term impact on economic growth in Lanzhou only (in Model 5), with a coefficient of 0.27 (no statistically significant effects are found for Guiyang or Beijing). The coefficient is similar with the health-related coefficients found in Li and Huang (2009) and population quality index coefficients of Yan and Zhong (2009), Schündeln (2014).
- Short-term impacts of the education index on economic growth, exhibit positive impacts are identified in Lanzhou Guiyang and Beijing with coefficients of 0.04, 0.05 and 0.09 respectively.

- A negative but very weak short-term impact of health is found in Lanzhou with a coefficient of -0.01 whereas a positive short-term impact of health is found in Beijing, with a coefficient of 0.11.
- Increases in the education index have both stronger long-run and short-run effects on economic growth compared with the health index across the three selected cities.
- Improvements in population quality, especially the education level, exhibits both stronger long-run and short-run impacts in Lanzhou and Guiyang than in Beijing, which might reflect the impact of related policies.
- Education has stronger impacts on economic growth for all three cities than health.
- Growth in total population positively affected economic growth in Guiyang when population quality variables are added - in Model 3 and 5 - with the coefficients of 6.68 and 6.20 respectively - but not in Lanzhou.

In the next section, recommendations are proposed in the context of policy makers, based on the empirical results and findings of the research.

6.2 Policy Implications and Recommendations

It is worth considering recent population changes between 2014 and 2018 before the policy implications and recommendations providing. Table 6.1 shows the recent changes of population quantity during 2014-2018. A lower average total population growth rate of China during 2014-2018 is identified compared with the rate of 0.9% during 1986-2013. For total population growth in selected provinces, provinces such as Liaoning, Jilin and Heilongjiang have positive and low population growth rates during the 1986-2013, but they had negative growth rates during the 2014-2018. Provinces such as Tibet, Tianjin, Ningxia and Guangdong had higher average population growth rates than other provinces in both time periods of 1986-2013 and 2014-2018. Beijing and Shanghai have high average population growth rates during 1986-2013, but have low rates during 2014-2018, which might because of the population control regulations by the 'Hukou' system (Gu, 2016). However, it is difficult to determine the proportion of population migration changes in total population because of the data limitation.

Table 6.1 Recent Population Quantity Changes: China and Selected Provinces

Country/Province/City	Total Population (10,000 people) in 2018 and Average Growth Rate (1985-2013; 2014- 2018)	Dependency Ratio and in 2018 and Average Growth Rate (1985-2013; 2014-2018)	Non-agricultural Population ratio in 2018 and Average Growth Rate (1985-2013; 2014- 2018)
Whole China	139,538 0.90% 0.46%	40.4 -1.99% 2.73%	59.6 3.17% 2.03%
Beijing	2154 2.90% 0.37%	30.6 -1.76% 4.47%	86.5 1.31% 0.05%
Tianjin	1560 2.17% 1.18%	29.2 -1.06% -1.38%	82.9 1.51% 0.28%
Hebei	7556 1.11% 0.60%	42.4 -1.46% 4.20%	55.0 4.64% 3.24%
Shanxi	3718 1.16% 0.48%	32.6 -2.33% 2.45%	57.3 3.36% 2.14%
Inner Mongolia	2534 0.78% 0.29%	32.3 -2.71% 1.17%	62.0 2.56% 1.33%
Liaoning	4359 0.62% -0.14%	32.0 -2.25% 5.31%	67.5 1.82% 0.49%
Jilin	2704 0.64% -0.34%	32.7 -2.59% 3.70%	56.7 1.38% 1.21%
Heilongjiang	3773 0.52% -0.33%	28.3 -2.87% 2.18%	59.4 1.22% 0.93%
Shanghai	2424 2.49% 0.07%	31.9 -1.21% 5.86%	87.7 1.17% -0.33%
Jiangsu	8051 0.88% 0.28%	37.7 -1.42% 2.50%	68.8 4.67% 1.66%
Zhejiang	5737 1.12% 0.86%	32.7 -2.35% 6.48%	68.0 5.19% 1.49%
Anhui	6324 0.56% 0.96%	47.3 -1.58% 2.90%	53.5 4.55% 2.71%
Fujian	3941 1.18% 0.87%	38.9 -2.43% 1.43%	64.8 4.95% 1.61%

Jiangxi	4648	0.96%	0.55%	45.7	-2.07%	1.34%	54.6	3.69%	2.77%
Shandong	10047	0.84%	0.64%	44.1	-1.64%	6.69%	60.6	5.29%	2.63%
Henan	9605	0.72%	0.40%	46.4	-1.59%	2.55%	50.2	4.79%	3.38%
Hubei	5917	0.58%	0.40%	39.0	-2.08%	3.17%	59.3	3.51%	2.04%
Hunan	6899	0.63%	0.61%	44.1	-1.49%	3.04%	54.6	4.55%	3.16%
Guangdong	11346	2.00%	1.29%	32.6	-2.36%	1.41%	69.9	4.14%	0.86%
Guangxi	4926	0.72%	0.86%	47.1	-1.65%	1.14%	49.2	5.13%	2.30%
Hainan	934	1.45%	0.86%	38.9	-2.46%	0.56%	58.0	5.22%	2.31%
Guizhou	3600	0.60%	0.55%	45.4	-1.57%	2.18%	46.0	4.24%	2.67%
Yunnan	4830	1.14%	0.60%	37.6	-2.01%	-0.40%	46.7	4.91%	3.39%
Tibet	344	1.61%	1.97%	42.4	-1.78%	0.89%	30.9	2.01%	5.61%
Shaanxi	3864	0.81%	0.53%	36.5	-1.99%	0.74%	56.8	3.85%	2.53%
Gansu	2637	0.84%	0.42%	38.7	-1.62%	3.23%	46.4	3.65%	3.52%
Qinghai	603	1.26%	0.85%	38.8	-2.44%	0.30%	53.1	1.89%	2.35%
Ningxia	688	1.63%	1.02%	36.7	-2.51%	1.91%	58.0	3.16%	2.52%
Xinjiang	2487	1.84%	0.90%	43.2	-2.24%	2.57%	49.4	1.26%	2.74%

Source: Author's analysis based on data collected from the Statistics Yearbook 2019 of each selected province & city and China Population & Employment Statistics Yearbook 2019.

A higher average growth rate of the dependency ratio is observed during 2014-2018, compared with the period 1986-2013 (-1.98%) in table 2.15, which might reflect population aging in China. Provinces or cities located in the Middle area such as Anhui, Shandong, Henan, and Jiangxi had both higher levels in 2018 and average growth rates of dependency ratio during 2013-2018. It is worth noting that few provinces in the Eastern area with good economic output such as Beijing, Shanghai and Jiangsu have low dependency ratios in 2018 - but had high growth rates during 1986-2013 and 2014-2018. Tianjin is the only province in China with a low level of dependency ratio in 2018 and negative growth rate during 2013-2018.

The non-agricultural population ratio of China was 59.6 in 2018, with an average growth rate of 2.73% during 2014-2018, slightly lower than the average growth rate of 1986-2013 (3.43%). Provinces located in the Eastern area or Developed area such as Beijing, Tianjin and Shanghai have higher levels but lower growth rates during 1986-2013 and 2014-2018. Provinces located in the Western area or Less-developed areas such as Tibet, Gansu, Guizhou and Yunnan have lower levels there but with higher growth rates during 1986-2013 and 2014-2018.

In terms of limitations of this analysis, population measurement is relevant as variables do not reflect the population moving between provinces. The limitation arises due to the nature of data collection which applies to any research using regional population data in China from the sources used here. It may be noted that alternatives are not readily available.

As outlined earlier in this section, population changes in recent years (2014-2018) are slightly different compared to the changes that occurred during 1985-2013, which provided the basis for the population projections produced for China by demographers. Based on the impacts of the population control policies in China, a slow population growth is identified during 2014-2018. Demographers such as Hu (1997), Zheng and Chen (2007), Wei and Wang (2016), Wang, Zhao and Zhao (2017), Liu et., al (2018) argued that a slow total population growth in China might continue until the year around 2030 and then, change to a slight decline, even though the 'Two-child Policy' was implemented since 2015. Smooth total population changes in China might be a positive factor for economic growth in the long term by avoiding the significant population changes (Bonnefond, 2015).

However, increases in the dependency ratio of China, and most Chinese provinces, during 2014-2018 reflects population aging, which is also in line with the projections by Xie (2004), Zheng and Chen (2007), Wang, Zhao and Zhao (2017), Liu (2018). Demographers argued that the negative impacts of 'One Child Policy' on the population age structure leads to increases in the proportion of those 65 years and older in the total population. Projections for this proportion were that it would reach 15% in 2025 and over 25% after 2035. Based on the implementation of the 'Two-child Policy', the proportion of working age population was predicted to potentially decrease to 60% approximately around 2035 – which was predicted to be harmful to economic growth in China (Hu, 1997; Liu, 2018). In addition, Hu (1997), Xie (2004), Zheng and Chen (2007) argued that the imbalance in development between developed and less-developed areas might lead to a serious population aging problem in less-developed areas because of the working age population migration.

A smooth growth of non-agricultural population in China facilitated by industrialization and population migration is projected by demographers such as Hu (1997), Zheng and Chen (2007), Yao, Li and Yin (2015); the proportion of non-agricultural population was predicted to reach over 62% by 2030. This projection is in line with the findings of Table 2.15. Imbalance of non-agricultural population proportions across different cities in same province might affect the industrialization of some provinces, such as Gansu and Guizhou in Table 2.15.

In addition, changes in population age-structure might also affect population quality in China. As the projections and discussions of Xie (2004), Zheng and Chen (2007), Liu (2018) outline, health-related industry might develop in the future based on demands generated by larger proportions of older citizens (65 years and older) in the population, thus supporting further improvement to population health levels. Increasing the proportion of 0-14 year olds in the population might enjoy better quality education in both developed and less-developed areas based on going education development in China. Both education and health levels of the population in China can be improved in future if the quality of education and health facilities and services are supported to improve particularly in less-developed areas (Xie, 2004; Yao, Zheng and Chen, 2007; Li and Yin, 2015).

Based on the empirical results and findings identified in earlier chapters, policy suggestions for both population quantity and quality are proposed. The negative impacts of the increase in population growth suggests that policymakers should adopt a cautious attitude to population quantity policy and try to encourage a smooth increase in population quantity. In line with the views of Becker and Barro (1989), an increase in the fertility rate might ease the pressure of population aging in the future, but it is also possible that it might negatively impact on economic growth in the short-term.

A significant change in population in China might present a new problem to the Chinese economy because of the significant decrease in income per capita and the proportion of working age population that could result. Based on the results in Chapter Two, population policy in China should, it could be argued, not only target the speed of total population change but also attempt to maintain a stable proportion of the working age population in the total population as the human capital to support economic growth in some less-developed areas and major population centres, such as the provinces of Guizhou, Guangxi Shandong and Anhui, in line with arguments in Lai (2006), Li (2011), Yao, Kinugasa and Hamori et al., (2013).

It is interesting to consider results in light of policy on population. In the past, the Chinese government published a series of population policies to control population growth, such as 'One Child Policy' (Yao, Kinugasa and Hamori, 2013). However, the working-age population exerts a positive effect on economic growth as observed in the results here. A smooth population quantity policy which focuses on labour supply over the long-term could be considered. Given the negative impacts of 'One Child Policy' on the working age population in future, the Chinese government published 'Two-child Policy' in 2015 to replace 'One Child Policy'[65]. The policy focuses on keeping a stable proportion of working age population in the long-term, and also minimizes the negative impact of further labour shortages on national and regional economic growth, which is in line with the above recommendation (Zhai, Zhang and Jin, 2014; Yu, 2015).

The Chinese government is increasingly concerned about the explosion of inequalities since the beginning of the 2000s, which represents a potential threat to social cohesion and sustainable economic development (Renard, 2002). Less-developed provinces,

[65] URL: http://www.xinhuanet.com/politics/2015-10/29/c_1116983078.htm.

such as Guizhou and Guangxi, have weak performance in both economic development and the working age population.[66] Lai (2006) and Chen (2011) argue that labour moving from less-developed provinces to work in developed provinces in China have a higher income, which might negatively affect the working-age population of their hometown. However, their parents and children still living in less-developed areas which might be seen as a burden to local economic growth. To solve this problem, policy should continue to focus on balancing the gap of economic performance between developed and less-developed provinces to ensure the labour supply for less-developed provinces. This is the similar to views of Lai (2006), Chen (2011), Yao, Kinugasa and Hamori (2013).

Based on the positive relationship between capital, industrialization (measured as non-agricultural population ratio in Chapter Two) and economic growth, especially in developing and less-developed provinces, policy focus is to promote capital investment to push economic growth in some areas, which also reduces the regional gap through industry-development programmes. For example, the ‘Great Western Development’ strategy was launched in 2000 to promote the regional development of western provinces, primarily using policies of financial support and lower tax on investment. Western areas such as Guizhou and Gansu have benefited from this (Bonnefond, 2015). Other less-developed provinces such as Heilongjiang benefited from regional economic development policies such as the ‘Revitalizing Old Industrial Bases in Northeast China’ to update the industrial system though government and other investment (Zhang, Lou and Li, 2016).

Furthermore, less-developed provinces in the South-western part of China, such as Guizhou and Gansu enjoyed the benefits of policies in the Twelfth and Thirteenth ‘Five-Year Plan’ (2010, 2015) through several means. Regional integration was advanced and urbanization and industrialization were promoted through supports for

[66] See Figure 2.2 and 2.5 in Chapter Two.

capital investment. In addition, improving the basis of developing and less- developed provinces was implemented in, e.g. transportation and business environment through a series of multiple detailed strategies (Bonnefond, 2015, Zhang, Lou and Li, 2016).

The results show that improvement in the education level is an effective method to improve population quality, and especially so in less-developed areas. Drawing on the analysis of education indicators, policy should continue support education development through finance, facilities and professional personnel, especially in less-developed areas to narrow the gap of the education level between less-developed and developed areas. This is in line with the recommendations of Xu (2005), Zhou, Liu and Zhu (2013), Eggoh et al., (2015). Indeed, education policies in the 'Thirteenth Five-Year Plan' (2016-2020) focus on the education level improvement in less-developed areas.[67] In general, policies in the 'Thirteenth Five-Year Plans' propose to continue to increase educational expenditure in less-developed areas, focusing on updating facilities and equipment, such as digital equipment and buildings. A special fund (no specific amount was mentioned) was set to support students from less-developed areas to finish their studies in primary and middle school. The quantity of education personnel is also focused on in the plan to decrease the student/teacher ratio. The number of 'special teachers[68] working in less-developed areas had 100,000 per year increase in each year during 2016-2020.

Detailed data in Chapter Four reflects the imbalance in the education expenditure per student and the average salary of educational personnel between Lanzhou, Guiyang and Beijing. This could be viewed as a key limitation of the existing key education policies. Fan and Fu (2011) argue that the differential in the salary of education personnel in developed relative to less-developed areas might negatively affect *both* the amount and quality of education personnel in less-developed areas. Policy might best continue to

[67] URL: http://www.12371.cn/special/sswgh/wen/#14.
[68] See 'Educational Policy 3: Financial Support to Teachers in Less-Developed Areas' in Chapter Three.

attempt to narrow the gaps in education expenditure per student and salary between the less-developed and developed areas, considerations that align with Xu (2005), Fan and Fu (2011), Zhou, Liu and Zhu (2013). Policies in the 'Thirteenth Five-Year Plan' (2016) not only target increases in education expenditure in less-developed areas, but also allow less developed areas' governments use fiscal revenue to improve the salaries of education personnel. The above plan allows education personnel who are working in less-developed areas to take education related part-time jobs to supplement their income.

Given the theoretical relationship between the education level and economic growth, policies might focus more on higher education development in less-developed areas to improve efficiency in capital use by higher quality labour. Similar recommendations are put forward in Chi (2008), Yan and Zhong (2009) and Pegkas (2012). Related policies in the 'Thirteenth Five-Year Plan' (2016) continually focus on higher education development in less-developed areas to match possible increasing local demand for skilled labour. For example, the high-quality universities' admission numbers in less-developed areas were further increased; universities in less-developed areas were promoted to co-operate with high quality universities in China, and overseas, to improve teaching quality.

A weak impact of the health level on economic growth is identified in empirical estimation. Policy should continue to support health level improvements in both developed and less-developed areas via financial investment, personnel and facilities support, and also focus on investment efficiency improvement. Similar recommendations are identified in Li and Huang (2009), Zhou, Liu and Zhu (2013) and Eggoh (2015). It is important to emphasise that this recommendation should not be interpreted as a reduction of investment in public health in less-developed areas. Low efficiency of the sector might be the reason for the non-effective impact of the improvements in the health level on economic growth in some regions in China - as is the case in African countries (Eggoh, 2015). In the 'Thirteenth Five-Year Plan' (2016), detailed health policies focus on updating the facilities and equipment, using funds from the central government. In order to improve the quality of medical personnel in less developed areas, a total of 500,000 trained medical personnel was planned to be dispatched between 2016 and 2020. Policies also promoting public medical institutions in less developed areas focused on increasing medical personnel salaries based on their performance to narrow the income gap between developed and less developed areas.

In addition, further policy might promote – via educational advertising programmes for example- improved understanding of the important roles of education and health to increase the expenditure in education and health of families and individuals to improve population quality. Xu (2005) argues that more expenditure from both government and private individuals in education and health in developed provinces explains the health and education differentials between more and less developed provinces in China. Considering the significant income gap between developed and less-developed areas in China, which might be a reason for limited expenditure in both education and health resources in less-developed areas, policy might consider how costs of education and medical services for families might be subsidized or reduced through other approaches.

Since the end of 2018, Chinese personal income tax regulations decreased the tax liabilities of those taxpayers who have expenditure on schooling children, professional skill training and major disease treatments to promote people spending more on education and medical services (Zhang, 2018; Wu, 2018). It might be worthwhile to make these regulations even more attractive for those in less-developed areas, and there is some precedent for this. Based on the policies in the ‘Thirteenth Five-Year Plan’ (2016) for example, multiple imported medicines for major diseases, such as cancer, are covered by the public health insurance that decreases the medical expenditure of people who living in less developed areas.

6.3 Concluding Comments

One of the main limitations of this research is that the population quantity variables do not reflect population mobility between provinces. The reason for this limitation is because of the limited statistical measurement methods used. Key data such as migration of population are not provided in any public official statistical sources in China. This limitation is similarly expressed in Bonnefond (2015), and impacts on any policy recommendations. The results would be more meaningful if population movements could be more comprehensively accounted for.

In addition, the data limitations mean that some indicators that would have been relevant for the research were not selected. For example, average schooling years and illiteracy rates are collected for demographic surveys every five years at city level. Given the problem of missing data for some indicators, however, this research only focused on collecting data that was complete for each indicator in each city. Hence, illiteracy rate and average schooling years are not included.

However, the above limitations might be further articulated into opportunities for future research. The key data of population migration might be provided to the research of certain official institutions in China, such as Social Science Academy. Further research about population quantity might set a corporation with related institutions in China to get the data. On the other hand, this limitation provides a chance to the further research focusing on population migration in China, which might push other rational methods generating in further research to identify the population migration based on the statistical methods and published data.

The limitation of detailed population quality indicators might provide more opportunities to let researcher continue their further research by cooperating with local government and statistical institutions of Chinese cities. that the results will benefit to the target cities' development. Statistical methods of index construction as an effective way to weak the negative impacts of part indicators missing might be developed in further research.

At the city-spatial level, further analysis across cities in other locations could add further insight into the findings identified here. Given the need to access data on a city by city basis and that such research requires accessing data in Chinese, there are some limitations to extending the research. However, this is a clear direction for further research. The method of education and health level identification and index construction applied in this research can be applied in further research to identify the population quality levels across different cities. Other indicators of education and health not selected in this research might be available for research focusing on other regions and cities. Considering the different weights of population quality indicators in the indexes, different impacts of indicators, such as investment and facilities of education and health in a certain region or city, which can be directly affected by the detailed policies in China can be continually identified by further research that might provide more pointed recommendations. In addition, complete population migration data is helpful for further research to completely identify population quantity changes, and explore its impacts on economic growth in a certain city or province in China, such as Beijing and Shanghai.

This research also provides potential contributions to practice. Index construction as the main statistical method for the population quality analysis in this research can be applied to the further study focusing on macro analysis with multiple detailed indicators. The positive impacts of industrialization on economic growth in the middle and developing areas in China might provide an inspiration to capital investment for enterprises in certain areas. Based on the higher growth rates of both education and health indexes in Lanzhou and Guiyang than Beijing, related enterprises might focus on some less-developed provinces and cities in China with growth potential to expand their business. Based on the empirical results, geopolitical factors and government policy should be considered for the location choice between the different areas with similar development levels in further research, which might lead the gap of key variables' coefficients.

The findings from this research might help understanding the broader geopolitical issues. Based on the discussion of Li (2012) and Wu (2019) et., al, Southeast Asia countries attract foreign investment by their cheaper land and labor price to development their manufacturing as China in 1980s. Chinese government might control the growth in population quantity but pay more attention to the population quality improving to keep its competitiveness in high-tech manufacturing which cannot be replaced by other competing countries. The findings of this research also provide an evidence to the united of Chinese government and enterprises for labor quality improving, such as the Big-data centre in Guiyang.

In addition, the framework for the index development in this thesis might help other countries which are competing with China. The framework provides a rational way to measure the status and process not only for population, but also for global business with multiple detailed factors from a macro angle. Countries which are competing with China could apply and advance the method to analyse China and themselves to identify their competitive advantage by further research; and might develop the theoretical and empirical findings of population quantity and quality changes on regional economic growth.

