Quantile Analysis on Provincial Household Income and Convergence in China

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Abstract: This thesis applies quantile regression for an analysis of China’s provincial household income differences. The analysis is based on the theory of economic growth convergence and using data from the year of reform and opening up in 1978. The definition of household income growth convergence and relative theory are introduced first. We apply quantile regression method to analyze China’s household income convergence. Then we apply $\sigma$-convergence approach to analyze household income growth by studying the variation in the coefficient of provincial per capita GDP and divide 34 years into three periods. Furthermore, we perform comparative theory to analyze absolute $\beta$-convergence with OLS and quantile regression over three periods separately. Conditional $\beta$-convergence analyses are followed to study the influence of factors on household income growth. Empirical quantile regression results show that there is absolute $\beta$-convergence and conditional $\beta$-convergence in the first period, a trend of divergence in the second period and a weak trend of convergence in the third period. We found that base period income regional income growth for income growth in following periods; the unquantifiable factor regional development level’s impact on regional income growth are not all the same.

Key words: Household income; convergence; quantile regression
Content

Quantile Analysis on Provincial Household Income and Convergence in China

1. Introduction ............................................................................................................. - 1 -
2. Literatures reviews ............................................................................................. - 4 -
3. The principles and advantages of quantile regression ...................................... - 7 -
   3.1 The basic principle of quantile regression ...................................................... - 7 -
   3.2 Panel data and quantile regression ................................................................. - 8 -
4. Model and the Data Description .......................................................................... - 10 -
   4.1 The principles of economic growth convergence .......................................... - 10 -
   4.2 Data Description ............................................................................................ - 12 -
5. Quantile regression analysis of provincial economic growth convergence ........ - 13 -
   5.1 σ-convergence ............................................................................................... - 13 -
   5.2 β-convergence ............................................................................................... - 15 -
6. Conclusion .............................................................................................................. - 23 -
Reference:.................................................................................................................... - 24 -
1. Introduction

Since the implementation of reform and opening-up policy from 1978, there is a rapid development of China’s economy and a transformation process from government-oriented planned economy to a socialist market system. Along with the development, the regional differences of development are expanding at the same time.

According to the studies of Shan (2007), Wang and Ouyang(2008) and, Lu and Xie (2011), regional differences have negative influences on the economy efficiency and not conducive to efficient allocation of resources if it prevail over a long period and is excessive widened. In addition, Baumol (1986), Delong (1988), Zhou and Wang (2010) provide results implying that the regional income differences led by regional economic development differences also affects social welfare. Zhou and Wang (2010) pointed out that the influence of income gap on social welfare is mainly manifested on the differences of pensions, health services and educational resources which are provided to residents in different regions in China. In order to make the vast majority of residents enjoy the fruits of economic development equally, we have to eliminate regional differences. The first step is to find the reasons which lead regional differences.

In economics, the economies of countries that start off poor generally grow faster than the economies of countries that start off rich. As a result, the national income of poor countries usually catches up with the national income of rich countries. This phenomenon is called catch-up effect, also known as convergence. 1 We can obtain the development of regional differences by analyzing the “catch-up” speed, or the convergence rate, and then we can find the causes and their influence on regional differences.

Despite there are a variety of indicators to measure regional differences, we apply household income as our indicator to measure regional differences since other indicators like pensions, health services and educational resources are difficult to quality. We will establish two quantile regression models in this article, one model with some quantifiable factors like per capita GDP, average of per capita investment rate, average growth rate of employment, average rate of technological growth and depreciation and human capital as independent variables; a dummy variable will be introduced to the other model as some unquantifiable factors. After that we will study the convergence of economic

1 Mankiw, N. G., Principles of Macroeconomics, seventh edition, Section 12-3, P246.
data by using quantile regression method in each model and compare the regression results of two models. The panel data we will use in this article contains information about periods and regions; we can also compare the regression results in different periods. Then we may get some understanding about the factors’ effects on household income increasing in different periods, regions and income level group.

2. Literatures reviews

On the basic of long-term economic growth in the neoclassical model which is suggested by Solow (1956), a large number of economists have suggested to study convergence when studying economic growth.

Baumol (1986) started the empirical research of productivity growth and convergence of output per labor hour among industrialized nations. He analyzed the Maddison’s 1870-1970 data and got the conclusion that since 1870, 16 richer countries showed strong growth convergence; growth rate has a high correlation with the initial output level. However DeLong (1988) pointed out that Baumol had a biased conclusion from sample selection bias, he analyzed a sample with more countries during the same period and found that there was no significant convergence.

Based on Arrow (1962), Romer (1986) proposed an endogenous growth theory model. In Romer’s model, the knowledge capital has an increasing effect in general consumer goods production and knowledge spillovers generate scale economy. That means the countries with higher initial output level and more developed economic system have higher per capita capital stock of knowledge, thus these countries will have higher per capita output, so Romer doubted from a theoretical point of convergence on growth.

Lucas (1988) introduced human capital into economic growth model and divided human capital into general human capital which get full-time formal education and specialized human capital accumulation through learning-by-doing. By outputs with general human capital spillover effects, Lucas concluded that an economic system with lower level of human and physical capital will continue to have lower output level than other economic system with higher level initial human and physical capital. After the introduction of specialized human capital, international trade between two countries economic growth produced a lock: the country with higher level initial human and physical
capital has a comparative advantage in high-tech commodity production and will continue to accumulate experience in the production of high-tech goods by specialization and trade; then it will consolidate the advantages of specialization and monopoly and will continue to have higher economic growth rate. On the contrary, the country with lower level initial human and physical capital will have to produce low-tech goods and obtain a lower economic growth rate. Lucas’s research supports the theory of inconsistent convergence.

Barro and Sala-I-Martin (1991) implied the neoclassical model as the basic framework and subdivide convergence into $\sigma$-convergence, absolute convergence and conditional convergence. $\sigma$-convergence means the deviation of per capita income between different economic systems tends to decrease over time. $\beta$-convergence means the economic system with lower initial productivity will have higher speed on per capita output growth rate and per capita capital growth rate than the system with higher initial productivity. In the other word, there is a negative correlation between per capita output growth rate and initial productivity among different economic systems. $\beta$-convergence focus on output increments, and $\sigma$-convergence is a description of the output stock level. $\beta$-convergence also includes two convergence: absolute $\beta$-convergence refers to the various economic systems with the same basic economic characteristics of poor countries or regions more often have higher growth rates than wealthier countries or regions; same economic characteristics is not assumed in $\beta$-convergence theory, which means that different economic systems have different steady state.

Galor (1996) considered that “convergence club” and conditional convergence as different concepts. This theory indicates that in early stage, different economic systems with similar development level in a group are converging under the premise of similar structural characteristics. In the other word, there are internal conditional convergence in poorer countries group and richer countries group, but there is convergence between the two groups. Galor attributed this phenomenon to the micro-level heterogeneity of labor endowments. Ben-David (1998) introduces subsistence consumption assumption into Solow model and obtained the same conclusion which explains the “convergence club” phenomenon. Deardorff (2001) elaborated the “convergence club” on the background of specialization and international trade.

As an application of Barro’s theory, Wei (1997) concluded that the provincial per capita GDP of China converges in the annual rate of 2% during 1978-1995. Xu (2004) analyzed the convergence of data from 216 Chinese cities from 1989-1999 and found that both $\sigma$-convergence and $\beta$-convergence
exist. Lin and Liu (2003) analyzed provincial per capita GDP from 1970 to 1997 and found that there is a significant convergence trend in Eastern China, the trend is weaker in central area and the gap increased in Western China.