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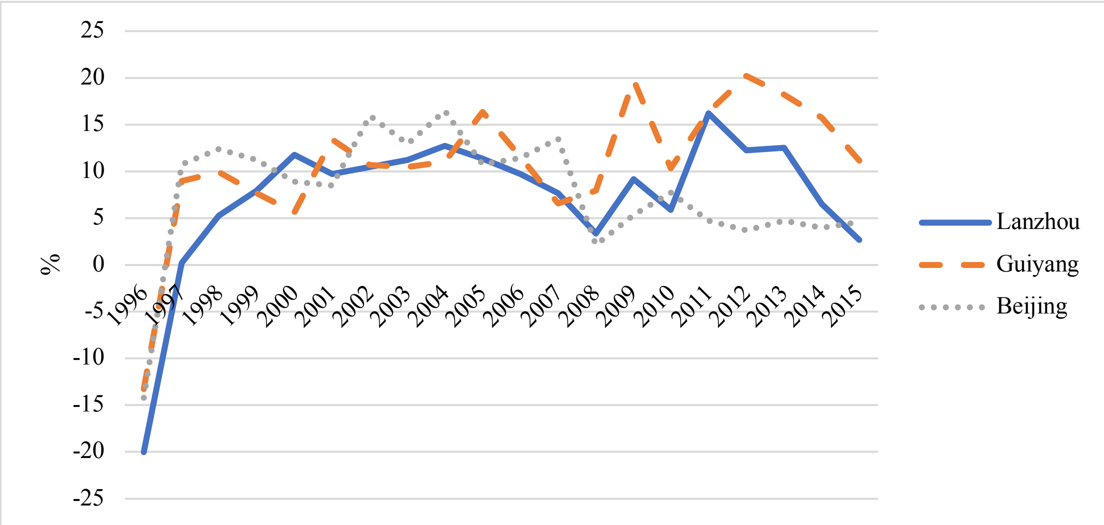
APPDENDICES

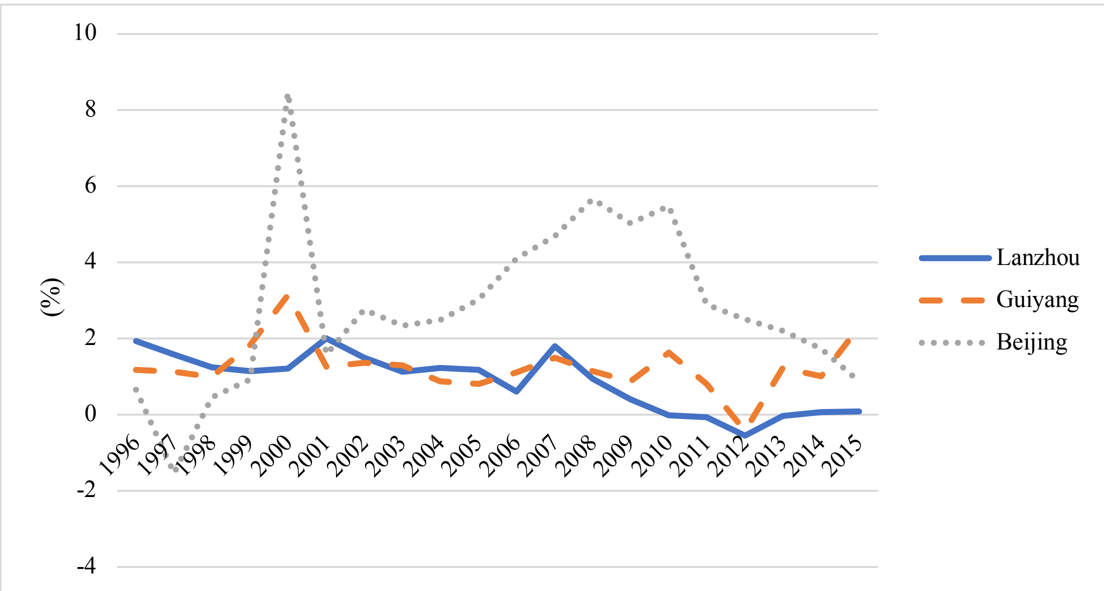
Appendix A: Figures of Key Variables of Selected Cities

Figure 1: Real GDP per capita Growth Rates in Lanzhou, Guiyang and Beijing, 1996-2015



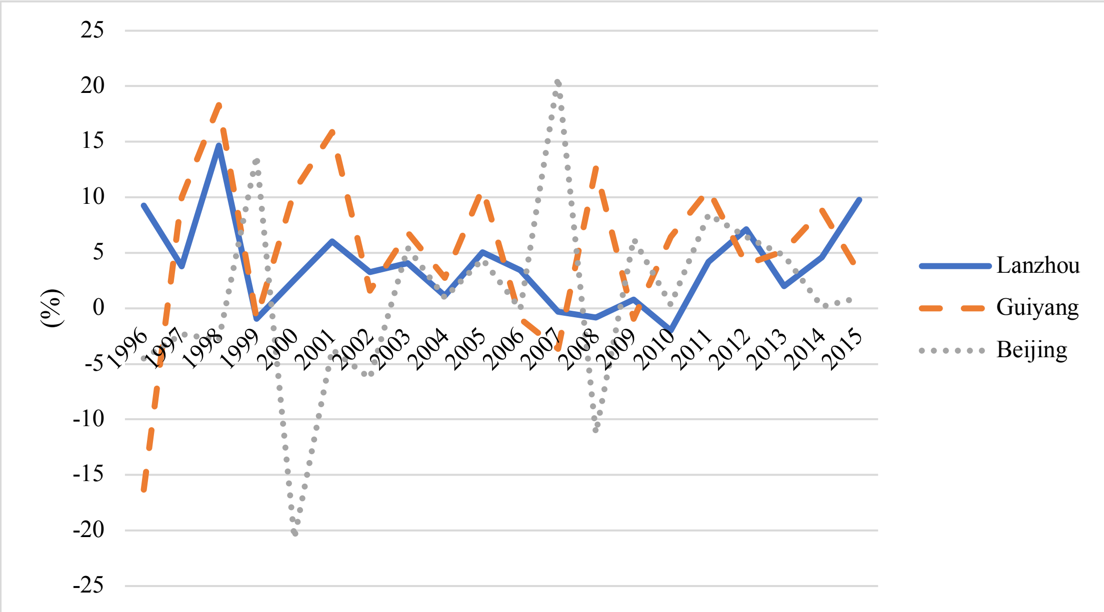
Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

Figure 2: Total Population Growth Rates in Lanzhou, Guiyang and Beijing, 1996-2015



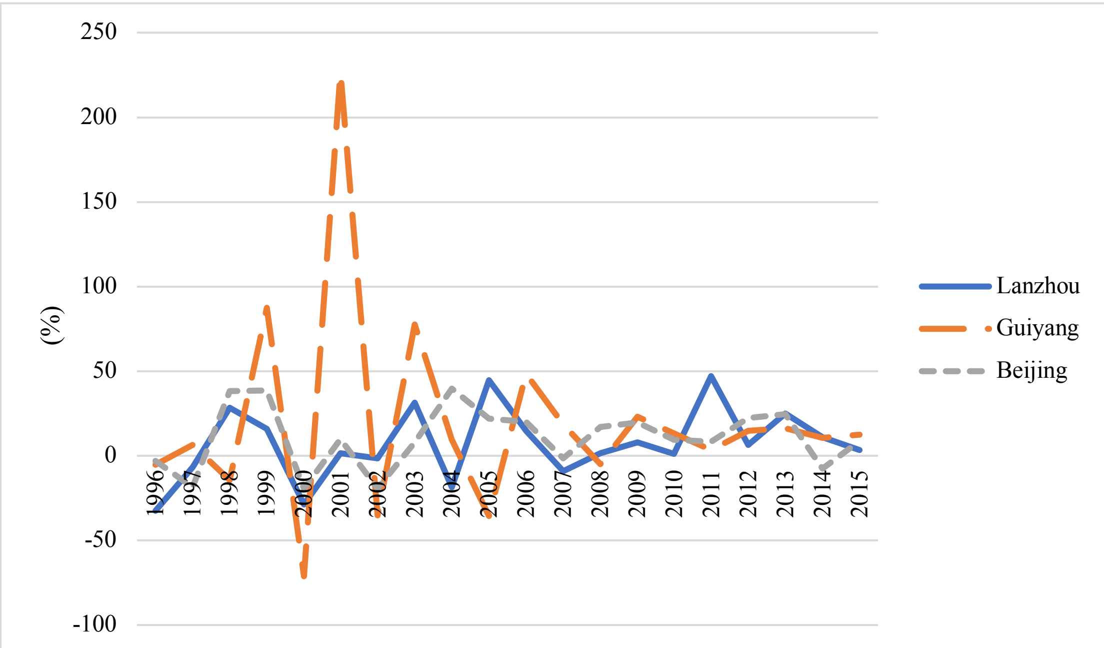
Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

Figure 3: Education Index Growth Rates in Lanzhou, Guiyang and Beijing, 1996-2015



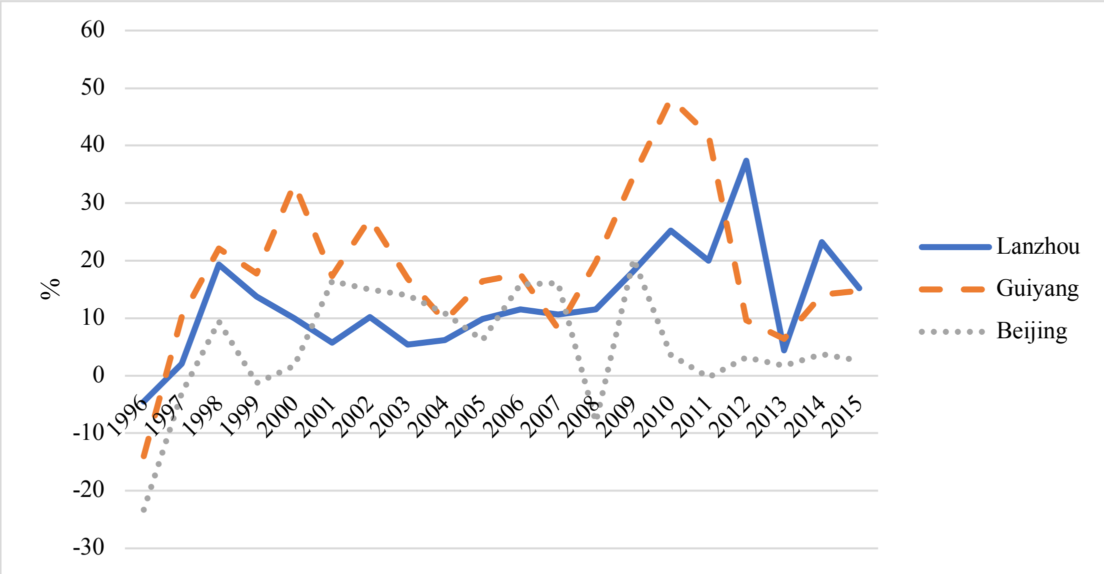
Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

Figure 4: Health Index Growth Rates in Lanzhou, Guiyang and Beijing, 1996-2015



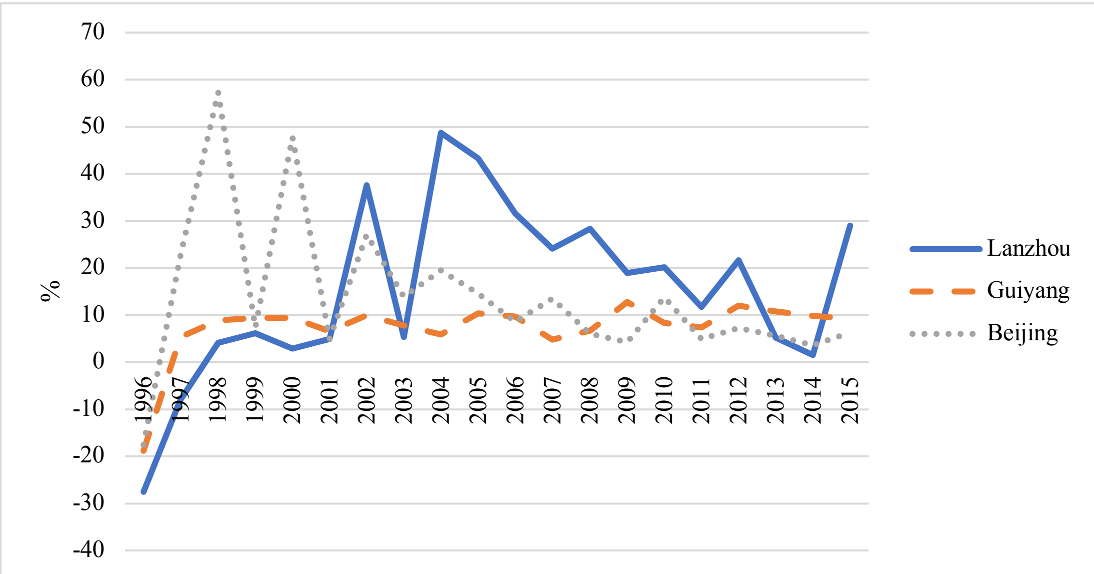
Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

Figure 5: Real Fixed Asset Investment per capita Growth Rates in Lanzhou, Guiyang and Beijing, 1996-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

Figure 6: Real R&D Expenditure per capita Growth Rates in Lanzhou, Guiyang and Beijing, 1996-2015



Source: Statistical Yearbooks of Lanzhou, Guiyang, and Beijing, 1996-2016

Appendix B: Key Regression Results for Chapter 2 and 5

Key Regression Results for Chapter 2:

```
Fixed-effects (within) regression               Number of obs      =       812
Group variable: province                        Number of groups   =        29
R-sq:                                           Obs per group:
      within  = 0.3769                                      min =           28
      between = 0.2603                                      avg =         28.0
      overall = 0.3698                                      max =           28
                                                F(5,778)           =     59.57
corr(u_i, Xb)  = -0.0785                        Prob > F           =    0.0000
------------------------------------------------------------------------------
realgdpper~e |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        pop1 |  -.4823859   .1167908    -4.13   0.000    -.7116483   -.2531235
        pop2 |  -.1222937   .0378751    -3.23   0.001    -.1966432   -.0479442
        pop3 |  -.0603637   .0481057    -1.25   0.210    -.1547961    .0340686
         inv |   .1958285   .0130093    15.05   0.000     .1702909    .2213661
          rd |  -.0100092   .0303159    -0.12   0.902    -.0619184    .0630999
       _cons |   6.811717   .3669265    18.56   0.000     6.091433       7.532
-------------+----------------------------------------------------------------
     sigma_u |  1.3756038
     sigma_e |  5.2779718
         rho |   .0636078   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(28, 778) = 1.86                  Prob > F = 0.0046
```

```
Random-effects GLS regression                   Number of obs      =       812
Group variable: province                        Number of groups   =        29
R-sq:                                           Obs per group:
      within  = 0.3867                                      min =           28
      between = 0.2641                                      avg =         28.0
      overall = 0.3704                                      max =           28
                                                Wald chi2(5)       =    295.34
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
------------------------------------------------------------------------------
realgdpper~e |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        pop1 |  -.4362513   .1132706    -3.85   0.000    -.6582576    -.214245
        pop2 |  -.1206045   .0377332    -3.20   0.001    -.1945603   -.0466487
        pop3 |  -.0732054   .0464611    -1.58   0.115    -.1642674    .0178566
         inv |   .1942134   .0129542    14.99   0.000     .1688237    .2196031
          rd |  -.0099383   .0306001    -0.13   0.894    -.0069064    .0060299
```

_cons	6.827564	.4062951	16.80	0.000	6.03124	7.623888
sigma_u	.98399179					
sigma_e	5.2779718					
rho	.03359002	(fraction of variance due to u_i)				

	---- Coefficients ---- (b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
pop1	-.4823859	-.4362513	-.0461346	.028458
pop2	-.1222937	-.1206045	-.0016892	.003275
pop3	-.0603637	-.0732054	.0128417	.0124711
inv	.1958285	.1942134	.0016151	.001197
rd	-.0100092	-.0099383	.000015	.0002829

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 3.45

Prob>chi2 = 0.6311

Dynamic panel-data estimation, two-step system GMM

Group variable: province	Number of obs = 783
Time variable : year	Number of groups = 29
Number of instruments = 54	Obs per group: min = 27
Wald chi2(6) = 107.69	avg = 27.00
Prob > chi2 = 0.000	max = 27

realgdpper~e	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
pop1	-1.443288	.5564709	-2.59	0.009	-2.533966	-.3526108
pop2	-.3406758	.1178818	-2.89	0.004	-.5715846	-.1096853
pop3	-.5885844	.2055189	-2.86	0.004	-.9915351	-.1856717
inv	.258733	.0373687	6.84	0.000	.1845415	.3329651
rd	.0187102	.0124673	1.50	0.133	-.0053922	.0430126
lGDP	-.0770931	.1011843	-0.77	0.443	-.2762253	.1204116
_cons	9.014467	1.294189	6.99	0.000	6.48871	11.54661

Arellano-Bond test for AR(1) in first differences: z = -3.14 Pr > z = 0.002
Arellano-Bond test for AR(2) in first differences: z = -0.58 Pr > z = 0.564

Hansen test of overid. restrictions: chi2(100) = 23.85 Prob > chi2 = 0.893

Eastern Area:

Fixed-effects (within) regression		Number of obs =	308
Group variable: province		Number of groups =	11
R-sq:		Obs per group:	
within = 0.4561		min =	28
between = 0.3662		avg =	28.0
overall = 0.4424		max =	28
		F(5,292) =	32.30
corr(u_i, Xb) = -0.0195		Prob > F =	0.0000

realgdpper~e	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
pop1	-.49423	.1222652	-4.04	0.000	-.7348627	-.2535972
pop2	-.1740175	.0577051	-3.02	0.003	-.2875881	-.0604469
pop3	-.0424654	.0670969	-0.63	0.527	-.1745201	.0895894
inv	.1927676	.0181561	10.62	0.000	.1570341	.228501
rd	.0687953	.0336367	1.40	0.098	-.011889	.1792983
_cons	7.067054	.5273898	13.40	0.000	6.029087	8.105021
sigma_u	1.5379423					
sigma_e	4.8996599					
rho	.08968878	(fraction of variance due to u_i)				

F test that all u_i=0: F(10, 292) = 2.73 Prob > F = 0.0032

Random-effects GLS regression		Number of obs =	308
Group variable: province		Number of groups =	11
R-sq:		Obs per group:	
within = 0.4560		min =	28
between = 0.3667		avg =	28.0
overall = 0.4427		max =	28
		Wald chi2(5) =	164.37
corr(u_i, X) = 0 (assumed)		Prob > chi2 =	0.0000

----
realgdpper~e | Coef. Std. Err. z P>|z| [95% Conf. Interval]

pop1	-.4875429	.1204906	-4.05	0.000	-.7237002	-.2513857
pop2	-.176829	.0573427	-3.08	0.002	-.2892185	-.0644394
pop3	-.0509465	.0657042	-0.78	0.438	-.1797243	.0778314
inv	.1922984	.0180288	10.67	0.000	.1569625	.2276342
rd	.0658695	.0356014	1.65	0.092	-.013884	.1721091
_cons	7.094676	.7039909	10.08	0.000	5.714879	8.474473
sigma_u	1.5741539					
sigma_e	4.8996599					
rho	.09356222	(fraction of variance due to u_i)				

	---- Coefficients ----			
	(b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
pop1	-.49423	-.4875429	-.006687	.0207554
pop2	-.1740175	-.176829	.0028115	.0064572
pop3	-.0424654	-.0509465	.0084811	.0135995
inv	.1927676	.1922984	.0004692	.002146
rd	.0687953	.0658695	.0029258	.0066294

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 0.59

Prob>chi2 = 0.9886

Dynamic panel-data estimation, two-step system GMM

Group variable: province	Number of obs = 297
Time variable : year	Number of groups = 11
Number of instruments = 54	Obs per group: min = 27
Wald chi2(6) = 51.85	avg = 27.00
Prob > chi2 = 0.000	max = 27

realgdpper~e	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf. Interval]	
pop1	-1.250308	.7442199	-1.69	0.091	-2.714953	-.2023358

```
        pop2 |   .1610874    .4175392     0.40    0.691     -.6522743    .9844491
        pop3 |   .6436354    .4666042     1.38    0.168     -.2708921    1.558163
         inv |   .1752904    .0819471     2.14    0.032      .0146771    .3359037
          rd |   .0187102    .0124673     1.50    0.133     -.0053922     .0430126
        lGDP |   .3495611     .3568775    0.98    0.327     -.3499059    1.049028
       _cons |   2.059067    1.294189     6.99    0.000       6.48871     11.54661
------------------------------------------------------------------------------
------------------------------------------------------------------------------
Arellano-Bond test for AR(1) in first differences: z =   -1.96   Pr > z =   0.044
Arellano-Bond test for AR(2) in first differences: z =    0.35   Pr > z =   0.723
------------------------------------------------------------------------------
Hansen test of overid. restrictions: chi2(47)   =   4.72   Prob > chi2 =   0.789
```

Middle Area:

```
Fixed-effects (within) regression               Number of obs      =        224
Group variable: province                        Number of groups   =          8
R-sq:                                           Obs per group:
     within   = 0.2561                                       min =           28
     between = 0.2414                                        avg =         28.0
     overall = 0.2410                                        max =           28
                                                F(5,211)           =      14.10
corr(u_i, Xb)   = -0.0402                       Prob > F           =     0.0000

------------------------------------------------------------------------------
realgdpper~e |      Coef.    Std. Err.      t     P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        pop1 |  -.2914228    .0822652    -4.80    0.000     -3893486    -.2032963
        pop2 |   .0217653    .0777751     0.28    0.780     -.1317532     .1750472
        pop3 |  -.218145    .0960969    -2.27    0.024     -.4074437    -.0288971
         inv |   .2027676    .0271561     7.39    0.000      .1463433     .253687
          rd |   .0083953    .0095367     0.88    0.380      -.011872     .0272365
       _cons |   6.917054    .7973898     8.73    0.000     5.357362     8.485012
-------------+----------------------------------------------------------------
     sigma_u |  .82994869
     sigma_e |  5.2499401
         rho |  .02464579   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(7, 211) = 2.56                  Prob > F = 0.0056

Random-effects GLS regression                   Number of obs      =        224
Group variable: province                        Number of groups   =          8

R-sq:                                           Obs per group:
     within   = 0.2568                                       min =           28
```

```
        between = 0.2415                                   avg =        28.0
        overall = 0.2413                                   max =          28

                                              Wald chi2(5)     =      73.36
corr(u_i, X)     = 0 (assumed)                Prob > chi2      =     0.0000

------------------------------------------------------------------------------
realgdpper~e |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        pop1 |  -.2672429   .0704906    -4.65   0.000     -3391143   -.1940987
        pop2 |   .0249365   .0770673     0.32   0.746    -.1261126    .1759857
        pop3 |  -.2076661   .0905937    -2.27   0.022    -.3852266   -.0301056
         inv |   .1908349   .0266382     7.50   0.000      .147625    .2520448
          rd |    .000926    .009437     0.90   0.328    -.0092702    .0277222
       _cons |   6.851795   .7653288     8.95   0.000     5.351778    8.351811
-------------+----------------------------------------------------------------
     sigma_u |  .35195622
     sigma_e |  5.2429401
         rho |  .00448616   (fraction of variance due to u_i)
------------------------------------------------------------------------------

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |       fe           re         Difference          S.E.
-------------+----------------------------------------------------------------
        pop1 |   -.2914228    -.2672429       -.0241799        .0105643
        pop2 |   .0217653     .0249365       -.0031712        .0054558
        pop3 |    -.218145    -.2076661       -.0104789        .0173946
         inv |    .2027676     .1908349        .0119327        .0307582
          rd |    .0083953      .000926       -.0013307        .0004786
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        0.63
                Prob>chi2 =      0.9864

Dynamic panel-data estimation, two-step system GMM
------------------------------------------------------------------------------
Group variable: province                      Number of obs      =       216
Time variable : year                          Number of groups   =         8
```

Number of instruments = 54 Obs per group: min = 27

Wald chi2(6) = 276.07 avg = 27.00

Prob > chi2 = 0.000 max = 27

realgdpper~e	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
pop1	-.6728566	.1691006	3.98	0.000	-1.004288	-.3414255
pop2	.0801663	.1317412	0.61	0.543	-.1780416	.3383743
pop3	.2153735	.0808016	2.67	0.008	.0570053	.3737418
inv	.2106145	.0188675	11.16	0.000	.1736349	.32475941
rd	.0054645	.1360709	0.61	0.545	-.0131293	.0248583
lGDP	.0345597	.0137885	2.51	0.012	.0075348	.0615846
_cons	5.360148	1.146293	4.68	0.000	3.113455	7.606841

Arellano-Bond test for AR(1) in first differences: z = -2.51 Pr > z = 0.012

Arellano-Bond test for AR(2) in first differences: z = -1.32 Pr > z = 0.186

Hansen test of overid. restrictions: chi2(47) = 4.96 Prob > chi2 = 0.830

Western Area:

Fixed-effects (within) regression Number of obs = 280

Group variable: province Number of groups = 10

R-sq: Obs per group:

within = 0.3455 min = 28

between = 0.2288 avg = 28.0

overall = 0.3348 max = 28

F(5,265) = 16.78

corr(u_i, Xb) = -0.1982 Prob > F = 0.0000

realgdpper~e	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
pop1	-.4344575	.3424066	-1.27	0.204	-1.105562	.236647
pop2	-.1678521	.0668164	-2.51	0.013	-.2994106	-.0362935
pop3	.0443832	.0940158	0.47	0.637	-.1407298	.2294963
inv	.1987744	.0256048	7.76	0.000	.1483597	.2491892
rd	.010182	.0047127	0.39	0.700	-.0074591	.0110991
_cons	6.631044	.7913247	8.38	0.000	5.072961	8.189128
sigma_u	1.7297418					
sigma_e	5.6845996					

```
             rho |   .08474336     (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(9, 265) = 2.29                     Prob > F = 0.0172

Random-effects GLS regression                   Number of obs      =       280
Group variable: province                        Number of groups   =        10
R-sq:                                           Obs per group:
       within  = 0.3424                                       min =         28
       between = 0.2205                                       avg =       28.0
       overall = 0.3407                                       max =         28
                                                Wald chi2(5)       =     80.03
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000
------------------------------------------------------------------------------
 realgdpper~e |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        pop1 |  -.6543863   .3621303    -1.81   0.072    -1.367405    .0586324
        pop2 |  -.1572271   .0665842    -2.36   0.018    -.2877298   -.0267244
        pop3 |   .0235754   .0919193     0.26   0.798    -.1565832    .2037339
         inv |   .1984136   .0255595     7.76   0.000     .1483178    .2485093
          rd |   .0115712   .0469750     0.33   0.738    -.0076357    .0107781
       _cons |   6.436864   .8815711     7.30   0.000     4.709016    8.164711
-------------+----------------------------------------------------------------
     sigma_u |  1.2879951
     sigma_e |  5.6845996
         rho |  .04883001   (fraction of variance due to u_i)
------------------------------------------------------------------------------


                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |       fe           re         Difference          S.E.
-------------+----------------------------------------------------------------
        pop3 |   -.4344575    -.6543863        .2199287        .1178817
        pop3 |   -.1678521    -.1572271        -.010625        .0055648
        pop3 |    .0443832     .0235754        .0208079        .0197437
         inv |    .1987744     .1984136        .0003609        .0015223
          rd |     .010182     .0115712       -.0013892        .0037864
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        5.06
```