3. The principles and advantages of quantile regression

3.1 The basic principle of quantile regression

Quantile regression is a type of regression analysis used in statistics and econometrics. Whereas the method of least squares results in estimates that approximate the conditional mean of the response variable given certain values of the predictor variables, quantile regression aims at estimating either the conditional median or other quantiles of the response variable. Quantile regression is a development of least squares method which based on classical conditional mean model. The median regression is a special case of quantile regression.

Define there is a continuous random variable $y$, the probability of $y$ less than $q_\tau$ is $\tau$, then we define that the $\tau$ quantile value for $y$ is $q_\tau$. Similarly, if we express the variable $y$ as a linear expression of explanatory variables $X$ and disturbance term $u$, the probability of the linear expression which less than $q_\tau$ is $\tau$ as well, then it is quantile regression.

To explain the principles of quantile regression, consider a linear model:

$$y = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \cdots + \alpha_k x_k + u$$  \hspace{1cm} \text{Equation 3.1}

Where $\alpha_1, \alpha_2, \ldots, \alpha_k$ are coefficients of explanatory variables, $u$ is error term. Under Gauss-Markov assumptions, we use OLS to get the expected $y$ as:

$$E(y|x) = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \cdots + \alpha_k x_k$$  \hspace{1cm} \text{Equation 3.2}

We can also define a quantile regression model, when the parameters in the quantile model are equal to those in the conditional mean model, then we have:

$$Q_y(\tau|x) = \alpha_{\tau 0} + \alpha_{\tau 1} x_{1i} + \alpha_{\tau 2} x_{2i} + \cdots + \alpha_{\tau k} x_{ki}$$  \hspace{1cm} \text{Equation 3.3}

Where $\tau$ quantile value for $y$ is $Q_y(\tau|x)$.

Wang(2008) suggested that linear programming method (LP) can be used for calculating the minimum weighted absolute deviation estimate, obtained by minimizing

$$\sum_{i=1}^{n} \rho_\tau(y_i - \alpha_{\tau 0} - \alpha_{\tau 1} x_{1i} - \alpha_{\tau 2} x_{2i} - \cdots - \alpha_{\tau k} x_{ki})$$  \hspace{1cm} \text{Equation 3.4}
where

\[ \rho_t(t) = t(t - I(t < 0)), \tau \in (0,1) \]  

Equation 3.5

According to Koenker (2005), if quantile regression is to “work,” a minimal asymptotic requirement should be consistency. Lv (2012) discussed the estimation and testing of non-fixed effects on panel data models by using quantile regression, and obtained asymptotic normality of estimate parameters and convergence rate. Lv (2012) also established a rank score statistic to test the fixed effects model, and proved that the rank score statistic is asymptotically standard normal distribution.

3.2 Panel data and quantile regression

Mello (2002) used the quantile regression method to determine the income convergence and the effectiveness of policy variables on conditional distribution of GDP growth rate among 98 nations during 1960-1985. Many scholars have applied quantile regression method in medical and health services, public administration utilities and other data which with extreme value distribution statistics. But quantile regression approach has not been used in studying China’s economic growth and regional convergence.

Wang (2008) made a comparative analysis by following the approach of Koenker (2004), Wang analyzed the effects of different regression estimation methods when analyzing panel data, his analyze process as follow:

When using panel data for the analysis, the regression model is often written as:

\[ y_{it} = x_{it}' \beta + \alpha_i + u_{it}, i = 1,2,\ldots,N, t = 1,2,\ldots,T. \]  

Equation 3.6

Where \( i \) represent individuals, \( t \) means the time point, \( u \) is error term, \( \beta \) is coefficient vector for explanatory variables, \( \alpha_i \) represents an unobservable individual effect. And

\[ x_{it} = (1, x_{i1}, x_{i2}, \ldots, x_{ip}) \]  

Equation 3.7

Rewrite the estimate equation in the form of a matrix as:

\[ y = X \beta + Z \alpha + u \]  

Equation 3.8

The OLS estimate equation of Equation 3.7 is:

\[ \hat{y}_{it} = \hat{\alpha}_i + x_{it}' \hat{\beta}_1 + x_{2t} \hat{\beta}_2 + \cdots x_{it} \hat{\beta}_i = X \beta + Z \alpha \]  