Prob>chi2 = 0.4085

Dynamic panel-data estimation, two-step system GMM

Group variable: province Number of obs = 270

Time variable : year Number of groups = 10

Number of instruments = 54 Obs per group: min = 27

Wald chi2(6) = 193.89 avg = 27.00

Prob > chi2 = 0.000 max = 27

----

realgdpper~e	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
pop1	-1.09662	.088315	-7.29	0.000	-1.139443	-.653487
pop2	-.273835	.0977489	-2.80	0.005	-.4654194	-.0822506
pop3	.0257772	.1335612	0.19	0.847	-.2359979	.2875523
inv	.2468404	.0474599	5.20	0.000	.1538208	.3398601
rd	.0069264	.0086849	0.80	0.425	-.0100956	.0239485
lGDP	.1148904	.1740294	0.66	0.509	-.2262011	.4559818
_cons	5.375169	1.934475	2.78	0.005	1.583668	9.16667

Arellano-Bond test for AR(1) in first differences: z = -2.72 Pr > z = 0.007

Arellano-Bond test for AR(2) in first differences: z = -0.35 Pr > z = 0.725

Hansen test of overid. restrictions: chi2(47) = 5.36 Prob > chi2 = 0.896

Developed Area:

Fixed-effects (within) regression Number of obs = 280

Group variable: province Number of groups = 10

R-sq: Obs per group:

within = 0.3492 min = 28

between = 0.2260 avg = 28.0

overall = 0.3304 max = 28

F(5,265) = 17.59

corr(u_i, Xb) = -0.0073 Prob > F = 0.0000

----

realgdpper~e	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
pop1	-.0101969	.158453	-0.06	0.949	-.322184	.3017902
pop2	-.2307589	.0595265	-3.88	0.000	-.3479639	-.1135539
pop3	-.1213478	.1023425	-1.19	0.237	-.3228557	.08016

```
         inv |   .1653613    .020091     8.23   0.000     .125803    .2049196
          rd |   .0203841   .0068241     1.84   0.066   -.0124018    .0409773
       _cons |   7.374932   .5964567    12.36   0.000    6.200534    8.549329
-------------+----------------------------------------------------------------
     sigma_u |  1.8403125
     sigma_e |  5.1239582
         rho |  .11425628   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(9, 265) = 3.56                      Prob > F = 0.0003

Random-effects GLS regression                   Number of obs      =       280
Group variable: province                        Number of groups   =        10
R-sq:                                           Obs per group:
     within  = 0.3489                                          min =        28
     between = 0.2205                                          avg =      28.0
     overall = 0.3301                                          max =        28
                                                Wald chi2(5)       =     89.39
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000

------------------------------------------------------------------------------
realgdpper~e |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        pop1 |  -.0060223   .1552508    -0.04   0.969    -.3103083    .2982638
        pop2 |   -.231335   .0590547    -3.92   0.000    -.3470802   -.1155899
        pop3 |   -.133502   .0991191    -1.35   0.178    -.3277719     .060768
         inv |   .1646194   .0199027     8.27   0.000     .1256109    .2036279
          rd |   .0218029   .0056769     1.88   0.060    -.0052937    .0416605
       _cons |   7.413708   .9105037     8.14   0.000     5.629154    9.198262
-------------+----------------------------------------------------------------
     sigma_u |  1.2123591
     sigma_e |  5.1239582
         rho |  .05213047   (fraction of variance due to u_i)
------------------------------------------------------------------------------
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |       fe           re         Difference          S.E.
-------------+----------------------------------------------------------------
        pop1 |   -.0101969    -.0060223       -.0041746        .0316945
        pop2 |   -.2307589     -.231335        .0005761        .0074792
        pop3 |   -.1213478     -.133502        .0121542        .0254829
         inv |    .1653613     .1646194         .000742        .0027445
          rd |    .0203841     .0218029       -.0014188        .0208656
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
```

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 0.27
Prob>chi2 = 0.9982

Dynamic panel-data estimation, two-step system GMM

Group variable: province		Number of obs =	270
Time variable : year		Number of groups =	10
Number of instruments = 54		Obs per group: min =	27
Wald chi2(6) =	45.65	avg =	27.00
Prob > chi2 =	0.000	max =	27

----

realgdpper~e	Coef.	Corrected Std. Err.	z	P>|z|	[95% Conf.	Interval]
pop1	-.9250971	.1671116	-5.54	0.000	-1.25263	-.5975644
pop2	-.4406322	.0770024	-5.66	0.000	-.593122	-.2881423
pop3	-.2194852	.1931917	-1.14	0.256	-.598134	.1591636
inv	.2529417	.0223957	11.29	0.000	.2090469	.2968364
rd	.061183	.01861705	-1.84	0.062	-.0062643	.1374862
lGDP	.0446659	.0068024	2.13	0.033	.0113402	.2779916
_cons	6.204335	.6193614	10.02	0.000	4.990409	7.418261

Arellano-Bond test for AR(1) in first differences: z = -2.83 Pr > z = 0.005
Arellano-Bond test for AR(2) in first differences: z = -0.37 Pr > z = 0.710

Hansen test of overid. restrictions: chi2(47) = 7.64 Prob > chi2 = 0.894

Developing Area:

Fixed-effects (within) regression		Number of obs =	280
Group variable: province		Number of groups =	10
R-sq:		Obs per group:	
within = 0.4756		min =	28
between = 0.3375		avg =	28.0
overall = 0.4732		max =	28
		F(5,265) =	31.88
corr(u_i, Xb) = -0.0074		Prob > F =	0.0000

```
------------------------------------------------------------------------------
 realgdpper~e |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        pop1 |  -.8616258   .1706659    -5.05   0.000    -1.197659   -.5255921
        pop2 |   -.017098   .0598993    -0.28   0.777    -.1349391    .1009392
        pop3 |  -.1782839   .0771632    -2.31   0.022    -.3302148   -.0263529
         inv |   .2134478   .0227947     9.36   0.000      .168566    .2583297
          rd |   .0061427   .0042279     0.74   0.458    -.0051818    .0114671
       _cons |   7.505078   .6056827    12.39   0.000     6.312515    8.697641
-------------+----------------------------------------------------------------
     sigma_u |  .71093219
     sigma_e |  4.7940965
         rho |   .0215177   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(9, 265) = 2.54                      Prob > F = 0.0082

Random-effects GLS regression                    Number of obs      =       280
Group variable: province                         Number of groups   =        10

R-sq:                                            Obs per group:
     within  = 0.4902                                          min =        28
     between = 0.3724                                          avg =      28.0
     overall = 0.4847                                          max =        28

                                                 Wald chi2(5)       =    163.21
corr(u_i, X)   = 0 (assumed)                     Prob > chi2        =    0.0000

------------------------------------------------------------------------------
realgdpper~e |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        pop1 |  -.8521686    .165112    -5.16   0.000    -1.175782   -.5285551
        pop2 |  -.0126964    .059282    -0.21   0.830     -.128887    .1034943
        pop3 |   .1739753   .0720341     2.42   0.016     .0327911    .3151596
         inv |   .2141223   .0224991     9.52   0.000     .1700248    .2582197
          rd |   .0076039   .0401724     0.86   0.388    -.0045739    .0017818
       _cons |   7.465283     .58635    12.73   0.000     6.316058    8.614508
-------------+----------------------------------------------------------------
     sigma_u |  .70420865
     sigma_e |  5.1455565
         rho |  .01838565   (fraction of variance due to u_i)
------------------------------------------------------------------------------

                 ---- Coefficients ----
```

	(b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
pop1	-.8616258	-.8521686	-.0094571	.0431843
pop1	-.017098	-.0126964	-.0043036	.0085774
pop1	-.1782839	-.1739753	-.0043086	.027663
inv	.2134478	.2141223	-.0006744	.0036592
rd	.0061427	.0076039	-.0014612	.0062823

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 0.67

Prob>chi2 = 0.9846

Dynamic panel-data estimation, two-step system GMM

Group variable: province — Number of obs = 270

Time variable : year — Number of groups = 10

Number of instruments = 55 — Obs per group: min = 27

Wald chi2(6) = 45.65 — avg = 27.00

Prob > chi2 = 0.000 — max = 27

realgdpper~e	Coef.	Corrected Std. Err.	z	P>|z|	[95% Conf.	Interval]
pop1	-1.381169	.5648823	-3.05	0.000	-2.62992	-.572419
pop2	-.0866796	.1499166	0.48	0.633	-.3410275	-.2074355
pop3	.2603163	.0479689	8.81	0.000	.1914984 .	3011343
inv	.2816461	.0301175	9.35	0.000	.2226168	.3406754
rd	.0408876	.0751397	0.52	0.605	-.0162643	.0174862
lGDP	.0446659	.1168024	1.26	0.208	-.0108393	.0186145
_cons	6.763439	.8861105	16.29	0.000	5.677077	7.229801

Arellano-Bond test for AR(1) in first differences: z = -2.18 Pr > z = 0.029

Arellano-Bond test for AR(2) in first differences: z = -0.69 Pr > z = 0.490

Hansen test of overid. restrictions: chi2(48) = 7.58 Prob > chi2 = 0.889

Less Developed Area

```
Fixed-effects (within) regression               Number of obs      =       252
Group variable: province                        Number of groups   =         9
R-sq:                                           Obs per group:
     within  = 0.3186                                          min =        28
     between = 0.4268                                          avg =      28.0
     overall = 0.3182                                          max =        28
                                                F(5,238)           =     22.26
corr(u_i, Xb)  = -0.0965                        Prob > F           =    0.0000
------------------------------------------------------------------------------
 realgdpper~e |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        pop1 |  -1.703898   .4276501    -3.98   0.000    -2.546361   -.8614357
        pop1 |  -.1708419   .0775995    -2.20   0.029    -.3237115   -.0179723
        pop1 |   .0466682   .0755408     0.62   0.537    -.1021459    .1954822
         inv |   .1936883   .0248663     7.79   0.000     .1447022    .2426744
          rd |    .007809   .0070176     1.11   0.267    -.0060156    .0216336
       _cons |   6.674891    .781573     8.54   0.000     5.135206    8.214575
-------------+----------------------------------------------------------------
     sigma_u |  .72686565
     sigma_e |  5.5987834
         rho |  .01657533   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(8, 238) = 3.15                     Prob > F = 0.0021
```

```
Random-effects GLS regression                   Number of obs      =       252
Group variable: province                        Number of groups   =         9
R-sq:                                           Obs per group:
     within  = 0.3184                                          min =        28
     between = 0.4309                                          avg =      28.0
     overall = 0.3184                                          max =        28
                                                Wald chi2(5)       =    114.94
corr(u_i, X)   = 0 (assumed)                    Prob > chi2        =    0.0000

------------------------------------------------------------------------------
 realgdpper~e |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        pop1 |  -1.581569   .3994348    -3.96   0.000    -2.364447   -.7986914
        pop2 |  -.1756829   .0763251    -2.24   0.025    -.3202775   -.0210884
        pop3 |   .0442594   .0724223     0.61   0.541    -.0976856    .1862044
         inv |   .1965068    .024538     7.93   0.000     .1464133    .2426004
          rd |    .007487   .0069172     1.08   0.279    -.0060705    .0210445
       _cons |   6.571116   .7597634     8.64   0.000     5.072007    8.050225
-------------+----------------------------------------------------------------
```

```
     sigma_u |   .61949452
     sigma_e |   5.5987834
         rho |   .01214845   (fraction of variance due to u_i)
------------------------------------------------------------------------------

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |       fe           re         Difference          S.E.
-------------+----------------------------------------------------------------
        pop1 |   -1.703898    -1.581569       -.1223293        .1527628
        pop2 |   -.1708419    -.1756829       -.0001589        .0140057
        pop3 |    .0466682     .0442594        .0024088         .021481
         inv |    .1936883     .1965068       -.0028185        .0040273
          rd |     .007809      .007487         .000322        .0011829
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        1.08
                Prob>chi2 =      0.9560

Dynamic panel-data estimation, two-step system GMM
------------------------------------------------------------------------------
Group variable: province                        Number of obs      =       243
Time variable : year                            Number of groups   =         9
Number of instruments = 56                      Obs per group: min =        27
Wald chi2(6)  =     18.87                                      avg =     27.00
Prob > chi2   =     0.003                                      max =        27
------------------------------------------------------------------------------
             |              Corrected
realgdpper~e |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        pop1 |  -2.497303   1.095129    -2.28   0.023    -4.643717   -.3508894
        pop2 |  -.1618088   .0697022     2.32   0.020    -.3410275   -.2074355
        pop3 |  -.0209045   .1826808    -0.11   0.909    -.3789524    .3371433
         inv |   .2550778   .0675282     3.78   0.000     .1227249    .3874307
          rd |  -.0365846   .1990102    -0.18   0.854    -.4266375    .3534683
        lGDP |   .0225242   .0086873     2.59   0.010     .0054974    .0395509
       _cons |   7.223202   1.500154     4.81   0.000     4.282953    10.16345
------------------------------------------------------------------------------
------------------------------------------------------------------------------
```

Arellano-Bond test for AR(1) in first differences: z = -2.60 Pr > z = 0.009
Arellano-Bond test for AR(2) in first differences: z = -0.73 Pr > z = 0.463

Hansen test of overid. restrictions: chi2(49) = 2.47 Prob > chi2 = 0.685

Granger Causality Tests for Each Province:

Beijing:
Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	4.2876	2	0.117
realgdppercapii~e	pop2	.13787	2	0.933
realgdppercapii~e	pop3	.88505	2	0.642
realgdppercapii~e	inv	5.7428	2	0.057
realgdppercapii~e	rd	4.3066	2	0.116
realgdppercapii~e	ALL	13.678	10	0.188
pop1	realgdppercapii~e	2.9686	2	0.227
pop1	pop2	2.666	2	0.264
pop1	pop3	12.392	2	0.002
pop1	inv	2.1056	2	0.349
pop1	rd	1.4649	2	0.481
pop1	ALL	26.46	10	0.003
pop2	realgdppercapii~e	2.0732	2	0.355
pop2	pop1	6.5278	2	0.038
pop2	pop3	1.945	2	0.378
pop2	inv	1.827	2	0.401
pop2	rd	1.4134	2	0.493
pop2	ALL	15.564	10	0.113
pop3	realgdppercapii~e	6.4518	2	0.040
pop3	pop1	2.2546	2	0.324
pop3	pop2	.19388	2	0.908
pop3	inv	.92977	2	0.628
pop3	rd	3.9084	2	0.142
pop3	ALL	10.898	10	0.366

Tianjin:
Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	4.4334	2	0.109
realgdppercapii~e	pop2	.24519	2	0.885
realgdppercapii~e	pop3	5.6989	2	0.058
realgdppercapii~e	inv	12.851	2	0.002
realgdppercapii~e	rd	1.8304	2	0.400
realgdppercapii~e	ALL	30.082	10	0.001
pop1	realgdppercapii~e	1.3248	2	0.516
pop1	pop2	4.5225	2	0.104
pop1	pop3	6.7744	2	0.034
pop1	inv	7.3207	2	0.026
pop1	rd	.70956	2	0.701
pop1	ALL	17.301	10	0.068
pop2	realgdppercapii~e	1.3585	2	0.507
pop2	pop1	4.0067	2	0.135
pop2	pop3	2.0404	2	0.361
pop2	inv	3.0028	2	0.223
pop2	rd	.40904	2	0.815
pop2	ALL	15.204	10	0.125
pop3	realgdppercapii~e	5.6593	2	0.059
pop3	pop1	5.6816	2	0.058
pop3	pop2	.02914	2	0.986
pop3	inv	3.2253	2	0.199
pop3	rd	.65402	2	0.721
pop3	ALL	11.109	10	0.349

Hebei:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	2.5583	2	0.278
realgdppercapii~e	pop2	1.4633	2	0.481
realgdppercapii~e	pop3	32.723	2	0.000
realgdppercapii~e	inv	.36483	2	0.833
realgdppercapii~e	rd	20.738	2	0.000
realgdppercapii~e	ALL	59.768	10	0.000
pop1	realgdppercapii~e	6.9413	2	0.031

pop1	pop2	.64107	2	0.726
pop1	pop3	.8842	2	0.643
pop1	inv	2.1517	2	0.341
pop1	rd	4.9872	2	0.083
pop1	ALL	29.281	10	0.001
pop2	realgdppercapii~e	.10867	2	0.947
pop2	pop1	4.4877	2	0.106
pop2	pop3	.35031	2	0.839
pop2	inv	2.888	2	0.236
pop2	rd	5.7355	2	0.057
pop2	ALL	16.547	10	0.085
pop3	realgdppercapii~e	2.3411	2	0.310
pop3	pop1	7.3604	2	0.025
pop3	pop2	4.427	2	0.109
pop3	inv	2.2873	2	0.319
pop3	rd	1.6839	2	0.431
pop3	ALL	18.612	10	0.045

Shanxi:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	2.3532	2	0.308
realgdppercapii~e	pop2	.6771	2	0.713
realgdppercapii~e	pop3	4.5563	2	0.102
realgdppercapii~e	inv	1.4016	2	0.496
realgdppercapii~e	rd	1.6288	2	0.443
realgdppercapii~e	ALL	14.23	10	0.163
pop1	realgdppercapii~e	4.9162	2	0.086
pop1	pop2	1.3346	2	0.513
pop1	pop3	8.3001	2	0.016
pop1	inv	1.8453	2	0.397
pop1	rd	3.5427	2	0.170
pop1	ALL	31.033	10	0.001
pop2	realgdppercapii~e	.03458	2	0.983
pop2	pop1	8.9386	2	0.011
pop2	pop3	.60883	2	0.738
pop2	inv	5.5749	2	0.062

pop2	rd	5.0207	2	0.081
pop2	ALL	14.816	10	0.139
pop3	realgdppercapii~e	14.936	2	0.001
pop3	pop1	4.219	2	0.121
pop3	pop2	15.212	2	0.000
pop3	inv	7.7714	2	0.021
pop3	rd	11.589	2	0.003
pop3	ALL	35.569	10	0.000

In. Mongolia:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	5.2483	2	0.072
realgdppercapii~e	pop2	5.7246	2	0.057
realgdppercapii~e	pop3	7.4569	2	0.024
realgdppercapii~e	inv	.21856	2	0.896
realgdppercapii~e	rd	6.4435	2	0.040
realgdppercapii~e	ALL	24.461	10	0.006
pop1	realgdppercapii~e	6.9811	2	0.030
pop1	pop2	2.2007	2	0.333
pop1	pop3	2.1687	2	0.338
pop1	inv	4.0641	2	0.131
pop1	rd	2.5795	2	0.275
pop1	ALL	19.835	10	0.031
pop2	realgdppercapii~e	1.1308	2	0.568
pop2	pop1	2.1089	2	0.348
pop2	pop3	1.3972	2	0.497
pop2	inv	1.2071	2	0.547
pop2	rd	1.2513	2	0.535
pop2	ALL	11.903	10	0.292
pop3	realgdppercapii~e	1.6425	2	0.440
pop3	pop1	.69608	2	0.706
pop3	pop2	5.1427	2	0.076
pop3	inv	1.2685	2	0.530
pop3	rd	.95169	2	0.621
pop3	ALL	7.9196	10	0.637

Liaoning:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	3.0146	2	0.222
realgdppercapii~e	pop2	8.7391	2	0.013
realgdppercapii~e	pop3	7.9415	2	0.019
realgdppercapii~e	inv	2.1887	2	0.335
realgdppercapii~e	rd	2.7096	2	0.258
realgdppercapii~e	ALL	21.84	10	0.016
pop1	realgdppercapii~e	1.3689	2	0.504
pop1	pop2	6.5108	2	0.039
pop1	pop3	7.3274	2	0.026
pop1	inv	6.8875	2	0.032
pop1	rd	8.2397	2	0.016
pop1	ALL	23.409	10	0.009
pop2	realgdppercapii~e	7.1595	2	0.028
pop2	pop1	4.156	2	0.125
pop2	pop3	13.887	2	0.001
pop2	inv	10.516	2	0.005
pop2	rd	8.1337	2	0.017
pop2	ALL	28.011	10	0.002
pop3	realgdppercapii~e	1.9682	2	0.374
pop3	pop1	2.6231	2	0.269
pop3	pop2	.55974	2	0.756
pop3	inv	3.9125	2	0.141
pop3	rd	1.9198	2	0.383
pop3	ALL	13.657	10	0.189

Jilin:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	1.2278	2	0.541
realgdppercapii~e	pop2	.85186	2	0.653
realgdppercapii~e	pop3	.1544	2	0.926
realgdppercapii~e	inv	1.5457	2	0.462

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	rd	7.8568	2	0.020
realgdppercapii~e	ALL	31.557	10	0.000
pop1	realgdppercapii~e	1.8249	2	0.402
pop1	pop2	2.9158	2	0.233
pop1	pop3	.01084	2	0.995
pop1	inv	.56962	2	0.752
pop1	rd	.32862	2	0.848
pop1	ALL	10.003	10	0.440
pop2	realgdppercapii~e	.85994	2	0.651
pop2	pop1	6.0125	2	0.049
pop2	pop3	3.0055	2	0.223
pop2	inv	5.4892	2	0.064
pop2	rd	3.5424	2	0.170
pop2	ALL	18.145	10	0.053
pop3	realgdppercapii~e	6.8264	2	0.033
pop3	pop1	1.5643	2	0.457
pop3	pop2	.04944	2	0.976
pop3	inv	3.1245	2	0.210
pop3	rd	20.494	2	0.000
pop3	ALL	45.959	10	0.000

Heilongjiang:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	4.7999	2	0.091
realgdppercapii~e	pop2	4.711	2	0.095
realgdppercapii~e	pop3	.3987	2	0.819
realgdppercapii~e	inv	3.693	2	0.158
realgdppercapii~e	rd	9.1618	2	0.010
realgdppercapii~e	ALL	29.446	10	0.001
pop1	realgdppercapii~e	8.5306	2	0.014
pop1	pop2	1.5047	2	0.471
pop1	pop3	7.0636	2	0.029
pop1	inv	3.6241	2	0.163
pop1	rd	7.2736	2	0.026
pop1	ALL	56.35	10	0.000

Equation	Excluded	chi2	df	Prob > chi2
pop2	realgdppercapii~e	3.614	2	0.164
pop2	pop1	2.0864	2	0.352
pop2	pop3	3.4746	2	0.176
pop2	inv	3.824	2	0.148
pop2	rd	.03572	2	0.982
pop2	ALL	16.757	10	0.080
pop3	realgdppercapii~e	.93263	2	0.627
pop3	pop1	13.407	2	0.001
pop3	pop2	4.4756	2	0.107
pop3	inv	3.309	2	0.191
pop3	rd	25.497	2	0.000
pop3	ALL	51.064	10	0.000

Shanghai:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	10.955	2	0.004
realgdppercapii~e	pop2	19.107	2	0.000
realgdppercapii~e	pop3	.49453	2	0.781
realgdppercapii~e	inv	14.441	2	0.001
realgdppercapii~e	rd	30.124	2	0.000
realgdppercapii~e	ALL	85.106	10	0.000
pop1	realgdppercapii~e	4.3571	2	0.113
pop1	pop2	1.5715	2	0.456
pop1	pop3	1.1113	2	0.574
pop1	inv	5.1944	2	0.074
pop1	rd	.68527	2	0.710
pop1	ALL	24.824	10	0.006
pop2	realgdppercapii~e	.91115	2	0.634
pop2	pop1	1.8632	2	0.394
pop2	pop3	5.1761	2	0.075
pop2	inv	1.5721	2	0.456
pop2	rd	3.9807	2	0.137
pop2	ALL	12.285	10	0.266
pop3	realgdppercapii~e	1.2181	2	0.544
pop3	pop1	6.6352	2	0.036
pop3	pop2	2.4688	2	0.291

pop3	inv	9.6119	2	0.008
pop3	rd	5.125	2	0.077
pop3	ALL	40.642	10	0.000

Jiangsu:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	.59823	2	0.741
realgdppercapii~e	pop2	2.0593	2	0.357
realgdppercapii~e	pop3	13.211	2	0.001
realgdppercapii~e	inv	5.0383	2	0.081
realgdppercapii~e	rd	8.7892	2	0.012
realgdppercapii~e	ALL	43.079	10	0.000
pop1	realgdppercapii~e	2.7244	2	0.256
pop1	pop2	.64657	2	0.724
pop1	pop3	3.4232	2	0.181
pop1	inv	1.9874	2	0.370
pop1	rd	.71082	2	0.701
pop1	ALL	9.3299	10	0.501
pop2	realgdppercapii~e	10.37	2	0.006
pop2	pop1	.45268	2	0.797
pop2	pop3	1.2853	2	0.526
pop2	inv	6.6173	2	0.037
pop2	rd	1.4541	2	0.483
pop2	ALL	17.164	10	0.071
pop3	realgdppercapii~e	3.0222	2	0.221
pop3	pop1	9.4409	2	0.009
pop3	pop2	7.1339	2	0.028
pop3	inv	1.915	2	0.384
pop3	rd	5.0389	2	0.081
pop3	ALL	39.114	10	0.000

Zhejiang:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2

realgdppercapii~e	pop1	3.0323	2	0.220
realgdppercapii~e	pop2	11.282	2	0.004
realgdppercapii~e	pop3	16.572	2	0.000
realgdppercapii~e	inv	4.6932	2	0.096
realgdppercapii~e	rd	6.8909	2	0.032
realgdppercapii~e	ALL	64.281	10	0.000
pop1	realgdppercapii~e	.16385	2	0.921
pop1	pop2	3.0539	2	0.217
pop1	pop3	3.0271	2	0.220
pop1	inv	.61529	2	0.735
pop1	rd	3.4917	2	0.174
pop1	ALL	24.241	10	0.007
pop2	realgdppercapii~e	1.7516	2	0.417
pop2	pop1	1.5975	2	0.450
pop2	pop3	3.8932	2	0.143
pop2	inv	.22114	2	0.895
pop2	rd	1.3945	2	0.498
pop2	ALL	21.421	10	0.018
pop3	realgdppercapii~e	22.992	2	0.000
pop3	pop1	17.684	2	0.000
pop3	pop2	39.484	2	0.000
pop3	inv	3.5071	2	0.173
pop3	rd	23.238	2	0.000
pop3	ALL	137.22	10	0.000

Anhui:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	.94141	2	0.625
realgdppercapii~e	pop2	4.2317	2	0.121
realgdppercapii~e	pop3	3.9071	2	0.142
realgdppercapii~e	inv	24.742	2	0.000
realgdppercapii~e	rd	.86637	2	0.648
realgdppercapii~e	ALL	37.798	10	0.000
pop1	realgdppercapii~e	.8335	2	0.659
pop1	pop2	1.1216	2	0.571
pop1	pop3	.12994	2	0.937

```
|                pop1                  inv |   7.4328      2     0.024     |
|                pop1                   rd |   4.2733      2     0.118     |
|                pop1                  ALL |   20.619     10     0.024     |
|--------------------------------------+--------------------------|
|                pop2   realgdppercapii~e |   3.1933      2     0.203     |
|                pop2                 pop1 |   .04144      2     0.979     |
|                pop2                 pop3 |   2.2815      2     0.320     |
|                pop2                  inv |   9.8627      2     0.007     |
|                pop2                   rd |   4.7918      2     0.091     |
|                pop2                  ALL |   22.701     10     0.012     |
|--------------------------------------+--------------------------|
|                pop3   realgdppercapii~e |   16.624      2     0.000     |
|                pop3                 pop1 |   6.2534      2     0.044     |
|                pop3                 pop2 |   .87068      2     0.647     |
|                pop3                  inv |    4.242      2     0.120     |
|                pop3                   rd |   3.2596      2     0.196     |
|                pop3                  ALL |   42.291     10     0.000     |
|--------------------------------------+--------------------------|
```

Fujian:

Granger causality Wald tests

```
+------------------------------------------------------------------+
|              Equation           Excluded |    chi2      df Prob > chi2 |
|--------------------------------------+--------------------------|
| realgdppercapii~e                  pop1 |   56.705      2     0.000     |
| realgdppercapii~e                  pop2 |   1.9553      2     0.376     |
| realgdppercapii~e                  pop3 |   23.493      2     0.000     |
| realgdppercapii~e                   inv |   12.648      2     0.002     |
| realgdppercapii~e                    rd |   35.275      2     0.000     |
| realgdppercapii~e                   ALL |   156.95     10     0.000     |
|--------------------------------------+--------------------------|
|                pop1   realgdppercapii~e |   4.8619      2     0.088     |
|                pop1                 pop2 |   .93012      2     0.628     |
|                pop1                 pop3 |     1.92      2     0.383     |
|                pop1                  inv |   6.4508      2     0.040     |
|                pop1                   rd |   3.0412      2     0.219     |
|                pop1                  ALL |   21.591     10     0.017     |
|--------------------------------------+--------------------------|
|                pop2   realgdppercapii~e |   2.2034      2     0.332     |
|                pop2                 pop1 |   2.0465      2     0.359     |
|                pop2                 pop3 |    1.444      2     0.486     |
|                pop2                  inv |   1.2969      2     0.523     |
|                pop2                   rd |   6.2258      2     0.044     |
|                pop2                  ALL |    12.51     10     0.252     |
```

pop3	realgdppercapii~e	8.7646	2	0.012
pop3	pop1	12.837	2	0.002
pop3	pop2	2.0408	2	0.360
pop3	inv	32.3	2	0.000
pop3	rd	3.1611	2	0.206
pop3	ALL	79.346	10	0.000

Jiangxi:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	12.129	2	0.002
realgdppercapii~e	pop2	9.0889	2	0.011
realgdppercapii~e	pop3	14.634	2	0.001
realgdppercapii~e	inv	10.431	2	0.005
realgdppercapii~e	rd	10.129	2	0.006
realgdppercapii~e	ALL	93.899	10	0.000
pop1	realgdppercapii~e	9.7798	2	0.008
pop1	pop2	9.5948	2	0.008
pop1	pop3	8.0026	2	0.018
pop1	inv	7.3136	2	0.026
pop1	rd	.38351	2	0.826
pop1	ALL	26.744	10	0.003
pop2	realgdppercapii~e	1.9561	2	0.376
pop2	pop1	2.8524	2	0.240
pop2	pop3	.74093	2	0.690
pop2	inv	6.1658	2	0.046
pop2	rd	.16908	2	0.919
pop2	ALL	12.648	10	0.244
pop3	realgdppercapii~e	9.2548	2	0.010
pop3	pop1	14.282	2	0.001
pop3	pop2	.78209	2	0.676
pop3	inv	3.3478	2	0.188
pop3	rd	3.6065	2	0.165
pop3	ALL	56.977	10	0.000

Shandong:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	.13448	2	0.935
realgdppercapii~e	pop2	.16589	2	0.920
realgdppercapii~e	pop3	2.7188	2	0.257
realgdppercapii~e	inv	2.2737	2	0.321
realgdppercapii~e	rd	12.613	2	0.002
realgdppercapii~e	ALL	27.531	10	0.002
pop1	realgdppercapii~e	.50732	2	0.776
pop1	pop2	.90442	2	0.636
pop1	pop3	3.3257	2	0.190
pop1	inv	1.9389	2	0.379
pop1	rd	.41605	2	0.812
pop1	ALL	10.486	10	0.399
pop2	realgdppercapii~e	13.563	2	0.001
pop2	pop1	1.6717	2	0.433
pop2	pop3	1.5649	2	0.457
pop2	inv	10.914	2	0.004
pop2	rd	2.943	2	0.230
pop2	ALL	23.886	10	0.008
pop3	realgdppercapii~e	12.004	2	0.002
pop3	pop1	1.7249	2	0.422
pop3	pop2	1.689	2	0.430
pop3	inv	10.547	2	0.005
pop3	rd	3.3401	2	0.188
pop3	ALL	17.948	10	0.056

Henan:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	5.5477	2	0.062
realgdppercapii~e	pop2	1.0743	2	0.584
realgdppercapii~e	pop3	1.6241	2	0.444
realgdppercapii~e	inv	12.769	2	0.002
realgdppercapii~e	rd	16.15	2	0.000
realgdppercapii~e	ALL	42.367	10	0.000

pop1	realgdppercapii~e	.15484	2	0.926
pop1	pop2	.69225	2	0.707
pop1	pop3	7.2591	2	0.027
pop1	inv	2.4957	2	0.287
pop1	rd	1.0149	2	0.602
pop1	ALL	20.57	10	0.024
pop2	realgdppercapii~e	4.9489	2	0.084
pop2	pop1	1.7175	2	0.424
pop2	pop3	.64726	2	0.724
pop2	inv	1.9837	2	0.371
pop2	rd	3.6638	2	0.160
pop2	ALL	17.586	10	0.062
pop3	realgdppercapii~e	6.4947	2	0.039
pop3	pop1	9.8152	2	0.007
pop3	pop2	6.0516	2	0.049
pop3	inv	1.8217	2	0.402
pop3	rd	17.102	2	0.000
pop3	ALL	34.691	10	0.000

Hubei:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	.21046	2	0.900
realgdppercapii~e	pop2	1.9191	2	0.383
realgdppercapii~e	pop3	.11812	2	0.943
realgdppercapii~e	inv	1.6198	2	0.445
realgdppercapii~e	rd	11.965	2	0.003
realgdppercapii~e	ALL	16.347	10	0.090
pop1	realgdppercapii~e	3.3398	2	0.188
pop1	pop2	1.6419	2	0.440
pop1	pop3	.49102	2	0.782
pop1	inv	13.033	2	0.001
pop1	rd	.82769	2	0.661
pop1	ALL	32.275	10	0.000
pop2	realgdppercapii~e	8.3824	2	0.015
pop2	pop1	8.6354	2	0.013

pop2	pop3	4.1564	2	0.125
pop2	inv	1.1035	2	0.576
pop2	rd	3.2412	2	0.198
pop2	ALL	18.573	10	0.046
pop3	realgdppercapii~e	8.9735	2	0.011
pop3	pop1	.28736	2	0.866
pop3	pop2	2.4261	2	0.297
pop3	inv	2.2871	2	0.319
pop3	rd	3.848	2	0.146
pop3	ALL	20.359	10	0.026

Hunan:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	.15566	2	0.925
realgdppercapii~e	pop2	2.5913	2	0.274
realgdppercapii~e	pop3	1.3822	2	0.501
realgdppercapii~e	inv	1.1032	2	0.576
realgdppercapii~e	rd	11.427	2	0.003
realgdppercapii~e	ALL	20.534	10	0.025
pop1	realgdppercapii~e	.60284	2	0.740
pop1	pop2	4.2179	2	0.121
pop1	pop3	16.353	2	0.000
pop1	inv	.27186	2	0.873
pop1	rd	.66969	2	0.715
pop1	ALL	26.616	10	0.003
pop2	realgdppercapii~e	1.0373	2	0.595
pop2	pop1	8.6667	2	0.013
pop2	pop3	3.4967	2	0.174
pop2	inv	.73566	2	0.692
pop2	rd	.36364	2	0.834
pop2	ALL	14.737	10	0.142
pop3	realgdppercapii~e	1.794	2	0.408
pop3	pop1	17.307	2	0.000
pop3	pop2	4.7969	2	0.091
pop3	inv	.03632	2	0.982
pop3	rd	4.0208	2	0.134

pop3	ALL	31.184	10	0.001

Guangdong:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	.1845	2	0.912
realgdppercapii~e	pop2	1.4422	2	0.486
realgdppercapii~e	pop3	2.2097	2	0.331
realgdppercapii~e	inv	2.1233	2	0.346
realgdppercapii~e	rd	11.263	2	0.004
realgdppercapii~e	ALL	19.323	10	0.036
pop1	realgdppercapii~e	.71625	2	0.699
pop1	pop2	3.053	2	0.217
pop1	pop3	.4572	2	0.796
pop1	inv	.48568	2	0.784
pop1	rd	2.4457	2	0.294
pop1	ALL	8.1929	10	0.610
pop2	realgdppercapii~e	.52199	2	0.770
pop2	pop1	7.0618	2	0.029
pop2	pop3	2.0596	2	0.357
pop2	inv	4.5652	2	0.102
pop2	rd	1.6792	2	0.432
pop2	ALL	11.142	10	0.347
pop3	realgdppercapii~e	5.2536	2	0.072
pop3	pop1	.09078	2	0.956
pop3	pop2	.26441	2	0.876
pop3	inv	4.0886	2	0.129
pop3	rd	.55179	2	0.759
pop3	ALL	10.632	10	0.387

Guangxi:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	.87798	2	0.645
realgdppercapii~e	pop2	.06359	2	0.969

realgdppercapii~e	pop3	3.1909	2	0.203
realgdppercapii~e	inv	6.9404	2	0.031
realgdppercapii~e	rd	.8251	2	0.662
realgdppercapii~e	ALL	14.314	10	0.159
pop1	realgdppercapii~e	5.8685	2	0.050
pop1	pop2	.62748	2	0.731
pop1	pop3	12.312	2	0.002
pop1	inv	19.844	2	0.000
pop1	rd	1.5262	2	0.466
pop1	ALL	92.92	10	0.000
pop2	realgdppercapii~e	8.2593	2	0.016
pop2	pop1	5.3617	2	0.069
pop2	pop3	8.2782	2	0.016
pop2	inv	8.8459	2	0.012
pop2	rd	3.1145	2	0.211
pop2	ALL	32.093	10	0.000
pop3	realgdppercapii~e	1.7976	2	0.407
pop3	pop1	7.1301	2	0.028
pop3	pop2	.70904	2	0.702
pop3	inv	1.2121	2	0.545
pop3	rd	2.7314	2	0.255
pop3	ALL	16.364	10	0.090

Hainan:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	1.5619	2	0.458
realgdppercapii~e	pop2	2.2428	2	0.326
realgdppercapii~e	pop3	3.1691	2	0.205
realgdppercapii~e	inv	11.419	2	0.003
realgdppercapii~e	rd	3.899	2	0.142
realgdppercapii~e	ALL	25.781	10	0.004
pop1	realgdppercapii~e	7.4448	2	0.024
pop1	pop2	4.5739	2	0.102
pop1	pop3	3.1271	2	0.209
pop1	inv	13.331	2	0.001
pop1	rd	1.0671	2	0.587

```
|                pop1                  ALL |    17.58      10     0.062     |
|------------------------------------+--------------------------|
|                pop2   realgdppercapii~e |   1.5259       2     0.466     |
|                pop2                 pop1 |   1.9581       2     0.376     |
|                pop2                 pop3 |   6.6007       2     0.037     |
|                pop2                  inv |   1.9352       2     0.380     |
|                pop2                   rd |     1.22       2     0.543     |
|                pop2                  ALL |   14.133      10     0.167     |
|------------------------------------+--------------------------|
|                pop3   realgdppercapii~e |   1.6608       2     0.436     |
|                pop3                 pop1 |   .24566       2     0.884     |
|                pop3                 pop2 |   .13185       2     0.936     |
|                pop3                  inv |   3.4268       2     0.180     |
|                pop3                   rd |   1.1655       2     0.558     |
|                pop3                  ALL |   6.5271      10     0.769     |
|------------------------------------+--------------------------|
```

Guizhou:

Granger causality Wald tests

```
+------------------------------------------------------------------+
|          Equation               Excluded |     chi2     df Prob > chi2 |
|------------------------------------+--------------------------|
| realgdppercapii~e                  pop1 |   .20823       2     0.901     |
| realgdppercapii~e                  pop2 |   .39681       2     0.820     |
| realgdppercapii~e                  pop3 |   5.0044       2     0.082     |
| realgdppercapii~e                   inv |   2.5502       2     0.279     |
| realgdppercapii~e                    rd |   25.006       2     0.000     |
| realgdppercapii~e                   ALL |   36.935      10     0.000     |
|------------------------------------+--------------------------|
|                pop1   realgdppercapii~e |   15.381       2     0.000     |
|                pop1                 pop2 |   .39371       2     0.821     |
|                pop1                 pop3 |   6.1365       2     0.047     |
|                pop1                  inv |   5.4485       2     0.066     |
|                pop1                   rd |   16.517       2     0.000     |
|                pop1                  ALL |   25.749      10     0.004     |
|------------------------------------+--------------------------|
|                pop2   realgdppercapii~e |   4.9855       2     0.083     |
|                pop2                 pop1 |   4.0838       2     0.130     |
|                pop2                 pop3 |   .96342       2     0.618     |
|                pop2                  inv |   .23085       2     0.891     |
|                pop2                   rd |   7.6159       2     0.022     |
|                pop2                  ALL |   10.851      10     0.369     |
|------------------------------------+--------------------------|
|                pop3   realgdppercapii~e |   5.8122       2     0.055     |
```

Equation	Excluded	chi2	df	Prob > chi2
pop3	pop1	12.013	2	0.002
pop3	pop2	27.226	2	0.000
pop3	inv	6.5362	2	0.038
pop3	rd	5.519	2	0.063
pop3	ALL	48.981	10	0.000

Yunnan:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	5.6523	2	0.049
realgdppercapii~e	pop2	1.8347	2	0.400
realgdppercapii~e	pop3	9.3163	2	0.009
realgdppercapii~e	inv	3.8033	2	0.149
realgdppercapii~e	rd	1.2456	2	0.536
realgdppercapii~e	ALL	33.529	10	0.000
pop1	realgdppercapii~e	2.613	2	0.271
pop1	pop2	1.1215	2	0.571
pop1	pop3	12.079	2	0.002
pop1	inv	5.7573	2	0.056
pop1	rd	1.2876	2	0.525
pop1	ALL	49.799	10	0.000
pop2	realgdppercapii~e	1.8762	2	0.391
pop2	pop1	1.7247	2	0.422
pop2	pop3	.52547	2	0.769
pop2	inv	.3899	2	0.823
pop2	rd	1.6164	2	0.446
pop2	ALL	5.1393	10	0.882
pop3	realgdppercapii~e	.50784	2	0.776
pop3	pop1	1.5389	2	0.463
pop3	pop2	1.7205	2	0.423
pop3	inv	3.3411	2	0.188
pop3	rd	7.8299	2	0.020
pop3	ALL	27.995	10	0.002

Tibet:

Granger causality Wald tests

```
|        Equation           Excluded |    chi2     df Prob > chi2 |
|--------------------------------------+---------------------------|
| realgdppercapii~e              pop1 |   6.4062     2    0.041     |
| realgdppercapii~e              pop2 |   4.4683     2    0.107     |
| realgdppercapii~e              pop3 |   3.9245     2    0.141     |
| realgdppercapii~e               inv |   .62797     2    0.731     |
| realgdppercapii~e                rd |   7.0114     2    0.030     |
| realgdppercapii~e               ALL |   21.198    10    0.020     |
|--------------------------------------+---------------------------|
|              pop1  realgdppercapii~e |   14.878     2    0.001     |
|              pop1               pop2 |   2.1609     2    0.339     |
|              pop1               pop3 |   5.0175     2    0.081     |
|              pop1                inv |   .50949     2    0.775     |
|              pop1                 rd |    5.963     2    0.051     |
|              pop1                ALL |   39.579    10    0.000     |
|--------------------------------------+---------------------------|
|              pop2  realgdppercapii~e |   .72658     2    0.695     |
|              pop2               pop1 |   3.5495     2    0.170     |
|              pop2               pop3 |   15.987     2    0.000     |
|              pop2                inv |   3.2442     2    0.197     |
|              pop2                 rd |   5.1446     2    0.076     |
|              pop2                ALL |   26.771    10    0.003     |
|--------------------------------------+---------------------------|
|              pop3  realgdppercapii~e |   3.1015     2    0.212     |
|              pop3               pop1 |   4.5242     2    0.104     |
|              pop3               pop2 |   1.7417     2    0.419     |
|              pop3                inv |   .71886     2    0.698     |
|              pop3                 rd |   2.5371     2    0.281     |
|              pop3                ALL |   13.726    10    0.186     |
|--------------------------------------+---------------------------|
```

Shaanxi:

Granger causality Wald tests

```
+------------------------------------------------------------------+
|        Equation           Excluded |    chi2     df Prob > chi2 |
|--------------------------------------+---------------------------|
| realgdppercapii~e              pop1 |   4.2185     2    0.121     |
| realgdppercapii~e              pop2 |   2.9541     2    0.228     |
| realgdppercapii~e              pop3 |   4.3046     2    0.116     |
| realgdppercapii~e               inv |   2.3345     2    0.311     |
| realgdppercapii~e                rd |   21.403     2    0.000     |
| realgdppercapii~e               ALL |   36.637    10    0.000     |
|--------------------------------------+---------------------------|
|              pop1  realgdppercapii~e |   9.9777     2    0.007     |
```

pop1	pop2	2.3976	2	0.302
pop1	pop3	6.4247	2	0.040
pop1	inv	1.5954	2	0.450
pop1	rd	10.809	2	0.004
pop1	ALL	44.471	10	0.000
pop2	realgdppercapii~e	1.3066	2	0.520
pop2	pop1	4.2783	2	0.118
pop2	pop3	4.4129	2	0.110
pop2	inv	6.1829	2	0.045
pop2	rd	1.8134	2	0.404
pop2	ALL	17.573	10	0.063
pop3	realgdppercapii~e	.73276	2	0.693
pop3	pop1	.05912	2	0.971
pop3	pop2	3.0415	2	0.219
pop3	inv	5.2963	2	0.071
pop3	rd	9.3866	2	0.009
pop3	ALL	17.339	10	0.067

Gansu:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	8.4781	2	0.014
realgdppercapii~e	pop2	2.7607	2	0.251
realgdppercapii~e	pop3	.14408	2	0.930
realgdppercapii~e	inv	1.23	2	0.541
realgdppercapii~e	rd	5.5568	2	0.062
realgdppercapii~e	ALL	16.741	10	0.080
pop1	realgdppercapii~e	12.851	2	0.002
pop1	pop2	3.9226	2	0.141
pop1	pop3	12.585	2	0.002
pop1	inv	32.333	2	0.000
pop1	rd	4.6386	2	0.098
pop1	ALL	88.502	10	0.000
pop2	realgdppercapii~e	14.683	2	0.001
pop2	pop1	17.02	2	0.000
pop2	pop3	5.8136	2	0.055
pop2	inv	5.3022	2	0.071

Equation	Excluded	chi2	df	Prob > chi2
pop2	rd	1.2886	2	0.525
pop2	ALL	30.378	10	0.001
pop3	realgdppercapii~e	10.291	2	0.006
pop3	pop1	6.707	2	0.035
pop3	pop2	12.316	2	0.002
pop3	inv	.46191	2	0.794
pop3	rd	4.21	2	0.122
pop3	ALL	36.194	10	0.000

Qinghai:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	7.4072	2	0.025
realgdppercapii~e	pop2	2.5625	2	0.278
realgdppercapii~e	pop3	1.5396	2	0.463
realgdppercapii~e	inv	.1923	2	0.908
realgdppercapii~e	rd	1.5023	2	0.472
realgdppercapii~e	ALL	26.297	10	0.003
pop1	realgdppercapii~e	18.38	2	0.000
pop1	pop2	2.3185	2	0.314
pop1	pop3	6.1255	2	0.047
pop1	inv	3.0901	2	0.213
pop1	rd	5.7754	2	0.056
pop1	ALL	96.508	10	0.000
pop2	realgdppercapii~e	2.2315	2	0.328
pop2	pop1	5.5329	2	0.063
pop2	pop3	2.9172	2	0.233
pop2	inv	10.58	2	0.005
pop2	rd	7.5861	2	0.023
pop2	ALL	22.034	10	0.015
pop3	realgdppercapii~e	25.619	2	0.000
pop3	pop1	11.929	2	0.003
pop3	pop2	6.1652	2	0.046
pop3	inv	76.93	2	0.000
pop3	rd	17.793	2	0.000
pop3	ALL	138.23	10	0.000