Equation 3.9
In the case of fixed effects, we can write the error term as:

$$u_{it} = y_{it} - \hat{y}_{it}$$  \hspace{1cm} \text{Equation 3.10}

For getting least squared estimator of coefficients, we minimize the sum of squared residuals:

$$u_{min}^2 = \min_{\alpha, \beta} \|y_{it} - \hat{y}_{it} \|^2 = \min_{\alpha, \beta} \|y_{it} - X\beta - Z\alpha \|^2$$  \hspace{1cm} \text{Equation 3.11}

And the least squared estimator of $\beta$ is:

$$\hat{\beta} = (X'MX)^{-1}X'My, M = I - P, P = Z(Z'Z)^{-1}Z'$$  \hspace{1cm} \text{Equation 3.12}

In the case of random effects, assuming $u \sim N(0, R), \alpha \sim N(0, W), v = Z\alpha + u$, then we have:

$$E(vv') = (ZW' + R) = V$$  \hspace{1cm} \text{Equation 3.13}

Now we can use both GLS and penalized least square (PLS)

$^2$ to estimate $\beta$, and the estimator of $\beta$ can be described as following methods respectively:

GLS:

$$\hat{\beta} = \min_{\beta} \|y - X\beta \|_{\hat{V}^{-1}}^2$$  \hspace{1cm} \text{Equation 3.14}

PLS:

$$\hat{\beta} = \min_{\alpha, \beta} \|y - X\beta \|_{R^{-1}}^2 + \|\alpha \|_{W^{-1}}^2$$  \hspace{1cm} \text{Equation 3.15}

Where $\|\alpha \|_{W^{-1}}^2$ is a constant as penalized factor. When the $\hat{\beta}$ in \text{Equation 3.11} equals that in \text{Equation 3.12}, then we get:

$$\hat{\beta} = (X'V^{-1}X)^{-1}X'V^{-1}y$$  \hspace{1cm} \text{Equation 3.16}

When we use quantile regression to analyze the panel data in \text{Equation 3.7}, we can establish a quantile equation as:

$$Q_{\gamma_i}(\tau_j | x_{it}, \alpha_i) = x_{it}\beta(\tau_j) + \alpha_i$$  \hspace{1cm} \text{Equation 3.17}

Here we should notice that \text{Equation 3.21} is different from \text{Equation 3.3}.

Assuming individuals effects are fixed in the quantile equation above, Koenker (2004) proposed the penalized quantile regression (PQR) and had comparative analysis of the effects of different regression estimation methods by Monte Carlo simulation approach under a small sample assumption. He found that for some non-normal distribution like t-distribution, the bias and RMSE in quantile regression, penalized quantile regression and fixed effects quantile regression are smaller.

$^2$ The penalized least square minimizes the sum of error squares + other penalized factors, this approach reflects the individual impact. One good example is the ridge regression.
than the bias and RMSE in OLS, PLS and least squares fixed effects regression.

4. Model and the Data Description

4.1 The principles of economic growth convergence

Convergence of economic growth means in a closed economy with several economic systems (countries or regions), negative correlation relationship exists between their initial static indicators (per capita output, per capita income) and growth rate; that means less developed economic systems have higher growth rate than developed ones which results in that the initial differences disappears in the process.

Barro and Sala-i-Martin (1992) proposed convergence of per capita income determination models:

$$\frac{1}{T} \log\left( \frac{y_{i,T}}{y_{i,0}} \right) = a - \left[ (1 - e^{-\beta T}) / T \right] \log(y_{i,0} + \mu_{i,0,T})$$  \hspace{1cm} \text{Equation 4.1}

Here, $T$ represents the period, $y_{i,T}$ represents the per capita income in the last year of this period, $y_{i,0}$ represents per capita income in base year, $\mu_{i,0,T}$ represents the average error term, $\beta$ represents the coefficient of speed that income convergence to the equilibrium. If the parameter estimate of $\beta$ is positive, it means that there is convergence of income and divergence if it is negative. The model can reflect the countries at the same level of technology converge to the same equilibrium. Therefore, we should observe that whether there is negative correlation between initial income level and income growth.