Ningxia:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	.143	2	0.931
realgdppercapii~e	pop2	2.0453	2	0.360
realgdppercapii~e	pop3	.29059	2	0.865
realgdppercapii~e	inv	2.7198	2	0.257
realgdppercapii~e	rd	1.388	2	0.500
realgdppercapii~e	ALL	12.571	10	0.249
pop1	realgdppercapii~e	6.9104	2	0.032
pop1	pop2	1.0912	2	0.579
pop1	pop3	3.5867	2	0.166
pop1	inv	4.6302	2	0.099
pop1	rd	.07569	2	0.963
pop1	ALL	25.093	10	0.005
pop2	realgdppercapii~e	1.6437	2	0.440
pop2	pop1	1.0284	2	0.598
pop2	pop3	.05682	2	0.972
pop2	inv	4.3688	2	0.113
pop2	rd	1.2751	2	0.529
pop2	ALL	13.405	10	0.202
pop3	realgdppercapii~e	3.401	2	0.183
pop3	pop1	6.2883	2	0.043
pop3	pop2	2.0704	2	0.355
pop3	inv	4.3254	2	0.115
pop3	rd	.02526	2	0.987
pop3	ALL	12.221	10	0.271

Xinjiang:

Granger causality Wald tests

Equation	Excluded	chi2	df	Prob > chi2
realgdppercapii~e	pop1	4.6727	2	0.097
realgdppercapii~e	pop2	4.6913	2	0.096
realgdppercapii~e	pop3	7.8117	2	0.020
realgdppercapii~e	inv	7.3825	2	0.025

```
| realgdppercapii~e                rd |   3.9531      2     0.139    |
| realgdppercapii~e               ALL |   23.74      10     0.008    |
|-------------------------------------+--------------------------|
|              pop1  realgdppercapii~e |  .41936      2     0.811    |
|              pop1               pop2 |  1.2726      2     0.529    |
|              pop1               pop3 |  .23814      2     0.888    |
|              pop1                inv |  1.4225      2     0.491    |
|              pop1                 rd |  3.8361      2     0.147    |
|              pop1                ALL |  10.216     10     0.422    |
|-------------------------------------+--------------------------|
|              pop2  realgdppercapii~e |  1.0582      2     0.589    |
|              pop2               pop1 |  .33933      2     0.844    |
|              pop2               pop3 |  .32575      2     0.850    |
|              pop2                inv |  8.5121      2     0.014    |
|              pop2                 rd |  .03562      2     0.982    |
|              pop2                ALL |  16.925     10     0.076    |
|-------------------------------------+--------------------------|
|              pop3  realgdppercapii~e |  1.0622      2     0.588    |
|              pop3               pop1 |  21.284      2     0.000    |
|              pop3               pop2 |   1.631      2     0.442    |
|              pop3                inv |  1.0261      2     0.599    |
|              pop3                 rd |  .64962      2     0.723    |
|              pop3                ALL |  27.371     10     0.002    |
|-------------------------------------+--------------------------|
```

Key Regression Results for Chapter 5:

Lanzhou:

Model (1)

Vector error-correction model

```
Sample:   1997 - 2015                       Number of obs     =         19
                                            AIC               =   7.097972
Log likelihood = -38.66174                  HQIC              =   7.159357
Det(Sigma_ml)  =   1.52534                  SBIC              =   7.543157

Equation            Parms     RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
D_realgdpcgrow~e      4     3.16094   0.5341   16.04622   0.0030
D_totalpopgrow~e      4      .50411   0.2280   4.135877   0.3879
----------------------------------------------------------------

------------------------------------------------------------------------------
                 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-----------------+------------------------------------------------------------
```

```
D_realgdpcgro~e |
           _ce1 |
            L1. |  -.5171078   .1760521    -2.94   0.003    -.8621636   -.1720519
                |
realgdpcgrowt~e |
            LD. |  -.0774398   .1275137    -0.61   0.544    -.3273622    .1724825
                |
totalpopgrowt~e |
            LD. |  -3.706865   1.499118    -2.47   0.013    -6.645082   -.7686488
                |
          _cons |  -.0075416   .7840993    -0.01   0.992    -1.544348    1.529265
----------------+----------------------------------------------------------------
D_totalpopgro~e |
           _ce1 |
            L1. |   .0345247    .028077     1.23   0.219    -.0205053    .0895547
                |
realgdpcgrowt~e |
            LD. |  -.0096158   .0203361    -0.47   0.636    -.0494737    .0302422
                |
totalpopgrowt~e |
            LD. |  -.3395539   .2390814    -1.42   0.156    -.8081448     .129037
                |
          _cons |  -.1129585   .1250493    -0.90   0.366    -.3580506    .1321335
---------------------------------------------------------------------------------
Cointegrating equations
Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                   1   22.54308   0.0043
-------------------------------------------

Identification:  beta is exactly identified
                 Johansen normalization restriction imposed
---------------------------------------------------------------------------------
           beta |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+----------------------------------------------------------------
_ce1            |
realgdpcgrowt~e |          1          .        .       .            .           .
totalpopgrowt~e |   3.716333   1.8421403    4.75   0.000     1.818162    4.374505
          _cons |  -4.401821          .        .       .            .           .
---------------------------------------------------------------------------------


   Lagrange-multiplier test
  +--------------------------------------+
```

```
| lag  |        chi2     df    Prob > chi2 |
|------+-------------------------------|
|   1  |     5.9174      4      0.20541    |
|   2  |     8.5907      4      0.07218    |
+-------------------------------------+
 H0: no autocorrelation at lag order

 Jarque-Bera test
+-------------------------------------------------------+
|              Equation |              chi2    df   Prob > chi2 |
|--------------------+-----------------------------------|
|D_realgdpcgrowthrate|              0.809    2    0.66730     |
|D_totalpopgrowthrate|              4.183    2     0.12348    |
|                  ALL |              4.992    4     0.28808    |
+-------------------------------------------------------+

 Skewness test
+-------------------------------------------------------+
|              Equation | Skewness    chi2    df   Prob > chi2 |
|--------------------+-----------------------------------|
|D_realgdpcgrowthrate|   .53217     0.802    1    0.37053     |
|D_totalpopgrowthrate|  1.1425     3.698    1     0.05446    |
|                  ALL |              4.500    2     0.10538    |
+-------------------------------------------------------+

 Kurtosis test
+-------------------------------------------------------+
|              Equation | Kurtosis    chi2    df   Prob > chi2 |
|--------------------+-----------------------------------|
|D_realgdpcgrowthrate|   3.1004     0.007    1    0.93267     |
|D_totalpopgrowthrate|   3.8274     0.485    1     0.48621    |
|                  ALL |              0.492    2     0.78191    |
+-------------------------------------------------------+
```

Model (2):

Vector error-correction model

```
Sample:   1998 - 2015                         Number of obs     =        18
                                                AIC                =    21.9894
Log likelihood = -170.9046                    HQIC              =   22.17356
Det(Sigma_ml)  =   2075.363                     SBIC              =   23.32496

Equation             Parms      RMSE      R-sq       chi2      P>chi2
----------------------------------------------------------------
D_realgdpcgrow~e        6      3.83488    0.4122    8.413486    0.2093
```

```
D_totalpopgrow~e          6         .507697      0.3289        5.88056      0.4367
D_fai                     6         8.55091      0.6273       20.19342      0.0026
D_rd                      6         12.6695      0.6628       23.58408      0.0006
----------------------------------------------------------------

--------------------------------------------------------------------------------
                 |      Coef.    Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+---------------------------------------------------------------
D_realgdpcgro~e |
            _ce1 |
             L1. |  -.4271948    .2712071    -1.58   0.115    -.9587509    .1043613
                 |
realgdpcgrowt~e |
             LD. |   .1488899    .1870257     0.80   0.426    -.2176738    .5154535
                 |
totalpopgrowt~e |
             LD. |  -3.127434    2.030365    -1.54   0.123    -7.106877     .852009
                 |
             fai |
             LD. |  -.1542675    .1461422    -1.06   0.291    -.4407009    .1321659
                 |
              rd |
             LD. |   .0064287    .0627532     0.10   0.918    -.1165653    .1294227
                 |
           _cons |   .1110521    .9873096     0.11   0.910    -1.824039    2.046143
----------------+---------------------------------------------------------------
D_totalpopgro~e |
            _ce1 |
             L1. |   .0589102    .0359049     1.64   0.101    -.0114621    .1292825
                 |
realgdpcgrowt~e |
             LD. |  -.0369009    .0247602    -1.49   0.136      -.08543    .0116281
                 |
totalpopgrowt~e |
             LD. |  -.4541289    .2687984    -1.69   0.091     -.980964    .0727063
                 |
             fai |
             LD. |   .0188656    .0193476     0.98   0.330    -.0190551    .0567863
                 |
              rd |
             LD. |   .0018143    .0083078     0.22   0.827    -.0144688    .0180974
                 |
           _cons |  -.1482696    .1307091    -1.13   0.257    -.4044547    .1079156
----------------+---------------------------------------------------------------
```

```
D_fai            |
            _ce1 |
             L1. |  -.1358517   .6047299    -0.22   0.822     -1.3211    1.049397
                 |
realgdpcgrowt~e |
             LD. |   1.017112   .4170247     2.44   0.015    .1997588    1.834465
                 |
totalpopgrowt~e |
             LD. |   1.017637   4.527251     0.22   0.822   -7.855612    9.890886
                 |
             fai |
             LD. |  -.6091219   .3258637    -1.87   0.062   -1.247803    .0295592
                 |
              rd |
             LD. |  -.0465196   .1399253    -0.33   0.740   -.3207681     .227729
                 |
           _cons |   .4413305   2.201475     0.20   0.841   -3.873481    4.756142
-----------------+----------------------------------------------------------------
D_rd             |
            _ce1 |
             L1. |   2.400905   .8960011     2.68   0.007    .6447753    4.157035
                 |
realgdpcgrowt~e |
             LD. |  -.0230524   .6178867    -0.04   0.970   -1.234088    1.187983
                 |
totalpopgrowt~e |
             LD. |   12.29187   6.707825     1.83   0.067   -.8552279    25.43896
                 |
             fai |
             LD. |   1.521836   .4828176     3.15   0.002    .5755306    2.468141
                 |
              rd |
             LD. |  -.4055371    .207321    -1.96   0.050   -.8118788    .0008047
                 |
           _cons |   .0483695   3.261827     0.01   0.988   -6.344693    6.441432
----------------------------------------------------------------------------------

Cointegrating equations
Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                   3   60.1941   0.0000
-------------------------------------------
Identification:  beta is exactly identified
```

Johansen normalization restriction imposed

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
_ce1						
realgdpcgrowt~e	1	.	.	.	.	.
totalpopgrowt~e	4.396357	1.420813	3.09	0.002	1.611614	7.181131
fai	-.7659118	.1412332	-5.42	0.000	-1.042724	-.4890997
rd	-.2346272	.0406554	-5.77	0.000	-.3143102	-.1549442
_cons	-9.742706	.	.	.	.	.

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	12.1727	16	0.73201
2	15.9597	16	0.45578

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_realgdpcgrowthrate	1.124	2	0.57010
D_totalpopgrowthrate	1.589	2	0.45170
D_fai	1.263	2	0.53186
D_rd	1.293	2	0.52376
ALL	5.270	8	0.72842

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_realgdpcgrowthrate	.56441	0.956	1	0.32828
D_totalpopgrowthrate	.71164	1.519	1	0.21773
D_fai	-.54831	0.902	1	0.34226
D_rd	-.58859	1.039	1	0.30798
ALL		4.416	4	0.35260

Kurtosis test

```
|              Equation | Kurtosis    chi2    df   Prob > chi2 |
|--------------------+-----------------------------------|
|D_realgdpcgrowthrate|   2.5264     0.168    1      0.68170    |
|D_totalpopgrowthrate|   2.6941     0.070    1      0.79109    |
|                D_fai |   3.6936     0.361    1      0.54807    |
|                 D_rd |   2.4179     0.254    1      0.61417    |
|                  ALL |              0.853    4      0.93116    |
+----------------------------------------------------+
```

Model (3)

Vector error-correction model

```
Sample:   1998 - 2015                          Number of obs     =        18
                                                AIC               =  27.58388
Log likelihood = -209.2549                     HQIC              =  27.84988
Det(Sigma_ml)  =  8614.129                      SBIC              =  29.51302

Equation           Parms    RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
D_realgdpcgrow~e     7      3.92989   0.4341   8.438391   0.2955
D_totalpopgrow~e     7      .558976   0.2543   3.750414   0.8080
D_eduindex           7      4.07051   0.6694   22.27594   0.0023
D_fai                7      8.73704   0.6433   19.83634   0.0059
D_rd                 7      13.7969   0.6334   19.00641   0.0082
----------------------------------------------------------------


------------------------------------------------------------------------------
                 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
D_realgdpcgro~e |
            _ce1 |
             L1. |  -.2626419   .2401991    -1.09   0.274    -.7334234    .2081397
                 |
realgdpcgrowt~e |
             LD. |   .0913335    .181379     0.50   0.615    -.2641628    .4468297
                 |
totalpopgrowt~e |
             LD. |  -3.492457   2.066991    -1.69   0.091    -7.543685    .5587704
                 |
        eduindex |
             LD. |  -.2666444   .1921002    -1.39   0.165     -.643154    .1098651
                 |
             fai |
             LD. |  -.0740737   .1817675    -0.41   0.684    -.4303314     .282184
```

```
                 |
              rd |
             LD. |   -.008006    .0677532    -0.12   0.906    -.1407998    .1247878
                 |
           _cons |  -.1270658    1.016059    -0.13   0.900    -2.118505    1.864373
-----------------+----------------------------------------------------------------
D_totalpopgro~e  |
             _ce1 |
             L1. |   .0357792    .0341652     1.05   0.295    -.0311833    .1027417
                 |
realgdpcgrowt~e  |
             LD. |  -.0269847    .0257988    -1.05   0.296    -.0775494      .02358
                 |
totalpopgrowt~e  |
             LD. |  -.3627324    .2940025    -1.23   0.217    -.9389666    .2135019
                 |
        eduindex |
             LD. |  -.0006001    .0273238    -0.02   0.982    -.0541536    .0529535
                 |
             fai |
             LD. |   .0174229    .0258541     0.67   0.500    -.0332501     .068096
                 |
              rd |
             LD. |   .0001767     .009637     0.02   0.985    -.0187115    .0190649
                 |
           _cons |  -.1324855    .1445211    -0.92   0.359    -.4157417    .1507707
-----------------+----------------------------------------------------------------
D_eduindex       |
             _ce1 |
             L1. |    .769981     .248794     3.09   0.002     .2823538    1.257608
                 |
realgdpcgrowt~e  |
             LD. |  -.0726248    .1878691    -0.39   0.699    -.4408415     .295592
                 |
totalpopgrowt~e  |
             LD. |   1.025944    2.140953     0.48   0.632    -3.170245    5.222134
                 |
        eduindex |
             LD. |  -.4542708     .198974    -2.28   0.022    -.8442527   -.0642889
                 |
             fai |
             LD. |   .4507612    .1882715     2.39   0.017     .0817557    .8197666
                 |
              rd |
```

```
             LD. |    .1110103    .0701776      1.58    0.114     -.0265352    .2485558
                 |
           _cons |   -.9557559    1.052416     -0.91    0.364     -3.018453    1.106941
----------------+------------------------------------------------------------------
D_fai            |
            _ce1 |
             L1. |    .2486043    .5340174      0.47    0.642     -.7980507    1.295259
                 |
realgdpcgrowt~e |
             LD. |    .8659434    .4032469      2.15    0.032      .0755941    1.656293
                 |
totalpopgrowt~e |
             LD. |     .696113    4.595393      0.15    0.880     -8.310691    9.702917
                 |
        eduindex |
             LD. |    .2664893    .4270827      0.62    0.533     -.5705774    1.103556
                 |
             fai |
             LD. |   -.4673481    .4041106     -1.16    0.247      -1.25939    .3246942
                 |
              rd |
             LD. |    .0173552    .1506308      0.12    0.908     -.2778758    .3125862
                 |
           _cons |    .1211065    2.258931      0.05    0.957     -4.306317     4.54853
----------------+------------------------------------------------------------------
D_rd             |
            _ce1 |
             L1. |    1.896729     .843279      2.25    0.024      .2439325    3.549526
                 |
realgdpcgrowt~e |
             LD. |    .2068756    .6367763      0.32    0.745     -1.041183    1.454934
                 |
totalpopgrowt~e |
             LD. |    15.77319    7.256689      2.17    0.030      1.550341    29.99604
                 |
        eduindex |
             LD. |    .4143212     .674416      0.61    0.539     -.9075098    1.736152
                 |
             fai |
             LD. |    1.623195    .6381402      2.54    0.011      .3724629    2.873927
                 |
              rd |
             LD. |   -.3842789    .2378645     -1.62    0.106     -.8504848    .0819271
                 |
```

_cons	.3570225	3.567129	0.10	0.920	-6.634423	7.348468

Cointegrating equations

Equation	Parms	chi2	P>chi2
_ce1	4	123.5465	0.0001

Identification: beta is exactly identified

Johansen normalization restriction imposed

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
_ce1						
realgdpcgrowt~e	1	.	.	.	.	.
totalpopgrowt~e	2.248748	.3768359	9.83	0.000	0.761206	3.736354
eduindex	-.9848449	.087411	-11.27	0.000	-1.156167	-.8135225
fai	-.7867174	.1286138	-6.12	0.000	-1.038796	-.5346389
rd	-.2800826	.0272282	-10.29	0.000	-.3334488	-.2267164
_cons	-8.491765	.	.	.	.	.

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	21.0073	25	0.69220
2	33.7706	25	0.11290

H0: no autocorrelation at lag order

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_realgdpcgrowthrate	2.521	2	0.28352.
D_totalpopgrowthrate	1.134	2	0.56730
D_eduindex	1.229	2	0.54095
D_fai	1.707	2	0.42582
D_rd	0.433	2	0.80537
ALL	7.024	10	0.72319

+---+

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_realgdpcgrowthrate	.90012	2.431	1	0.11898.
D_totalpopgrowthrate	.58947	1.042	1	0.30726
D_eduindex	-.47741	0.684	1	0.40829
D_fai	-.28578	0.245	1	0.62061
D_rd	-.3102	0.289	1	0.59108
ALL		4.691	5	0.45480

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_realgdpcgrowthrate	3.347	0.090	1	0.76378.
D_totalpopgrowthrate	2.6511	0.091	1	0.76255
D_eduindex	2.1475	0.545	1	0.46034
D_fai	4.3964	1.462	1	0.22654
D_rd	2.5614	0.144	1	0.70410
ALL		2.333	5	0.80135

Model (4)

Sample: 1998 - 2015 Number of obs = 18

AIC = 30.28943

Log likelihood = -233.6049 HQIC = 30.55544

Det(Sigma_ml) = 128890 SBIC = 32.21857

Equation	Parms	RMSE	R-sq	chi2	P>chi2
D_realgdpcgrow~e	7	4.14344	0.3709	6.486313	0.4842
D_totalpopgrow~e	7	.336767	0.7293	29.63781	0.0001
D_helindex	7	15.5379	0.8520	63.31659	0.0000
D_fai	7	7.12419	0.7628	35.37891	0.0000
D_rd	7	15.7389	0.5229	12.05829	0.0987

	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]

D_realgdpcgro~e						
_ce1						
L1.	-.1667584	.1694111	-0.98	0.325	-.4987981	.1652814
realgdpcgrowt~e						
LD.	.0092878	.1946541	0.05	0.962	-.3722273	.3908028
totalpopgrowt~e						
LD.	-2.952346	2.257646	-1.31	0.191	-7.377251	1.472559
helindex						
LD.	.0584763	.0501727	1.17	0.244	-.0398604	.156813
fai						
LD.	-.0065838	.106444	-0.06	0.951	-.2152103	.2020426
rd						
LD.	.0234975	.0778879	0.30	0.763	-.12916	.176155
_cons	-.2792821	1.025575	-0.27	0.785	-2.289372	1.730807
D_totalpopgro~e						
_ce1						
L1.	.0355591	.0137693	2.58	0.010	.0085719	.0625463
realgdpcgrowt~e						
LD.	-.0069133	.0158209	-0.44	0.662	-.0379217	.0240952
totalpopgrowt~e						
LD.	-.5492173	.183495	-2.99	0.003	-.9088609	-.1895737
helindex						
LD.	-.0188297	.0040779	-4.62	0.000	-.0268222	-.0108371
fai						
LD.	.0003479	.0086515	0.04	0.968	-.0166087	.0173045
rd						
LD.	-.0035424	.0063305	-0.56	0.576	-.01595	.0088651
_cons	-.0950657	.0833558	-1.14	0.254	-.25844	.0683086
D_helindex						
_ce1						

```
             L1. |  -2.536938   .6352913    -3.99   0.000    -3.782086    -1.29179
                 |
realgdpcgrowt~e |
             LD. |   1.250455   .7299524     1.71   0.087    -.1802258    2.681135
                 |
totalpopgrowt~e |
             LD. |   13.66548   8.466166     1.61   0.106    -2.927898    30.25886
                 |
        helindex |
             LD. |   .1873519   .1881476     1.00   0.319    -.1814106    .5561144
                 |
             fai |
             LD. |  -.4207058   .3991648    -1.05   0.292    -1.203054    .3616429
                 |
              rd |
             LD. |   .5421539   .2920794     1.86   0.063    -.0303112    1.114619
                 |
           _cons |   .5699144   3.845902     0.15   0.882    -6.967915    8.107744
----------------+----------------------------------------------------------------
D_fai            |
            _ce1 |
             L1. |  -.4718947   .2912837    -1.62   0.105      -1.0428    .0990108
                 |
realgdpcgrowt~e |
             LD. |   .9295168   .3346862     2.78   0.005     .2735439     1.58549
                 |
totalpopgrowt~e |
             LD. |   2.958969   3.881772     0.76   0.446    -4.649165     10.5671
                 |
        helindex |
             LD. |   .2164727   .0862664     2.51   0.012     .0473936    .3855518
                 |
             fai |
             LD. |  -.6292596   .1830187    -3.44   0.001    -.9879697   -.2705495
                 |
              rd |
             LD. |  -.0581638   .1339196    -0.43   0.664    -.3206414    .2043138
                 |
           _cons |     .41068   1.763362     0.23   0.816    -3.045446    3.866806
----------------+----------------------------------------------------------------
D_rd             |
            _ce1 |
             L1. |   .7150349   .6435085     1.11   0.267    -.5462186    1.976288
                 |
```

```
realgdpcgrowt~e |
            LD. |   .4831083    .739394     0.65   0.514   -.9660774    1.932294
                |
totalpopgrowt~e |
            LD. |   12.69741   8.575673     1.48   0.139     -4.1106    29.50542
                |
       helindex |
            LD. |  -.0929444   .1905812    -0.49   0.626   -.4664767    .2805878
                |
            fai |
            LD. |   .6606954   .4043279     1.63   0.102   -.1317727    1.453163
                |
             rd |
            LD. |  -.4153895   .2958573    -1.40   0.160   -.9952591    .1644802
                |
          _cons |    2.23268   3.895647     0.57   0.567   -5.402648    9.868008
------------------------------------------------------------------------------
Cointegrating equations

Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                   4   101.6849   0.0003
-------------------------------------------

Identification:  beta is exactly identified

                 Johansen normalization restriction imposed
------------------------------------------------------------------------------
           beta |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
_ce1            |
realgdpcgrowt~e |          1          .        .       .           .           .
totalpopgrowt~e |   4.464342    1.63392     2.73   0.006    1.261917    7.666767
       helindex |  -.4593827   .0585601    -7.84   0.000   -.5741585    -.344607
            fai |  -.3785192   .1587641    -2.38   0.017   -.6896911   -.0673474
             rd |  -.2991478   .0485169    -8.23   0.000   -.3942391   -.2040565
          _cons |  -4.899068          .        .       .           .           .
------------------------------------------------------------------------------

   Lagrange-multiplier test
  +--------------------------------------+
  | lag  |      chi2    df   Prob > chi2 |
  |------+-------------------------------|
  |   1  |   20.4719    25     0.72165   |
```

lag	chi2	df	Prob > chi2
2	29.9769	25	0.22515

H0: no autocorrelation at lag order

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_realgdpcgrowthrate	1.062	2	0.58788.
D_totalpopgrowthrate	1.519	2	0.46785
D_helindex	0.388	2	0.82357
D_fai	3.867	2	0.14466
D_rd	0.547	2	0.76080
ALL	7.383	10	0.68881

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_realgdpcgrowthrate	.5605	0.942	1	0.33164.
D_totalpopgrowthrate	-.02167	0.001	1	0.97006
D_helindex	-.33802	0.343	1	0.55823
D_fai	-.76018	1.734	1	0.18795
D_rd	.20645	0.128	1	0.72065
ALL		3.148	5	0.67716

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_realgdpcgrowthrate	2.6	0.120	1	0.72905.
D_totalpopgrowthrate	1.5774	1.518	1	0.21795
D_helindex	3.2461	0.045	1	0.83120
D_fai	4.6865	2.133	1	0.14414
D_rd	2.2527	0.419	1	0.51749
ALL		4.235	5	0.51606

Model (5)

Vector error-correction model

Sample: 1999 - 2015 Number of obs = 17

AIC = -53.67594

Log likelihood = 363.0301 HQIC = -53.24234

Det(Sigma_ml) = 1.83e-28 SBIC = -49.31383

Equation	Parms	RMSE	R-sq	chi2	P>chi2
D_realgdpcgrow~e	14	3.77501	0.8653	37.46618	0.0006
D_totalpopgrow~e	14	.343277	0.7443	29.11111	0.0003
D_eduindex	14	5.78896	0.3922	6.452302	0.5967
D_helindex	14	24.7967	0.6573	19.17977	0.0139
D_fai	14	8.09574	0.7216	25.91527	0.0011
D_rd	14	16.0715	0.5478	12.11366	0.1462

		Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
D_realgdpcgro~e							
_ce1							
	L1.	-.047212	.0223058	-2.12	0.034	-.0909305	-.0034935
realgdpcgrowt~e							
	LD.	.2144576	.3885969	0.55	0.581	-.5471783	.9760936
	L2D.	.3267863	.0472968	2.81	0.005	-.0399785	.6012788
totalpopgrowt~e							
	LD.	.7801891	.8437582	0.82	0.413	-.6733651	6.23374
	L2D.	.5228959	.3738048	1.34	0.180	-2.08964	0.135433
eduindex							
	LD.	.0370997	.0052414	2.26	0.024	.0056276	.0865719
	L2D.	.5507601	.4386475	1.27	0.204	-.3029731	1.416493
helindex							
	LD.	-.0137425	.0060923	-2.58	0.011	-.0276832	-.0038018
	L2D.	.1802736	.1325904	1.36	0.174	-.0795989	.4401461
fai							
	LD.	-.5374465	.3376049	-1.59	0.111	-1.19914	.124247
	L2D.	-.2877141	.2427491	-1.19	0.236	-.7634937	.1880654
rd							
	LD.	.0378446	.0655201	0.58	0.564	-.0905724	.1662617
	L2D.	.2254899	.1899236	1.19	0.235	-.1467535	.5977333

```
                |
          _cons |   1.669853   .4400787     2.75   0.006     .4473149    1.972392
----------------+----------------------------------------------------------------
D_totalpopgro~e |
            _ce1 |
            L1. |  -.0685072   .0356876    -1.92   0.055    -.1384537    .0014392
                |
realgdpcgrowt~e |
            LD. |   .0143706   .0373763     0.38   0.701    -.0588857    .0876268
           L2D. |   .1085558   .0454915     2.39   0.017     .0193942    .1977174
                |
totalpopgrowt~e |
            LD. |   .7504071    .562069     1.34   0.182    -.3512279    1.852042
           L2D. |   .4928531    .324502     1.52   0.129    -.1431591    1.128865
                |
       eduindex |
            LD. |   .2445334    .107552     2.27   0.023     .0337354    .4553315
           L2D. |   .0680479   .0421903     1.61   0.107    -.0146437    .1507394
                |
       helindex |
            LD. |  -.0125645   .0051112    -2.46   0.014    -.0225824   -.0025467
           L2D. |   .0334474   .0127529     2.62   0.009     .0084522    .0584427
                |
            fai |
            LD. |  -.1006837   .0324718    -3.10   0.002    -.1643272   -.0370401
           L2D. |  -.0475776   .0233483    -2.04   0.042    -.0933394   -.0018158
                |
             rd |
            LD. |  -.0063828   .0063019    -1.01   0.311    -.0187343    .0059687
           L2D. |   .0426422   .0182674     2.33   0.020     .0068388    .0784456
                |
          _cons |     1.3679   2.179866     0.63   0.532    -2.908781    5.636138
----------------+----------------------------------------------------------------
D_eduindex      |
            _ce1 |
            L1. |  -.8539918   .6305563    -1.35   0.176    -2.089859    .3818758
                |
realgdpcgrowt~u |
            LD. |   .6693716   .6603939     1.01   0.311    -.6249767     1.96372
           L2D. |   1.008953    .803778     1.26   0.209    -.5664229    2.584329
                |
totalpopgrowt~e |
            LD. |   7.486656   9.931068     0.75   0.451    -11.97788    26.95119
           L2D. |   3.285811   5.733551     0.57   0.567    -7.951741    14.52336
```

```
                 |
        eduindex |
             LD. |   1.632589   1.900311     0.86   0.390    -2.091953    5.357131
            L2D. |   .6269476   .7454515     0.84   0.400    -.8341104    2.088006
                 |
        helindex |
             LD. |   .0247511   .0903093     0.27   0.784    -.1522519    .2017541
            L2D. |    .205896   .2253284     0.91   0.361    -.2357396    .6475316
                 |
             fai |
             LD. |  -.8663613   .5737366    -1.51   0.131    -1.990864    .2581417
            L2D. |  -.7780034   .4125356    -1.89   0.059    -1.586558    .0305515
                 |
              rd |
             LD. |   .0476791    .111347     0.43   0.669     -.170557    .2659151
            L2D. |    .269487   .3227622     0.83   0.404    -.3631153    .9020892
                 |
           _cons |    .606479   1.469074     0.41   0.680    -2.272853    3.485811
----------------+-------------------------------------------------------------
D_helindex       |
            _ce1 |
             L1. |  -2.642511   2.451014    -1.08   0.281     -7.44641    2.161388
                 |
realgdpcgrowt~u |
             LD. |  -1.986158   2.566995    -0.77   0.439    -7.017375    3.045059
            L2D. |   2.396977   3.124338     0.77   0.443    -3.726613    8.520567
                 |
totalpopgrowt~e |
             LD. |   17.21234   38.60272     0.45   0.656    -58.44759    92.87228
            L2D. |  -9.466871   22.28669    -0.42   0.671    -53.14798    34.21424
                 |
        eduindex |
             LD. |   8.904442   7.386636     1.21   0.228    -5.573099    23.38198
            L2D. |   1.265235   2.897619     0.44   0.662    -4.413994    6.944464
                 |
        helindex |
             LD. |  -.4752409   .3510382    -1.35   0.176    -1.163263    .2127814
            L2D. |   .4277604   .8758664     0.49   0.625    -1.288906    2.144427
                 |
             fai |
             LD. |  -2.394612   2.230152    -1.07   0.283     -6.76563    1.976405
            L2D. |  -.9574905   1.603553    -0.60   0.550    -4.100397    2.185416
                 |
              rd |
```

```
             LD. |   1.673396    .432813     3.87   0.000     .825098    2.521694
            L2D. |   .9471366   1.254598     0.75   0.450    -1.51183    3.406103
                 |
           _cons |   .0420543   5.710388     0.01   0.994    -11.1501    11.23421
----------------+-------------------------------------------------------------
D_fai            |
             _ce1 |
             L1. |   .1710875   .8772973     0.20   0.845   -1.548384    1.890559
                 |
realgdpcgrowt~e |
             LD. |  -.3030237   .9188106    -0.33   0.742   -2.103859    1.497812
            L2D. |  -.9294165   1.118302    -0.83   0.406   -3.121248    1.262415
                 |
totalpopgrowt~e |
             LD. |   .3787078   13.81716     0.03   0.978   -26.70243    27.45985
            L2D. |  -4.424672   7.977128    -0.55   0.579   -20.05956    11.21021
                 |
        eduindex |
             LD. |  -1.052912   2.643916    -0.40   0.690   -6.234893    4.129069
            L2D. |  -1.408822   1.037152    -1.36   0.174   -3.441602    .6239577
                 |
        helindex |
             LD. |   .3897087    .125648     3.10   0.002    .1434433    .6359742
            L2D. |   .0892622    .313501     0.28   0.776   -.5251884    .7037129
                 |
             fai |
             LD. |  -.2481191   .7982436    -0.31   0.756   -1.812648     1.31641
            L2D. |   .3419023   .5739636     0.60   0.551   -.7830457     1.46685
                 |
              rd |
             LD. |   .1045597   .1549178     0.67   0.500   -.1990736     .408193
            L2D. |  -.4400719   .4490612    -0.98   0.327   -1.320216    .4400719
                 |
           _cons |   .5095516   2.043933     0.25   0.803   -3.496483    4.515586
----------------+-------------------------------------------------------------
D_rd             |
             _ce1 |
             L1. |  -.1315757   2.939911    -0.04   0.964   -5.893696    5.630544
                 |
realgdpcgrowt~e |
             LD. |   1.106357   3.079026     0.36   0.719   -4.928423    7.141138
            L2D. |   2.205415   3.747541     0.59   0.556   -5.139631    9.550461
                 |
totalpopgrowt~e |
```

LD.	1.367997	46.3027	0.03	0.976	-89.38362	92.11961
L2D.	-9.422745	26.73216	-0.35	0.724	-61.81681	42.97132
eduindex						
LD.	-1.029767	8.860029	-0.12	0.907	-18.3951	16.33557
L2D.	-.0853013	3.475599	-0.02	0.980	-6.897351	6.726748
helindex						
LD.	.410752	.4210589	0.98	0.329	-.4145083	1.236012
L2D.	.0992016	1.050573	0.09	0.925	-1.959884	2.158287
fai						
LD.	-1.035017	2.674994	-0.39	0.699	-6.277909	4.207875
L2D.	-1.978977	1.92341	-1.03	0.304	-5.74879	1.790837
rd						
LD.	-.7197366	.519145	-1.39	0.166	-1.737242	.2977689
L2D.	-.4452377	1.504849	-0.30	0.767	-3.394688	2.504212
_cons	-1.067571	6.849424	-0.16	0.876	-14.49219	12.35705

Cointegrating equations

Equation	Parms	chi2	P>chi2
_ce1	5	138.1247	0.0000

Identification: beta is exactly identified

Johansen normalization restriction imposed

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
_ce1						
realgdpcgrowt~e	1	.	.	.	.	.
totalpopgrowt~e	8.338781	2.188661	3.81	0.000	4.049083	12.62848
eduindex	-1.23129	.4678468	-2.63	0.008	2.148253	.3143273
helindex	-.2742747	.1170747	-2.34	0.019	-.5037368	-.0448125
fai	-.7365693	.1892692	-3.89	0.000	-1.10753	-.3656085
rd	-.0191587	.088465	-0.22	0.829	-.1925469	.1542294
_cons	-7.522119	.	.	.	.	.

Lagrange-multiplier test

+-------------------------------------+

lag	chi2	df	Prob > chi2
1	20.4719	25	0.72165
2	29.9769	25	0.22515
3	25.4988	25	0.43472
4	36.3412	25	0.06658

H0: no autocorrelation at lag order

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_realgdpcgrowthrate	0.703	2	0.70372.
D_totalpopgrowthrate	2.219	2	0.32966
D_eduindex	1.076	2	0.58395
D_helindex	0.547	2	0.76074
D_fai	0.411	2	0.81430
D_rd	0.396	2	0.82046
ALL	4.352	12	0.93405

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_realgdpcgrowthrate	.21576	0.132	1	0.71647
D_totalpopgrowthrate	.87515	2.170	1	0.14072
D_eduindex	-.28724	0.234	1	0.62874
D_helindex	-.19076	0.103	1	0.74814
D_fai	.37615	0.401	1	0.52664
D_rd	.18567	0.098	1	0.75463
ALL		3.138	6	0.71485

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_realgdpcgrowthrate.	2.1023	0.571	1	0.44992.
D_totalpopgrowthrate	2.7361	0.049	1	0.82420
D_eduindex	2.0496	0.640	1	0.42379
D_helindex	2.2084	0.444	1	0.50528

```
|                D_fai |   3.1186      0.010     1      0.92048     |
|                 D_rd |   2.3513      0.298     1      0.58507     |
|                  ALL |               2.557     6      0.92734     |
+----------------------------------------------------+
```

Guiyang
Model (1)

```
Vector error-correction model
Sample:   1997 - 2015                        Number of obs     =         19
                                             AIC               =   7.392506
Log likelihood = -65.22081                   HQIC              =   7.434568
Det(Sigma_ml)  =   3.288515                  SBIC              =   7.641042

Equation           Parms      RMSE     R-sq      chi2     P>chi2
----------------------------------------------------------------
D_realgdpcgrow~e     2      3.74066   0.2468   5.570596   0.0617
D_totalpopgrow~e     2      .897838   0.0082   .1412925   0.9318
----------------------------------------------------------------

------------------------------------------------------------------------------
                 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
D_realgdpcgro~e |
            _ce1 |
             L1. |  -.8044132   .3427811    -2.35   0.019    -1.476252   -.1325745
                 |
           _cons |   .0016028   .8630254     0.00   0.999    -1.689896    1.693101
----------------+-------------------------------------------------------------
D_totalpopgro~e |
            _ce1 |
             L1. |   .0200543   .0822747     0.24   0.807    -.1412011    .1813098
                 |
           _cons |   .0642899   .2071443     0.31   0.756    -.3417055    .4702853
------------------------------------------------------------------------------

Cointegrating equations
Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                 1    6.574962   0.0103
-------------------------------------------

Identification:  beta is exactly identified

                 Johansen normalization restriction imposed
```

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
_ce1						
realgdpcgrowt~e	1	.	.	.	.	.
totalpopgrowt~e	2.811939	1.094628	2.56	0.010	.6625879	4.96129
_cons	-6.612394	.	.	.	.	.

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	5.7798	4	0.21621
2	2.9225	4	0.57087

H0: no autocorrelation at lag order

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_realgdpcgrowthrate	0.294	2	0.86340
D_totalpopgrowthrate	2.305	2	0.31588
ALL	2.599	4	0.62708

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_realgdpcgrowthrate	.06449	0.012	1	0.91356
D_totalpopgrowthrate	.88517	2.220	1	0.13623
ALL		2.232	2	0.32762

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_realgdpcgrowthrate	2.3691	0.282	1	0.59542
D_totalpopgrowthrate	3.346	0.085	1	0.77091
ALL		0.367	2	0.83246

Model (2)

Vector error-correction model

```
Sample:    1998 - 2015                       Number of obs    =        18
                                                 AIC          =   20.1584
Log likelihood = -154.4256                   HQIC             =  20.34256
Det(Sigma_ml)  =   332.5845                    SBIC           =  21.49396

Equation              Parms      RMSE      R-sq      chi2      P>chi2
----------------------------------------------------------------
D_realgdpcgrow~e        6      3.29856    0.5470   14.48756    0.0246
D_totalpopgrow~e        6      .679923    0.5985   17.88502    0.0065
D_fai                   6      16.3773    0.1959   2.923082    0.8184
D_rd                    6      3.57605    0.7698   40.13234    0.0000
----------------------------------------------------------------


------------------------------------------------------------------------------
                 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-----------------+------------------------------------------------------------
D_realgdpcgro~e |
            _ce1 |
             L1. |  -.0570417   .0214014    -2.67   0.008    -.0989876   -.0150958
                 |
realgdpcgrowt~e |
             LD. |   .1339224   .3011925     0.44   0.657    -.4564041    .7242489
                 |
totalpopgrowt~e |
             LD. |   4.739613   1.672186     2.83   0.005     1.462188    8.017038
                 |
             fai |
             LD. |   .0201676   .0822506     0.25   0.806    -.1410407    .1813759
                 |
              rd |
             LD. |   .1075219   .1279931     0.84   0.401      -.14334    .3583839
                 |
           _cons |  -.1222152   .7935498    -0.15   0.878    -1.677544    1.433114
-----------------+------------------------------------------------------------
D_totalpopgro~e |
            _ce1 |
             L1. |   .0120928   .0044114     2.74   0.006     .0034466     .020739
                 |
realgdpcgrowt~e |
```

```
             LD. |  -.1657681   .0620839    -2.67   0.008    -.2874503    -.044086
                 |
totalpopgrowt~e |
             LD. |   -1.05203   .3446826    -3.05   0.002    -1.727596   -.3764648
                 |
             fai |
             LD. |  -.0273709   .0169541    -1.61   0.106    -.0606002    .0058585
                 |
              rd |
             LD. |   .0003864   .0263828     0.01   0.988     -.051323    .0520958
                 |
           _cons |    .134611    .163572     0.82   0.411    -.1859841    .4552062
----------------+----------------------------------------------------------------
D_fai            |
             _ce1 |
             L1. |   .0842601   .1062574     0.79   0.428    -.1240006    .2925208
                 |
realgdpcgrowt~e |
             LD. |   .6176742   1.495416     0.41   0.680    -2.313287    3.548635
                 |
totalpopgrowt~e |
             LD. |  -3.737014   8.302377    -0.45   0.653    -20.00937    12.53535
                 |
             fai |
             LD. |  -.2230731   .4083729    -0.55   0.585    -1.023469    .5773232
                 |
              rd |
             LD. |   .0694444   .6354838     0.11   0.913    -1.176081     1.31497
                 |
           _cons |  -1.184683   3.939961    -0.30   0.764    -8.906866    6.537499
----------------+----------------------------------------------------------------
D_rd             |
             _ce1 |
             L1. |  -.0795148   .0232017    -3.43   0.001    -.1249893   -.0340403
                 |
realgdpcgrowt~e |
             LD. |   .8798166   .3265296     2.69   0.007     .2398304    1.519803
                 |
totalpopgrowt~e |
             LD. |   2.123745   1.812855     1.17   0.241    -1.429385    5.676875
                 |
             fai |
             LD. |   .0247645   .0891697     0.28   0.781     -.150005     .199534
                 |
```

rd						
LD.	.0369866	.1387602	0.27	0.790	-.2349785	.3089517
_cons	-1.147236	.8603052	-1.33	0.182	-2.833404	.5389307

Cointegrating equations

Equation	Parms	chi2	P>chi2
_ce1	3	54.17089	0.0000

Identification: beta is exactly identified

Johansen normalization restriction imposed

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
_ce1						
realgdpcgrowt~e	1	.	.	.	.	.
totalpopgrowt~e	8.081609	1.162325	3.59	0.000	6.406711	9.756507
fai	-1.887867	.6547349	-2.88	0.004	-3.171124	-.6046106
rd	-.3746797	.0814339	-13.00	0.000	-.4205894	-.3365781
_cons	-13.78116	.	.	.	.	.

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	9.4201	16	0.89511
2	9.2238	16	0.90391

H0: no autocorrelation at lag order

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_realgdpcgrowthrate	0.704	2	0.70328
D_totalpopgrowthrate	1.366	2	0.50520
D_fai	3.648	2	0.16139
D_rd	0.683	2	0.71083

```
|                  ALL |              6.400    8     0.60251    |
+-------------------------------------------------------+

 Skewness test
+-------------------------------------------------------+
|              Equation | Skewness    chi2    df   Prob > chi2 |
|--------------------+-----------------------------------|
|D_realgdpcgrowthrate|   .12954     0.050    1      0.82247    |
|D_totalpopgrowthrate|   .61163     1.122    1      0.28943    |
|                 D_fai |   .98771     2.927    1      0.08713    |
|                  D_rd | -.35656     0.381    1      0.53685    |
|                  ALL |              4.481    4      0.34484    |
+-------------------------------------------------------+

 Kurtosis test
+-------------------------------------------------------+
|              Equation | Kurtosis    chi2    df   Prob > chi2 |
|--------------------+-----------------------------------|
|D_realgdpcgrowthrate|   2.0664     0.654    1      0.41881    |
|D_totalpopgrowthrate|   2.4304     0.243    1      0.62183    |
|                 D_fai |   3.9806     0.721    1      0.39576    |
|                  D_rd |   2.3662     0.301    1      0.58311    |
|                  ALL |              1.919    4      0.75058    |
+-------------------------------------------------------+
```

Model (3)
Vector error-correction model

```
Sample:   1998 - 2015                         Number of obs     =        18
                                                AIC              =   26.27106
Log likelihood = -197.4395                    HQIC              =   26.53706
Det(Sigma_ml)  =   2317.727                    SBIC              =   28.2002

Equation             Parms      RMSE      R-sq       chi2       P>chi2
----------------------------------------------------------------
D_realgdpcgrow~e       7      2.20221    0.7149    48.42568    0.0000
D_totalpopgrow~e       7      .497503    0.8029    44.81881    0.0000
D_eduindex             7      5.95768    0.7663    36.07489    0.0000
D_fai                  7      12.6094    0.5630    14.17433    0.0482
D_rd                   7      5.18182    0.5570    13.82844    0.0543
----------------------------------------------------------------

--------------------------------------------------------------------------------
                   |      Coef.   Std. Err.      z     P>|z|     [95% Conf. Interval]
```

```
----------------+----------------------------------------------------------------
D_realgdpcgro~e |
           _ce1 |
            L1. |   .2879572   .0597674     4.82   0.000     .1708153    .4050991
                |
realgdpcgrowt~e |
            LD. |  -.6479185   .2736348    -2.37   0.018    -1.184233   -.1116042
                |
totalpopgrowt~e |
            LD. |   1.059791     1.0355     1.02   0.306    -.9697507    3.089333
                |
       eduindex |
            LD. |   .3785967   .0773579     4.89   0.000      .226978    .5302154
                |
            fai |
            LD. |  -.2323301   .0681345    -3.41   0.001    -.3658713   -.0987889
                |
             rd |
            LD. |   .1476656   .0822381     1.80   0.073     -.013518    .3088493
                |
          _cons |  -.2284304   .5309169    -0.43   0.667    -1.269008    .8121475
----------------+----------------------------------------------------------------
D_totalpopgro~e |
           _ce1 |
            L1. |  -.0617506   .0135021    -4.57   0.000    -.0882142   -.0352869
                |
realgdpcgrowt~e |
            LD. |  -.0249257   .0618171    -0.40   0.687    -.1460849    .0962336
                |
totalpopgrowt~e |
            LD. |  -.2951166   .2339307    -1.26   0.207    -.7536122    .1633791
                |
       eduindex |
            LD. |  -.0710365    .017476    -4.06   0.000    -.1052889   -.0367842
                |
            fai |
            LD. |   .0219603   .0153923     1.43   0.154    -.0082081    .0521287
                |
             rd |
            LD. |  -.0053944   .0185785    -0.29   0.772    -.0418076    .0310187
                |
          _cons |   .1571347   .1199399     1.31   0.190    -.0779432    .3922126
----------------+----------------------------------------------------------------
D_eduindex      |
```