Baumol (1986) and Barro (1997) proposed a linear form of Equation 4.1:

$$\frac{1}{T} \log\left( \frac{y_{i,T}}{y_{i,0}} \right) = a + b \log(y_{i,0}) + \mu_{i,0,T}$$  \hspace{1cm} \text{Equation 4.2}

Here $b = -(1 - e^{-\beta T})$. Half-life is calculated according to the formula $-\ln(0.5)/\beta$. Half-life is the amount of time required for a quantity to fall to half its value as measured at the beginning of the time period; it often represent the period which an economic indicator adjust to a new equilibrium after changed by some factors. Longer half-life means that the annual fluctuation is smaller, longer half-life also means a country or region has a stable development process during the adjusted period.

Based on Equation 4.1 and Equation 4.2, following equation is considered in this article:

$$\ln \frac{y_i}{y_0} = \beta_0 + \beta_1 \ln Y_0 + \epsilon_i$$  \hspace{1cm} \text{Equation 4.3}
Mankiw, Romer and Weil (1992) (the method they used to analyze the convergence is known as the MRW analysis framework) recognize the limitations of many neoclassical assumptions, so they amended the assumptions of countries with same consumer preferences and techniques level and re-interpretation the neoclassical theory of economic growth. In empirical analysis, using Cobb-Douglas production function:

\[ Y = K^\alpha H^\beta (AL)^{1-\alpha - \beta} \]  
*Equation 4.4*

where \( Y \) is total output, \( K \) is the capital invested, \( H \) is the number of labor inputs (units are people), \( AL \) is a comprehensive technical level index, \( \alpha \) is the elasticity coefficient of labor output, \( \beta \) is the capital-output elasticity coefficient.

Mankiw, Romer and Weil (1992) are assuming that the same production function applies to human capital, physical capital and consumption. They constructed MRW model by estimating the approximate steady state and obtained a national convergence rate to steady state. The convergence rate \( \lambda \) is calculated as:

\[ \lambda = (n + g + \vartheta)(1 - \alpha - \beta) \]  
*Equation 4.5*

Where \( n \) represents average growth rate of employment; \( g + \vartheta \) represents the average rate of technological growth and depreciation.

An extended econometric model is established by introducing physical capital investment, human capital investment and population growth rate as variables. Mankiw, Romer and Weil (1992) believe that human capital slowed down the speed of diminishing marginal returns on physical capita. Mankiw, Romer and Weil (1992) thought that although the convergence speed slower than Solow’s model has foreshadowed, it confirmed the existence of convergence. It should be noted that, the MRW model implies conditional convergence but not absolute convergence - countries converges to individual equilibriums in long-term development rather than converge toward the same equilibrium.

In this thesis, two equations which are based on the MRW model are selected from Mello and Novo (2002), one is:

\[
\ln\left(\frac{y_{i,T}}{y_{i,0}}\right) = \beta_0 + \beta_1 \ln\left(y_{i,0}\right) + \beta_2 \ln\left(I/GDP\right) + \beta_3 \ln\left(n + g + \vartheta\right) + \varepsilon_{i,0,T}
\]  
*Equation 4.6*

Add log of human capital (\( h \)) into Equation 4.6 as a new variable and get the second model as:

\[
\ln\left(\frac{y_{i,T}}{y_{i,0}}\right) = \beta_0 + \beta_1 \ln\left(y_{i,0}\right) + \beta_2 \ln\left(I/GDP\right) + \beta_3 \ln\left(n + g + \vartheta\right) + \beta_4 \ln\left(h\right) + \varepsilon_{i,0,T}
\]
Here, $y_{l,T}$ represents the final per capita GDP; $y_{l,0}$ represents per capita GDP in base year; $I/GDP$ represents the average of per capita investment rate from base year to the end; $n$ represents an average growth rate of employment; $g + \vartheta$ represents the average rate of technological growth and depreciation; Mankiw, Romer and Weil (1992) assumes the reasonable value of $g + \vartheta$ is 0.05 or 0.1\textsuperscript{3}; $h$ represents human capital.

4.2 Data Description

In this thesis, the data are from China Statistical Yearbooks over years, Comprehensive Statistical Data and Materials on 60 Years of New China, China Financial Yearbooks which are released by China's National Bureau of Statistics. Their samples are large and survey range is national wide, data was adjusted according to the actual pace of development and the rate of inflation, CPI and other factors.

The data of provinces and municipalities in China mainland after 1978 economy reform will be used for the analysis. It should be noted that, the provinces and municipalities had several changes since People’s Republic of China was founded in 1949. Hainan Province originally belonged to Guangdong Province before 1988, Chongqing separated from Sichuan Province for becoming a municipality in 1997. In the Statistic Yearbooks and Comprehensive Statistical Data and Materials on 60 Years of New China, the data of Chongqing and Sichuan (does not contain Chongqing) since 1978 can be found since the National Bureau of Statistics do recalculations based on original data and provincial and municipal levels yearbooks during compilation. Data of Hainan before 1988 could not be found. In order to maintain the consistency of data samples, the data of Hainan Province will not be included in the analysis. As a result, there are 30 provincial-sectional units and time span of 34 years in our data set.

The average investment rate ($I/GDP$) from base year to final year comes from the arithmetic mean of original data. Since the data source limitations, university and college student enrollment per 10 000 population on base year is used as an alternative variable of human capital ($h$). The average growth rate of employment ($n$) in the provinces in the sample period can be calculated by

\footnotesize{\textsuperscript{3} Mello, M. and Novo, Á., The New Empirics of Economics Growth: Quantile Regression Estimation of Growth Equations, 2002.}
\[ n = \left( \frac{\text{ending amount}}{\text{base period amount}} \right)^{\frac{1}{\text{sample period}}} - 1 \]  

Equation 4.8

5. Quantile regression analysis of provincial economic growth convergence

According to the hypothesis of convergence, quantile regression method will be used to analyze regional economic growth convergence in China from both \(\sigma\)-convergence and \(\beta\)-convergence (including absolute and relative convergence) points. The definitions of \(\sigma\)-convergence and \(\beta\)-convergence have been mentioned in Section 2.

5.1 \(\sigma\)-convergence

In order to study the trend of inter-provincial economic differences, the per capita GDP of 30 provinces and municipalities in mainland China are used and the mean, range, standard deviation and coefficient of variation of cross-sectional data for each year from 1978 to 2011 are calculated.

\[\begin{array}{l}
\textbf{Table1. Quantile and OLS regression result of per capita GDP of 30 provinces and municipalities in three periods. (Estimation of Model 4.3, t-values in parenthesis.)}\\
\beta & 0.1 & -0.2667 (-6.93*** ) & 0.1158 (2.84*** ) & -0.2500 (-6.15*** ) \\
& 0.25 & -0.2500 (-5.49*** ) & 0.1014 (1.72*) & -0.2836 (0.08) \\
& 0.5 & -0.2733 (-4.28*** ) & 0.1448 (2.17**) & -0.2655 (-0.88) \\
& 0.75 & -0.2267 (-2.05**) & 0.1646 (1.55) & -0.1633 (-1.01) \\
& 0.9 & -0.2640 (-5.86*** ) & 0.1424 (7.43*** ) & -0.2304 (-2.20**) \\
OLS & & -0.2791 (-4.06*** ) & 0.1727 (2.96*** ) & -0.0806 (-2.59**) \\
Constant & 0.1 & 2.8573 (12.75*** ) & 0.6326 (0.44) & 1.4088 (8.11*** ) \\
& 0.25 & 3.0627 (9.77*** ) & 0.8572 (0.60) & 0.8984 (1.54) \\
& 0.5 & 3.4860 (7.70*** ) & 0.6030 (0.49) & 0.8556 (2.08**) \\
& 0.75 & 3.0649 (4.36*** ) & 0.5541 (0.63) & 1.0185 (2.20**) \\
\end{array}\]
<p>| | | | |</p>
<table>
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</tr>
</thead>
<tbody>
<tr>
<td>0.9</td>
<td>4.1783(9.6***)</td>
<td>0.2047 (0.53)</td>
<td>1.5943(3.30***)</td>
</tr>
<tr>
<td>OLS</td>
<td>3.2428(7.95***)</td>
<td>0.6338 (0.45)</td>
<td>1.2535 (4.30***)</td>
</tr>
</tbody>
</table>