_ce1 |						
L1. |	.5356552	.1616898	3.31	0.001	.2187491	.8525613
|						
realgdpcgrowt~e |						
LD. |	-.7574049	.740269	-1.02	0.306	-2.208306	.6934957
|						
totalpopgrowt~e |						
LD. |	5.02547	2.801356	1.79	0.073	-.4650858	10.51603
|						
eduindex |						
LD. |	-.0049088	.2092777	-0.02	0.981	-.4150855	.405268
|						
fai |						
LD. |	-.4585031	.1843256	-2.49	0.013	-.8197746	-.0972317
|						
rd |						
LD. |	.8212445	.2224801	3.69	0.000	.3851915	1.257298
|						
_cons |	-.8090722	1.436299	-0.56	0.573	-3.624166	2.006022
----------------+---						
D_fai |						
_ce1 |						
L1. |	-.7542877	.3422144	-2.20	0.028	-1.425016	-.0835597
|						
realgdpcgrowt~e |						
LD. |	3.658141	1.56677	2.33	0.020	.5873273	6.728955
|						
totalpopgrowt~e |						
LD. |	4.60577	5.929035	0.78	0.437	-7.014926	16.22647
|						
eduindex |						
LD. |	-1.375618	.4429338	-3.11	0.002	-2.243752	-.5074839
|						
fai |						
LD. |	.5801088	.3901228	1.49	0.137	-.1845179	1.344735
|						
rd |						
LD. |	-.3689821	.4708765	-0.78	0.433	-1.291883	.5539189
|						
_cons |	-.6776126	3.039909	-0.22	0.824	-6.635726	5.2805
----------------+---						
D_rd |						
_ce1 |						
L1. |	.0025107	.1406331	0.02	0.986	-.2731251	.2781464

```
                 |
realgdpcgrowt~e |
              LD. |    1.087023    .6438646     1.69   0.091    -.1749288    2.348974
                 |
totalpopgrowt~e |
              LD. |   -.4865238    2.436538    -0.20   0.842    -5.262051    4.289003
                 |
         eduindex |
              LD. |   -.0870976    .1820237    -0.48   0.632    -.4438576    .2696623
                 |
              fai |
              LD. |    .0194829    .1603211     0.12   0.903    -.2947405    .3337064
                 |
               rd |
              LD. |   -.2457614    .1935068    -1.27   0.204    -.6250278     .133505
                 |
            _cons |   -.8960482    1.249251    -0.72   0.473    -3.344536     1.55244
------------------------------------------------------------------------------

Cointegrating equations

Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                   4   58.6729   0.0000
-------------------------------------------

Identification:  beta is exactly identified

                 Johansen normalization restriction imposed
------------------------------------------------------------------------------
            beta |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
_ce1             |
realgdpcgrowt~e |          1          .        .        .            .           .
totalpopgrowt~e |   -6.686702   3.251258    -2.06   0.040    -13.05905    .3143543
         eduindex |   -1.523663   .3672014    -4.15   0.000    -2.243364   -.8039612
              fai |   -.6829153   .1292274    -5.28   0.000    -.9361964   -.4296342
               rd |   -.9790762   .4049333    -2.39   0.017    -1.780571   -.1775816
            _cons |   -3.858416          .        .        .            .           .
------------------------------------------------------------------------------
13.05905
   Lagrange-multiplier test
  +--------------------------------------+
  | lag  |      chi2    df   Prob > chi2 |
```

lag	chi2	df	Prob > chi2
1	47.7802	25	0.00396
2	28.4476	25	0.28766

H0: no autocorrelation at lag order

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_realgdpcgrowthrate	1.503	2	0.47177
D_totalpopgrowthrate	0.240	2	0.88709
D_eduindex	1.287	2	0.52545
D_fai	0.747	2	0.68825
D_rd	1.077	2	0.58352
ALL	4.854	10	0.90073

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_realgdpcgrowthrate	.61907	1.150	1	0.28360
D_totalpopgrowthrate	.24634	0.182	1	0.66962
D_eduindex	.61054	1.118	1	0.29029
D_fai	.44703	0.600	1	0.43877
D_rd	.46298	0.643	1	0.42260
ALL		3.693	5	0.59446

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_realgdpcgrowthrate	2.3142	0.353	1	0.55255
D_totalpopgrowthrate	2.7229	0.058	1	0.81037
D_eduindex	2.5257	0.169	1	0.68126
D_fai	2.5562	0.148	1	0.70074
D_rd	2.239	0.434	1	0.50989
ALL		1.161	5	0.94856

Model (4)

Vector error-correction model

```
Sample:    1998 - 2015                                  Number of obs    =        18
                                                          AIC              =  30.07747
Log likelihood = -231.6973                              HQIC             =  30.34347
Det(Sigma_ml)  =   104271.5                             SBIC             =  32.00661

Equation           Parms      RMSE      R-sq       chi2      P>chi2
----------------------------------------------------------------
D_realgdpcgrow~e      7      3.67266    0.4852    10.36634    0.1687
D_totalpopgrow~e      7      .778961    0.5169    11.76882    0.1084
D_helindex            7      49.0026    0.8811    81.53468    0.0000
D_fai                 7      16.9608    0.2094    2.913936    0.8928
D_rd                  7      2.80828    0.8699    73.53436    0.0000
----------------------------------------------------------------


------------------------------------------------------------------------------
                 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
D_realgdpcgro~e |
            _ce1 |
             L1. |  -.1194601   .1284113    -0.93   0.352    -.3711416    .1322214
                 |
realgdpcgrowt~e |
             LD. |   .4191876   .3799441     1.10   0.270    -.3254892    1.163864
                 |
totalpopgrowt~e |
             LD. |   4.280977   2.314335     1.85   0.064    -.2550368    8.816991
                 |
        helindex |
             LD. |  -.0238804   .0115279    -2.07   0.038    -.0464747   -.0012862
                 |
             fai |
             LD. |   -.007518   .1085057    -0.07   0.945    -.2201852    .2051492
                 |
              rd |
             LD. |  -.0327427   .1223594    -0.27   0.789    -.2725628    .2070773
                 |
           _cons |  -.0090212   .8809998    -0.01   0.992    -1.735749    1.717707
----------------+-------------------------------------------------------------
D_totalpopgro~e |
            _ce1 |
             L1. |   .0385049   .0272357     1.41   0.157    -.0148761    .0918859
                 |
```

realgdpcgrowt~e						
LD.	-.2335059	.0805851	-2.90	0.004	-.3914499	-.075562
totalpopgrowt~e						
LD.	-1.116366	.4908644	-2.27	0.023	-2.078443	-.1542895
helindex						
LD.	.0047324	.002445	1.94	0.053	-.0000598	.0095246
fai						
LD.	-.029762	.0230138	-1.29	0.196	-.0748681	.0153442
rd						
LD.	.029748	.0259521	1.15	0.252	-.0211172	.0806132
_cons	.1101535	.1868577	0.59	0.556	-.256081	.4763879
D_helindex						
_ce1						
L1.	6.122082	1.713334	3.57	0.000	2.76401	9.480154
realgdpcgrowt~e						
LD.	.6970606	5.069422	0.14	0.891	-9.238824	10.63295
totalpopgrowt~e						
LD.	-55.86566	30.87912	-1.81	0.070	-116.3876	4.656316
helindex						
LD.	-.4763663	.1538117	-3.10	0.002	-.7778317	-.1749009
fai						
LD.	-.8915428	1.447742	-0.62	0.538	-3.729065	1.945979
rd						
LD.	-3.166981	1.632586	-1.94	0.052	-6.366791	.0328296
_cons	-.0987138	11.75478	-0.01	0.993	-23.13766	22.94023
D_fai						
_ce1						
L1.	-.2507968	.59302	-0.42	0.672	-1.413095	.9115011
realgdpcgrowt~e						
LD.	.6591469	1.754631	0.38	0.707	-2.779867	4.098161

totalpopgrowt~e						
LD.	2.286703	10.6879	0.21	0.831	-18.6612	23.2346
helindex						
LD.	.0201984	.0532374	0.38	0.704	-.084145	.1245418
fai						
LD.	.0185609	.5010932	0.04	0.970	-.9635638	1.000686
rd						
LD.	.3268156	.5650717	0.58	0.563	-.7807046	1.434336
_cons	-1.402733	4.068572	-0.34	0.730	-9.376987	6.571521
D_rd						
_ce1						
L1.	-.2415432	.0981889	-2.46	0.014	-.43399	-.0490964
realgdpcgrowt~e						
LD.	1.445778	.2905221	4.98	0.000	.8763654	2.015191
totalpopgrowt~e						
LD.	2.464632	1.769643	1.39	0.164	-1.003804	5.933069
helindex						
LD.	-.0458025	.0088148	-5.20	0.000	-.0630791	-.0285259
fai						
LD.	-.0042438	.0829682	-0.05	0.959	-.1668585	.158371
rd						
LD.	-.1351724	.0935614	-1.44	0.149	-.3185495	.0482046
_cons	-1.023545	.6736514	-1.52	0.129	-2.343878	.2967874

Cointegrating equations

Equation	Parms	chi2	P>chi2
_ce1	4	67.7517	0.0000

Identification: beta is exactly identified

Johansen normalization restriction imposed

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
_ce1						
realgdpcgrowt~e	1	.	.	.	.	.
totalpopgrowt~e	9.66483	1.236203	6.08	0.000	3.321992	16.00767
helindex	-.1907503	.0429251	-4.44	0.000	-.2748819	-.1066186
fai	-.3251223	.1136561	-2.86	0.004	-.547884	-.1023605
rd	-.0507498	.0830574	-0.11	0.910	-.3307605	.3854608
_cons	-4.93292	.	.	.	.	.

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	17.5884	25	0.85936
2	23.8216	25	0.52970

H0: no autocorrelation at lag order

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_realgdpcgrowthrate	0.856	2	0.65193
D_totalpopgrowthrate	1.466	2	0.48056
D_helindex	1.804	2	0.40569
D_fai	10.018	2	0.00668
D_rd	0.962	2	0.61803
ALL	15.106	10	0.12824

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_realgdpcgrowthrate	.24684	0.183	1	0.66898
D_totalpopgrowthrate	.68977	1.427	1	0.23220
D_helindex	.44055	0.582	1	0.44543
D_fai	1.4624	6.416	1	0.01131

```
|                D_rd |   .22245     0.148    1    0.70001   |
|                 ALL |              8.757    5    0.11917   |
+--------------------------------------------------------+
```

Kurtosis test

```
+--------------------------------------------------------+
|            Equation | Kurtosis    chi2    df   Prob > chi2 |
|--------------------+------------------------------------|
|D_realgdpcgrowthrate|   2.0528     0.673    1    0.41206   |
|D_totalpopgrowthrate|   2.7741     0.038    1    0.84487   |
|          D_helindex |   1.7235     1.222    1    0.26895   |
|               D_fai |   5.1916     3.602    1    0.05770   |
|                D_rd |   1.9582     0.814    1    0.36695   |
|                 ALL |              6.349    5    0.27369   |
+--------------------------------------------------------+
```

Model (5)

Vector error-correction model

```
Sample:   1999 - 2015                          Number of obs     =         17
                                                AIC               =  -53.52213
Log likelihood =   545.2381                     HQIC              =  -53.08852
Det(Sigma_ml)  =   6.51e-36                     SBIC              =  -49.16001

Equation           Parms    RMSE     R-sq      chi2      P>chi2
----------------------------------------------------------------
D_realgdpcgrow~e     14     3.06491   0.7341   20.68015   0.0080
D_totalpopgrow~e     14     .691018   0.6544   18.93302   0.0152
D_eduindex           14     7.95192   0.6216   16.42407   0.0367
D_helindex           14     44.6252   0.9104   101.579    0.0000
D_fai                14     15.5346   0.3971   6.586081   0.5819
D_rd                 14     3.10527   0.8554   59.13749   0.0000
----------------------------------------------------------------

------------------------------------------------------------------------------
                |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
D_realgdpcgro~e |
            _ce1 |
             L1. |  -.0793712   .0123058    -3.94   0.000    -.0909305   -.0678119
                |
realgdpcgrowt~e |
             LD. |  -.0766786   .8480099    -0.09   0.928    -1.738747     1.58539
```

L2D.	-.6252142	.8524642	-0.73	0.465	-2.294013	1.047585
totalpopgrowt~e						
LD.	-.0225545	.0131045	-1.94	0.052	-.0361666	.0314969
L2D.	-.3416199	.4409792	-1.12	0.262	-.4554417	1.756177
eduindex						
LD.	.0415036	.5237787	0.08	0.938	-.9968435	1.079851
L2D.	.0545509	.0214496	2.54	0.011	.0125104	.0965914
helindex						
LD.	.0201267	.0515181	0.39	0.696	-.0808469	.1211003
L2D.	.0442752	.0341201	1.33	0.185	-.021599	.1121494
fai						
LD.	-.0941215	.202842	-0.46	0.643	-.4916846	.3034416
L2D.	.1896096	.1269526	1.49	0.135	-.059213	.4384321
rd						
LD.	.3777385	.5692505	0.66	0.507	-.7379719	1.493449
L2D.	-.0374273	.2221637	-0.17	0.866	-.4728601	.3980056
_cons	.6420377	.0630963	4.75	0.000	.4595724	.8245031
D_totalpopgro~e						
_ce1						
L1.	.0483092	.0647953	0.75	0.456	-.0786872	.1753056
realgdpcgrowt~e						
LD.	-.3514076	.2228007	-1.58	0.115	-.788089	.0852738
L2D.	-.0003157	.223971	-0.00	0.999	-.4392909	.4386595
totalpopgrowt~e						
LD.	.0977959	.7805936	0.13	0.900	-1.432139	1.627731
L2D.	.7361809	.5503725	1.34	0.181	-.3425293	1.814891
eduindex						
LD.	.1060161	.1391907	0.76	0.446	-.1667927	.3788248
L2D.	.1277826	.0862654	1.48	0.139	-.0412944	.2968596
helindex						
LD.	-.0088837	.0135355	-0.66	0.512	-.0354129	.0176455
L2D.	-.0075916	.0089645	-0.85	0.397	-.0251617	.0099785

fai						
LD.	-.0445004	.0532934	-0.84	0.404	-.1489536	.0599528
L2D.	-.0425138	.0333547	-1.27	0.202	-.1078879	.0228602
rd						
LD.	.0505642	.1495613	0.34	0.735	-.2425704	.3436989
L2D.	-.0169171	.0583699	-0.29	0.772	-.1313199	.0974858
_cons	.169777	.2801101	0.61	0.544	-.3792288	.7187827
D_eduindex						
_ce1						
L1.	.2451165	.4769063	0.51	0.607	-.6896025	1.179836
realgdpcgrowt~e						
LD.	1.101918	1.639858	0.67	0.502	-2.112145	4.315982
L2D.	.2667271	1.648472	0.16	0.871	-2.964219	3.497673
totalpopgrowt~e						
LD.	6.010863	5.745326	1.05	0.295	-5.249769	17.2715
L2D.	2.916506	4.050852	0.72	0.472	-5.023018	10.85603
eduindex						
LD.	-.6849116	1.024472	-0.67	0.504	-2.692839	1.323016
L2D.	-.6473351	.6349304	-1.02	0.308	-1.891776	.5971057
helindex						
LD.	-.0390517	.0996243	-0.39	0.695	-.2343117	.1562083
L2D.	.0451398	.0659806	0.68	0.494	-.0841798	.1744593
fai						
LD.	-.2509473	.3922504	-0.64	0.522	-1.019744	.5178493
L2D.	.2261939	.2454975	0.92	0.357	-.2549723	.70736
rd						
LD.	.4198072	1.100801	0.38	0.703	-1.737723	2.577337
L2D.	.0831942	.4296141	0.19	0.846	-.7588339	.9252224
_cons	-.3833788	2.061667	-0.19	0.852	-4.424172	3.657414
D_helindex						
_ce1						
L1.	-4.923484	3.92424	-1.25	0.210	-12.61485	2.767885

```
realgdpcgrowt~e |
            LD. |  -3.558337   13.49363    -0.26   0.792    -30.00537    22.8887
           L2D. |   5.337406   13.56451     0.39   0.694    -21.24854   31.92336
                |
totalpopgrowt~e |
            LD. |   88.56791   47.27562     1.87   0.061    -4.090601   181.2264
           L2D. |   48.61125   33.33258     1.46   0.145    -16.71941   113.9419
                |
       eduindex |
            LD. |   .1074671     8.4299     0.01   0.990    -16.41483   16.62977
           L2D. |   -.925805   5.224548    -0.18   0.859    -11.16573    9.31412
                |
       helindex |
            LD. |  -.0754195   .8197618    -0.09   0.927    -1.682123   1.531284
           L2D. |   .4912229   .5429235     0.90   0.366    -.5728875   1.555333
                |
            fai |
            LD. |  -4.159649   3.227646    -1.29   0.197    -10.48572   2.166421
           L2D. |   4.372023   2.020085     2.16   0.030     .4127301   8.331316
                |
             rd |
            LD. |   18.12852    9.05798     2.00   0.045     .3752095   35.88184
           L2D. |  -1.094272   3.535095    -0.31   0.757     -8.02293   5.834387
                |
          _cons |  -.0208915    16.9645    -0.00   0.999     -33.2707   33.22892
----------------+----------------------------------------------------------------
D_fai           |
            _ce1 |
             L1. |   .1184447   1.971048     0.06   0.952    -3.744739   3.981629
                |
realgdpcgrowt~e |
            LD. |    .995651   6.777517     0.15   0.883    -12.28804   14.27934
           L2D. |  -3.341407   6.813117    -0.49   0.624    -16.69487   10.01206
                |
totalpopgrowt~e |
            LD. |  -4.598727   23.74537    -0.19   0.846     -51.1388   41.94134
           L2D. |   1.347569   16.74213     0.08   0.936     -31.4664   34.16154
                |
       eduindex |
            LD. |  -.3268391    4.23413    -0.08   0.938    -8.625581   7.971903
           L2D. |   .6687556   2.624161     0.25   0.799    -4.474505   5.812016
                |
       helindex |
            LD. |   .0793353    .411746     0.19   0.847     -.727672   .8863427
```

```
             L2D. |   .0600568    .272697     0.22   0.826    -.4744195    .5945331
                  |
              fai |
              LD. |   .4073891   1.621167     0.25   0.802    -2.770039    3.584817
             L2D. |  -.8600461   1.014638    -0.85   0.397    -2.848701    1.128609
                  |
               rd |
              LD. |    .761387   4.549599     0.17   0.867    -8.155662    9.678436
             L2D. |   .8811556    1.77559     0.50   0.620    -2.598938    4.361249
                  |
            _cons |   .1779991   8.520847     0.02   0.983    -16.52255    16.87855
----------------+----------------------------------------------------------------
D_rd              |
             _ce1 |
              L1. |   .0312603   .2845074     0.11   0.913     -.526364    .5888847
                  |
realgdpcgrowt~e |
              LD. |   .3953038   .9782884     0.40   0.686    -1.522106    2.312714
             L2D. |  -1.897968   .9834271    -1.93   0.054    -3.825449    .0295141
                  |
totalpopgrowt~e |
              LD. |  -4.108084   3.427483    -1.20   0.231    -10.82583    2.609659
             L2D. |  -2.920782   2.416612    -1.21   0.227    -7.657255    1.815691
                  |
         eduindex |
              LD. |   .2041196   .6111678     0.33   0.738    -.9937474    1.401987
             L2D. |   .2989456   .3787798     0.79   0.430    -.4434491     1.04134
                  |
         helindex |
              LD. |  -.0045176   .0594327    -0.08   0.939    -.1210036    .1119684
             L2D. |   .0349933    .039362     0.89   0.374    -.0421547    .1121413
                  |
              fai |
              LD. |   .0360047   .2340044     0.15   0.878    -.4226354    .4946449
             L2D. |  -.1725234   .1464561    -1.18   0.239    -.4595722    .1145254
                  |
               rd |
              LD. |    .158107   .6567036     0.24   0.810    -1.129008    1.445222
             L2D. |   .0796606   .2562944     0.31   0.756    -.4226672    .5819884
                  |
            _cons |   .4080234   1.229926     0.33   0.740    -2.002588    2.818635
---------------------------------------------------------------------------------
Cointegrating equations
```

Equation	Parms	chi2	P>chi2
_ce1	5	94.63472	0.0000

Identification: beta is exactly identified

Johansen normalization restriction imposed

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
_ce1						
realgdpcgrowt~e	1	.	.	.	.	.
totalpopgrowt~e	-6.204653	2.207989	-7.34	0.000	-10.53223	-1.877072
eduindex	-.9323553	.3133916	-2.98	0.003	.3181191	1.546592
helindex	.2721649	.221845	1.23	0.220	-.1626434	.7069732
fai	-.3033782	.0747865	-4.12	0.000	-.454957	-.1617995
rd	-.2222289	.0308904	-7.19	0.000	-.282773	-.1616849
_cons	-7.220824	.	.	.	.	.

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	21.6136	25	0.65794
2	21.7852	25	0.64812
3	23.7916	25	0.53144
4	59.4978	25	0.00012

H0: no autocorrelation at lag order

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_realgdpcgrowthrate	2.403	2	0.30076
D_totalpopgrowthrate	0.839	2	0.65738
D_eduindex	0.891	2	0.64037
D_helindex	0.817	2	0.66481
D_fai	0.657	2	0.72009
D_rd	1.213	2	0.54520
ALL	6.819	12	0.82124

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_realgdpcgrowthrate	.91999	2.398	1	0.12149
D_totalpopgrowthrate	.25122	0.179	1	0.67239
D_eduindex	.53963	0.825	1	0.36370
D_helindex	-.30348	0.261	1	0.60946
D_fai	.47794	0.647	1	0.42111
D_rd	-.65023	1.198	1	0.27374
ALL		5.508	6	0.45578

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_realgdpcgrowthrate	2.9177	0.005	1	0.94475
D_totalpopgrowthrate	2.0346	0.660	1	0.41650
D_eduindex	2.694	0.066	1	0.79674
D_helindex	2.1144	0.556	1	0.45605
D_fai	2.8838	0.010	1	0.92208
D_rd	2.853	0.015	1	0.90156
ALL		1.311	6	0.94045

Beijing:
Model (1)
Vector error-correction model

Sample: 1997 - 2015   Number of obs = 19
AIC = 9.891921
Log likelihood = -80.02429   HQIC = 9.953306
Det(Sigma_ml) = 24.93236   SBIC = 10.33711

Equation	Parms	RMSE	R-sq	chi2	P>chi2
D_realgdpcgrow~e	4	2.98907	0.5796	19.30002	0.0007
D_totalpopgrow~e	4	2.43659	0.3141	6.410948	0.1705

	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]

```
----------------+----------------------------------------------------------------
D_realgdpcgro~e |
           _ce1 |
            L1. |  -1.400568   .3568686    -3.92   0.000    -2.100017    -.701118
                |
realgdpcgrowt~e |
            LD. |   .3944712   .2499561     1.58   0.115    -.0954339    .8843762
                |
totalpopgrowt~e |
            LD. |  -.2541808     .28546    -0.89   0.373    -.8136722    .3053106
                |
          _cons |   .0121449    .712919     0.02   0.986    -1.385151     1.40944
----------------+----------------------------------------------------------------
D_totalpopgro~e |
           _ce1 |
            L1. |   .2876467   .2909074     0.99   0.323    -.2825213    .8578147
                |
realgdpcgrowt~e |
            LD. |  -.2623503   .2037559    -1.29   0.198    -.6617045    .1370039
                |
totalpopgrowt~e |
            LD. |  -.3762293   .2326975    -1.62   0.106     -.832308    .0798493
                |
          _cons |   .0591341   .5811477     0.10   0.919    -1.079895    1.198163
---------------------------------------------------------------------------------

Cointegrating equations

Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                   1   3.929011   0.0475
-------------------------------------------

Identification:  beta is exactly identified

                 Johansen normalization restriction imposed
---------------------------------------------------------------------------------
           beta |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+----------------------------------------------------------------
_ce1            |
realgdpcgrowt~e |          1          .        .       .            .           .
totalpopgrowt~e |  -.4288276   .2163421    -1.98   0.047    -.8528503   -.0048048
          _cons |  -2.772373          .        .       .            .           .
---------------------------------------------------------------------------------
```

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	3.5219	4	0.47456
2	0.7265	4	0.94802

H0: no autocorrelation at lag order

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_realgdpcgrowthrate	0.291	2	0.86467
D_totalpopgrowthrate	3.273	2	0.19470
ALL	3.563	4	0.46831

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_realgdpcgrowthrate	.28918	0.237	1	0.62642
D_totalpopgrowthrate	1.0134	2.910	1	0.08804
ALL		3.147	2	0.20735

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_realgdpcgrowthrate	2.7242	0.054	1	0.81648
D_totalpopgrowthrate	3.7157	0.363	1	0.54697
ALL		0.417	2	0.81195

Model (2)

Vector error-correction model

Sample: 1998 - 2015		Number of obs	= 18
		AIC	= 25.24579
Log likelihood = -200.2121		HQIC	= 25.42994
Det(Sigma_ml)	= 53867.39	SBIC	= 26.58135

```
Equation               Parms      RMSE      R-sq       chi2      P>chi2
----------------------------------------------------------------
D_realgdpcgrow~e         6      2.90842    0.6588    23.17227    0.0007
D_totalpopgrow~e         6       2.1294    0.5510    14.72475    0.0225
D_fai                    6       11.631    0.3993    7.976185    0.2399
D_rd                     6      19.0097    0.5657    15.62897    0.0159
----------------------------------------------------------------

------------------------------------------------------------------------------
                 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
D_realgdpcgro~e |
            _ce1 |
             L1. |  -.8268271    .3061302    -2.70   0.007    -1.426831   -.2268229
                 |
realgdpcgrowt~e |
             LD. |   .0668086    .2060653     0.32   0.746    -.3370719    .4706891
                 |
totalpopgrowt~e |
             LD. |   .2951632    .4126403     0.72   0.474    -.5135971    1.103923
                 |
             fai |
             LD. |   .0786148    .0763671     1.03   0.303     -.071062    .2282917
                 |
              rd |
             LD. |  -.0459152     .044007    -1.04   0.297    -.1321673     .040337
                 |
           _cons |  -1.011824    .7077271    -1.43   0.153    -2.398944    .3752955
----------------+-------------------------------------------------------------
D_totalpopgro~e |
            _ce1 |
             L1. |   .4551704    .2241327     2.03   0.042     .0158784    .8944625
                 |
realgdpcgrowt~e |
             LD. |  -.2032341    .1508704    -1.35   0.178    -.4989346    .0924663
                 |
totalpopgrowt~e |
             LD. |   .1488561     .302114     0.49   0.622    -.4432763    .7409886
                 |
             fai |
             LD. |   .1061981    .0559121     1.90   0.058    -.0033875    .2157838
                 |
              rd |
```

```
             LD. |  -.0846229   .0322197    -2.63   0.009    -.1477722   -.0214735
                 |
           _cons |   .3581787   .5181612     0.69   0.489    -.6573986    1.373756
-----------------+----------------------------------------------------------------
D_fai            |
            _ce1 |
             L1. |    1.27935    1.22424     1.05   0.296    -1.120117    3.678817
                 |
realgdpcgrowt~e |
             LD. |  -2.012532   .8240722    -2.44   0.015    -3.627684   -.3973798
                 |
totalpopgrowt~e |
             LD. |   .1552607   1.650183     0.09   0.925    -3.079039     3.38956
                 |
             fai |
             LD. |  -.1674419   .3053986    -0.55   0.584    -.7660121    .4311283
                 |
              rd |
             LD. |   .0798567   .1759877     0.45   0.650    -.2650728    .4247862
                 |
           _cons |   .3320394    2.83026     0.12   0.907    -5.215168    5.879246
-----------------+----------------------------------------------------------------
D_rd             |
            _ce1 |
             L1. |   1.101185    2.00089     0.55   0.582    -2.820486    5.022857
                 |
realgdpcgrowt~e |
             LD. |  -.3687775   1.346858    -0.27   0.784    -3.008571    2.271016
                 |
totalpopgrowt~e |
             LD. |  -2.840197   2.697048    -1.05   0.292    -8.126313     2.44592
                 |
             fai |
             LD. |     .56204   .4991413     1.13   0.260    -.4162589    1.540339
                 |
              rd |
             LD. |  -.4730095    .287633    -1.64   0.100     -1.03676    .0907409
                 |
           _cons |  -1.293543   4.625757    -0.28   0.780    -10.35986    7.772774
----------------------------------------------------------------------------------
```

Cointegrating equations

```
Equation           Parms    chi2     P>chi2
```

```
-----------------------------------------
_ce1                          3       29.0199      0.0000
-----------------------------------------

Identification:    beta is exactly identified

                        Johansen normalization restriction imposed
------------------------------------------------------------------------------
               beta |          Coef.     Std. Err.         z       P>|z|        [95% Conf. Interval]
----------------+-------------------------------------------------------------
_ce1                    |
realgdpcgrowt~e |                 1                 .             .            .                   .                 .
totalpopgrowt~e |      -.652294      .2028284        -3.22      0.001          -1.04983       -.2547577
                   fai |   -.1932137      .0555503        -3.48       0.001          -.3020902      -.0843371
                    rd |   -.2900711      .0543117        -3.14       0.000          -.4749187      -.1052235
              _cons |      -1.55165                 .             .            .                   .                 .
------------------------------------------------------------------------------

   Lagrange-multiplier test
  +--------------------------------------+
  | lag    |          chi2       df      Prob > chi2 |
  |------+-------------------------------|
  |     1    |     23.8794       16          0.09217      |
  |     2    |     17.6744       16          0.34331      |
  +--------------------------------------+
   H0: no autocorrelation at lag order

   Jarque-Bera test
  +-------------------------------------------------------+
  |                   Equation |                     chi2      df    Prob > chi2 |
  |------------------+----------------------------------|
  |D_realgdpcgrowthrate|                   0.751      2        0.68683      |
  |D_totalpopgrowthrate|                  1.149      2        0.56292      |
  |                        D_fai |                     5.687      2        0.05822      |
  |                          D_rd |                     0.958      2        0.61931      |
  |                            ALL |                     8.546      8        0.38203      |
  +-------------------------------------------------------+

   Skewness test
  +-------------------------------------------------------+
  |                   Equation | Skewness      chi2       df    Prob > chi2 |
  |------------------+----------------------------------|
  |D_realgdpcgrowthrate|    .47149        0.667       1        0.41413      |
  |D_totalpopgrowthrate| -.61623        1.139       1        0.28581      |
```

```
|                    D_fai |   -1.125      3.797     1       0.05135     |
|                     D_rd | -.51133      0.784     1       0.37580     |
|                      ALL |                 6.387    4       0.17204     |
+--------------------------------------------------------+
```

Kurtosis test

```
+--------------------------------------------------------+
|                Equation | Kurtosis     chi2     df   Prob > chi2 |
|--------------------+-----------------------------------|
|D_realgdpcgrowthrate|    3.3355       0.084      1       0.77139     |
|D_totalpopgrowthrate|   2.8844       0.010      1       0.92029     |
|                    D_fai |   4.5876       1.890      1       0.16915     |
|                     D_rd |   2.5184       0.174      1       0.67665     |
|                      ALL |                 2.159      4       0.70657     |
+--------------------------------------------------------+
```

Model (3)

Vector error-correction model

```
Sample:    1998 - 2015                          Number of obs      =            18
                                                 AIC                =     29.14064
Log likelihood = -223.2618                      HQIC               =     29.40664
Det(Sigma_ml)   =   40860.56                    SBIC               =     31.06978

Equation                Parms       RMSE       R-sq        chi2       P>chi2
----------------------------------------------------------------
D_realgdpcgrow~e          7       3.54598     0.5351     12.66153     0.0808
D_totalpopgrow~e          7        2.0593     0.6151      17.5752     0.0140
D_eduindex                7       9.02955     0.7670     36.20367     0.0000
D_fai                     7       4.60253     0.9138      116.572     0.0000
D_rd                      7       16.3283     0.7063     26.44817     0.0004
----------------------------------------------------------------


------------------------------------------------------------------------------
                 |      Coef.    Std. Err.       z      P>|z|      [95% Conf. Interval]
----------------+-------------------------------------------------------------
D_realgdpcgro~e |
            _ce1 |
             L1. |  -.3618593    .2979452     -1.21    0.225      -.945821      .2221025
                 |
realgdpcgrowt~e |
             LD. |   .0487852    .2924097      0.17    0.867     -.5243274      .6218977
                 |
```

```
totalpopgrowt~e |
             LD. |   .1001575   .7263189     0.14   0.890    -1.323401    1.523716
                 |
        eduindex |
             LD. |  -.2930871   .2083345    -1.41   0.159    -.7014151    .1152409
                 |
             fai |
             LD. |   .2107442   .0930617     2.26   0.024     .0283465    .3931418
                 |
              rd |
             LD. |  -.1648437   .0632172    -2.61   0.009     -.288747   -.0409403
                 |
           _cons |   -.718556   .8497804    -0.85   0.398    -2.384095    .9469828
----------------+----------------------------------------------------------------
D_totalpopgro~e |
             _ce1 |
             L1. |   .0348364    .173029     0.20   0.840    -.3042941     .373967
                 |
realgdpcgrowt~e |
             LD. |  -.2525745   .1698143    -1.49   0.137    -.5854045    .0802555
                 |
totalpopgrowt~e |
             LD. |   .0851426   .4218032     0.20   0.840    -.7415765    .9118616
                 |
        eduindex |
             LD. |   .1671277   .1209884     1.38   0.167    -.0700051    .4042605
                 |
             fai |
             LD. |   -.031541   .0540448    -0.58   0.559    -.1374668    .0743848
                 |
              rd |
             LD. |   .0042211   .0367128     0.11   0.908    -.0677347    .0761768
                 |
           _cons |   .1238894   .4935023     0.25   0.802    -.8433573    1.091136
----------------+----------------------------------------------------------------
D_eduindex       |
             _ce1 |
             L1. |   -1.62954   .7586931    -2.15   0.032    -3.116551   -.1425289
                 |
realgdpcgrowt~e |
             LD. |    .349989   .7445977     0.47   0.638    -1.109396    1.809374
                 |
totalpopgrowt~e |
             LD. |  -4.503913   1.849512    -2.44   0.015     -8.12889   -.8789355
```

eduindex						
LD.	-1.836055	.5305068	-3.46	0.001	-2.875829	-.7962809
fai						
LD.	.0694908	.2369741	0.29	0.769	-.3949699	.5339516
rd						
LD.	-.0385703	.1609774	-0.24	0.811	-.3540801	.2769395
_cons	-.5662425	2.163897	-0.26	0.794	-4.807402	3.674917
----------------+---						
D_fai						
_ce1						
L1.	2.129631	.38672	5.51	0.000	1.371674	2.887589
realgdpcgrowt~e						
LD.	-1.490015	.3795352	-3.93	0.000	-2.233891	-.7461401
totalpopgrowt~e						
LD.	2.164058	.9427306	2.30	0.022	.3163399	4.011776
eduindex						
LD.	.4520307	.2704091	1.67	0.095	-.0779615	.9820228
fai						
LD.	.2218815	.1207901	1.84	0.066	-.0148627	.4586258
rd						
LD.	.0596018	.0820531	0.73	0.468	-.1012194	.220423
_cons	.5637447	1.102978	0.51	0.609	-1.598053	2.725542
----------------+---						
D_rd						
_ce1						
L1.	3.168936	1.37196	2.31	0.021	.4799431	5.857929
realgdpcgrowt~e						
LD.	-1.196936	1.346471	-0.89	0.374	-3.835971	1.4421
totalpopgrowt~e						
LD.	2.089369	3.344511	0.62	0.532	-4.465752	8.64449
eduindex						

```
LD. |   1.668201   .9593264    1.74   0.082   -.2120444   3.548446
    |
fai |
LD. |   .7593624   .4285252    1.77   0.076   -.0805316   1.599256
    |
 rd |
LD. |  -.2130802   .2910987   -0.73   0.464   -.7836232   .3574627
    |
_cons |  -.7534446   3.913019   -0.19   0.847   -8.422821   6.915932
------------------------------------------------------------------------------
```

Cointegrating equations

```
Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                   4   315.9756   0.0000
-------------------------------------------
```

Identification: beta is exactly identified

Johansen normalization restriction imposed

```
------------------------------------------------------------------------------
         beta |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+-------------------------------------------------------------
_ce1            |
realgdpcgrowt~e |          1          .        .       .            .          .
totalpopgrowt~e |   -.538222   .1361048    -3.95   0.000    -.8049826   -.2714614
       eduindex |  -.6307768   .0589667   -10.70   0.000    -.7463493   -.5152042
            fai |  -.5058339   .0388867   -13.01   0.000    -.5820504   -.4296175
             rd |  -.2255548      .0215   -10.49   0.000     -.267694   -.1834156
          _cons |    7.20708          .        .       .            .          .
------------------------------------------------------------------------------
```

```
   Lagrange-multiplier test
  +--------------------------------------+
  | lag  |      chi2    df   Prob > chi2 |
  |------+-------------------------------|
  |   1  |   22.5111    25     0.60609   |
  |   2  |   15.9869    25     0.91522   |
  +--------------------------------------+
   H0: no autocorrelation at lag order

   Jarque-Bera test
  +-------------------------------------------------------+
```

Equation	chi2	df	Prob > chi2
D_realgdpcgrowthrate	0.244	2	0.88525
D_totalpopgrowthrate	2.691	2	0.26037
D_eduindex	0.888	2	0.64137
D_fai	0.272	2	0.87290
D_rd	1.949	2	0.37732
ALL	6.045	10	0.81150

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_realgdpcgrowthrate	.00395	0.000	1	0.99454
D_totalpopgrowthrate	.93922	2.646	1	0.10378
D_eduindex	.08423	0.021	1	0.88401
D_fai	.18866	0.107	1	0.74384
D_rd	.79283	1.886	1	0.16968
ALL		4.660	5	0.45873

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_realgdpcgrowthrate	2.43	0.244	1	0.62154
D_totalpopgrowthrate	3.2448	0.045	1	0.83213
D_eduindex	1.9248	0.867	1	0.35179
D_fai	2.5308	0.165	1	0.68450
D_rd	3.2912	0.064	1	0.80092
ALL		1.384	5	0.92602

Model (4)
Vector error-correction model

Sample: 1998 - 2015 Number of obs = 18
AIC = 32.60166
Log likelihood = -254.4149 HQIC = 32.86766
Det(Sigma_ml) = 1301388 SBIC = 34.5308

Equation Parms RMSE R-sq chi2 P>chi2

```
D_realgdpcgrow~e          7        3.50227      0.5465      13.25579      0.0661
D_totalpopgrow~e          7        1.62221      0.7611      35.04848      0.0000
D_helindex                7        20.7631      0.6291      18.65563      0.0093
D_fai                     7        10.8019      0.5251      12.16063      0.0954
D_rd                      7        17.0223      0.6808      23.45682      0.0014
----------------------------------------------------------------


----------------------------------------------------------------------------------
                 |        Coef.    Std. Err.        z     P>|z|      [95% Conf. Interval]
----------------+-----------------------------------------------------------------
D_realgdpcgro~e |
            _ce1 |
             L1. |  -.5024267    .3484113     -1.44    0.149       -1.1853      .1804468
                 |
realgdpcgrowt~e |
             LD. |   .0714937    .3267849      0.22    0.827      -.568993      .7119804
                 |
totalpopgrowt~e |
             LD. |   .9853369    .4675156      2.11    0.035      .0690231      1.901651
                 |
        helindex |
             LD. |   .0574965    .0641983      0.90    0.370     -.0683298      .1833227
                 |
             fai |
             LD. |   .2099063    .0753659      2.79    0.005      .0621918      .3576208
                 |
              rd |
             LD. |  -.0977835    .0455963     -2.14    0.032     -.1871507     -.0084163
                 |
           _cons |  -1.028242    .8811336     -1.17    0.243     -2.755232      .6987483
----------------+-----------------------------------------------------------------
D_totalpopgro~e |
            _ce1 |
             L1. |   .6433493    .1613793      3.99    0.000      .3270515       .959647
                 |
realgdpcgrowt~e |
             LD. |  -.4380373    .1513623     -2.89    0.004      -.734702     -.1413726
                 |
totalpopgrowt~e |
             LD. |  -.3269104    .2165468     -1.51    0.131     -.7513344      .0975136
                 |
        helindex |
             LD. |  -.0800762    .0297358     -2.69    0.007     -.1383572     -.0217952
                 |
```

```
             fai |
             LD. |   .0253895   .0349085     0.73   0.467    -.0430299    .0938088
                 |
              rd |
             LD. |  -.0634859   .0211196    -3.01   0.003    -.1048795   -.0220922
                 |
           _cons |   .6676169   .4081291     1.64   0.102    -.1323014    1.467535
-----------------+----------------------------------------------------------------
D_helindex       |
             _ce1 |
             L1. |  -.7476957   2.065544    -0.36   0.717    -4.796087    3.300696
                 |
realgdpcgrowt~e |
             LD. |   .3159829   1.937333     0.16   0.870     -3.48112    4.113086
                 |
totalpopgrowt~e |
             LD. |  -3.477443    2.77165    -1.25   0.210    -8.909777    1.954891
                 |
        helindex |
             LD. |  -.1647477   .3805971    -0.43   0.665    -.9107044     .581209
                 |
             fai |
             LD. |  -.3473064   .4468042    -0.78   0.437    -1.223027    .5284139
                 |
              rd |
             LD. |   .8897805   .2703163     3.29   0.001     .3599702    1.419591
                 |
           _cons |   .4460349    5.22377     0.09   0.932    -9.792365    10.68444
-----------------+----------------------------------------------------------------
D_fai            |
             _ce1 |
             L1. |  -.1267771   1.074586    -0.12   0.906    -2.232927    1.979373
                 |
realgdpcgrowt~e |
             LD. |  -2.008197   1.007885    -1.99   0.046    -3.983615   -.0327779
                 |
totalpopgrowt~e |
             LD. |  -1.796258   1.441933    -1.25   0.213    -4.622396    1.029879
                 |
        helindex |
             LD. |  -.2161625   .1980033    -1.09   0.275    -.6042417    .1719168
                 |
             fai |
             LD. |  -.4060128   .2324471    -1.75   0.081    -.8616007    .0495751
```

```
                 |
              rd |
             LD. |   .1947467   .1406304     1.38   0.166    -.0808838    .4703771
                 |
           _cons |  -.3989544   2.717633    -0.15   0.883    -5.725417    4.927509
-----------------+----------------------------------------------------------------
D_rd             |
            _ce1 |
             L1. |   .4488959   1.693407     0.27   0.791    -2.870121    3.767913
                 |
realgdpcgrowt~e  |
             LD. |  -1.134377   1.588295    -0.71   0.475    -4.247379    1.978624
                 |
totalpopgrowt~e  |
             LD. |  -5.496279   2.272298    -2.42   0.016    -9.949902   -1.042656
                 |
        helindex |
             LD. |  -.4426118   .3120272    -1.42   0.156    -1.054174    .1689504
                 |
             fai |
             LD. |   .3018386   .3663062     0.82   0.410    -.4161084    1.019786
                 |
              rd |
             LD. |  -.3732776   .2216151    -1.68   0.092    -.8076352      .06108
                 |
           _cons |  -1.477418   4.282634    -0.34   0.730    -9.871228    6.916391
----------------------------------------------------------------------------------

Cointegrating equations

Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                 4   299.8796   0.0000
-------------------------------------------

Identification:  beta is exactly identified

                 Johansen normalization restriction imposed
----------------------------------------------------------------------------------
            beta |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-----------------+----------------------------------------------------------------
_ce1             |
realgdpcgrowt~e  |          1          .        .       .            .           .
totalpopgrowt~e  |  -.6450141    .098584    -6.54   0.000    -.8382353    -.451793
```

helindex	-.1367381	.0152374	-8.97	0.000	-.1666029.	-.1068733
fai	-.1119892	.0276575	-4.05	0.000	-.1661968	-.0577816
rd	-.0909717	.0154677	5.88	0.000	-.1212879	-.0606555
_cons	-7.80119	.	.	.	.	.

Lagrange-multiplier test

lag	chi2	df	Prob > chi2
1	31.6041	25	0.16979
2	18.8841	25	0.80264

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_realgdpcgrowthrate	2.283	2	0.31936
D_totalpopgrowthrate	1.444	2	0.48587
D_helindex	0.204	2	0.90294
D_fai	2.153	2	0.34079
D_rd	6.912	2	0.03155
ALL	12.996	10	0.22390

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_realgdpcgrowthrate	.89364	2.263	1	0.13252
D_totalpopgrowthrate	.54243	0.834	1	0.36121
D_helindex	.21743	0.134	1	0.71437
D_fai	.85231	2.058	1	0.15139
D_rd	-1.2706	4.574	1	0.03245
ALL		9.863	5	0.07921

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_realgdpcgrowthrate	3.1689	0.020	1	0.88698
D_totalpopgrowthrate	2.072	0.610	1	0.43481

D_helindex	3.3149 0.070 1 0.79097
D_fai	2.6343 0.095 1 0.75826
D_rd	4.8167 2.338 1 0.12626
ALL	3.133 5 0.67949
+---+

Model (5)
Vector error-correction model

Sample: 1999 - 2015 Number of obs = 17
AIC = -53.89501
Log likelihood = 547.1036 HQIC = -53.4614
Det(Sigma_ml) = 4.48e-36 SBIC = -49.53289

Equation	Parms	RMSE	R-sq	chi2	P>chi2
D_realgdpcgrow~e	14	2.09034	0.8050	63.71416	0.0000
D_totalpopgrow~e	14	.949912	0.8769	126.8974	0.0000
D_eduindex	14	8.444	0.8444	50.97379	0.0000
D_helindex	14	16.1599	0.8181	33.61324	0.0023
D_fai	14	7.76481	0.8313	40.65997	0.0002
D_rd	14	7.95433	0.8789	138.9378	0.0000

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
D_realgdpcgro~e						
_ce1						
L1.	-.0421783	.0147973	-2.99	0.003	-.0732204	-.0152156
realgdpcgrowt~e						
LD.	.6609023	.4929031	1.32	0.185	-.3169298	1.638734
L2D.	.1914624	.3844998	0.50	0.619	-.5621433	.9450681
totalpopgrowt~e						
LD.	-.8326094	.6139951	-1.36	0.175	-2.036018	.3707988
L2D.	-.0325788	.3826989	-0.00	0.997	-1.843395	1.836237
eduindex						
LD.	.1691819	.1629759	1.01	0.314	-.1600449	.4984086
L2D.	.0908514	.0110684	3.13	0.002	.0393678	.1480335
helindex						

```
             LD. |  -.0126498   .0500574    -0.25   0.800    -.1107605    .0854608
            L2D. |   .1129549   .0204481     2.35   0.019     .0356798    .2902299
                 |
             fai |
             LD. |  -.1884606    .100788    -1.87   0.062    -.3860015    .0090804
            L2D. |  -.1942702   .0859434    -2.26   0.024    -.3627162   -.0258243
                 |
              rd |
             LD. |   .0933514   .0241482     3.87   0.000     .0460222    .1406814
            L2D. |   .3899545   .1151175     3.39   0.001     .1643285    .6155806
                 |
           _cons |   .4293498   .2548157    -1.68   0.092     .0700798    .9287795
----------------+--------------------------------------------------------------
Cointegrating equations

Equation           Parms    chi2     P>chi2
-------------------------------------------
_ce1                   5   523.7374   0.0000
-------------------------------------------

Identification:  beta is exactly identified

                 Johansen normalization restriction imposed
------------------------------------------------------------------------------
            beta |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
----------------+--------------------------------------------------------------
_ce1             |
realgdpcgrowt~e |          1          .        .       .            .           .
totalpopgrowt~e |  -1.029045   .4070851    -2.53   0.011    -1.826917   -.2311732
        eduindex |  -0.613536    .131219   -12.30   0.000     -0.87072   -0.356352
        helindex |   .1002725   .1525113     1.31   0.191    -.0798452    .4003903
             fai |  -.7741709   .1040328    -7.44   0.000    -.9780715   -.5702703
              rd |  -.4736756    .059465    -7.97   0.000     -.590225   -.3571263
           _cons |   6.730353          .        .       .            .           .
------------------------------------------------------------------------------

   Lagrange-multiplier test
  +--------------------------------------+
  | lag  |      chi2    df   Prob > chi2 |
  |------+-------------------------------|
  |   1  |   35.5307    25     0.07903   |
  |   2  |   39.1660    25     0.03545   |
  |   3  |   28.5420    25     0.28352   |
  |   4  |   22.2989    25     0.61843
```

+--------------------------------------+
H0: no autocorrelation at lag order

Jarque-Bera test

Equation	chi2	df	Prob > chi2
D_realgdpcgrowthrate	0.005	2	0.99749
D_totalpopgrowthrate	0.213	2	0.89918
D_eduindex	0.989	2	0.60993
D_helindex	1.126	2	0.00725
D_fai	0.361	2	0.83474
D_rd	1.626	2	0.44349
ALL	4.320	12	0.97649

Skewness test

Equation	Skewness	chi2	df	Prob > chi2
D_realgdpcgrowthrate	.03002	0.003	1	0.95970
D_totalpopgrowthrate	.25409	0.183	1	0.66888
D_eduindex	-.57304	0.930	1	0.33476
D_helindex	-.55604	0.929	1	0.33550
D_fai	-.33693	0.322	1	0.57062
D_rd	.70898	1.424	1	0.23271
ALL		3.791	6	0.72129

Kurtosis test

Equation	Kurtosis	chi2	df	Prob > chi2
D_realgdpcgrowthrate	2.9409	0.002	1	0.96035
D_totalpopgrowthrate	3.2045	0.030	1	0.86336
D_eduindex	2.7129	0.058	1	0.80904
D_helindex	2.4851	0.199	1	0.65564
D_fai	2.7635	0.040	1	0.84223
D_rd	2.466	0.202	1	0.65314
ALL		0.531	6	0.99700