* (**, ****) denote 1% (5%, 10%) significant level (the same below).

Figure 1 shows the ranges of per capita GDP over the regions in the years 1978-2010. Figures 2 and 3 show corresponding results for the standard deviation and the coefficient of variation of per capita GDP over regions. The figures show that along with rapid economic development in the past years, the regional difference aggravated as well.
From Figure 3, we conclude that in the periods from 1978 to 1990 and from 2004 to 2011, per capita GDP gap between provinces gradually reduced, which implies σ-convergence. From 1991 to 2003, the province's per capita GDP gap is widening. Combined with China's actual situation, China's two stock exchanges were established at the end of 1990, followed by expansion of free-market economic reforms. During this period, provinces and municipalities continued to develop local economy and the gap are wide with no signs of σ-convergence. The state began to focus on reducing the gap between regions since 2002, and thus results in σ-convergence from 2004 to 2011. Therefore, the following empirical study will be divided into three time periods for modeling and analysis. For convenience, the first period is from 1978 to 1990, from 1991 to 2003 as the second period, and from 2004 to 2011 as third period.

5.2 $\beta$-convergence

5.2.1 Absolute $\beta$-convergence

On the basic of Equation 4.3, we analyze the absolute convergence with OLS and quantile regression methods in the three periods.

From Table1 we can see that $\beta$-coefficient is significantly negative in the first period, indicating
In accordance with the convergence rate and half-life calculation formulas aforementioned, absolute convergence rate and half-life of two absolute convergence periods are given in Table 2. OLS results indicate that the absolute convergence of economic growth from 2004 to 2011 is superior to that in first period, which means the regional differences of China’s economy has been controlled more effectively. OLS cannot tell the convergence rates at different quantile levels, whereby we cannot study convergence in regions with different household income. Quantile
regression in Table 2 describe that in the first period, highest income areas have the highest economic convergence rate and the poorest regions the lowest. During the third period, the absolute convergence rates are higher than that in first period; convergence rates on 0.1, 0.25, 0.5 and 0.9 quantiles are higher than OLS.

Chen (1996) used provincial data from 1952 to 1993 and Solow model analysis to show that from 1978 to 1993 in China's economy showed a trend of convergence with the convergence rate of 5.7%. Wei (1997) believed that regional economic convergence rate is 2%, which is similar to the result of in the first period obtained here in the OLS and quantile regression. Depending on different quantile, the half-life periods of regions with different economic growth rate are not similar. For instance, in first period, the half-life period of low economic growth rate regions is 39.45 years, but it is 21.70 years in high rate regions, so we can infer that the regions with higher economic growth rate are stable, which gives more information on regional wealth aspects as compared with the OLS estimates of an half-life estimate of 32.38 years. In the third period, the half-life period of low economic growth rate regions quickly shortened to 20.85 years, which is near to that in high rate regions, this conclusion is consistent with the theory about gap control in low economic growth rate regions aforementioned. The regions with middle level economic growth rate have the longest half-life period, followed by high-income areas, these match the absolute convergence analysis result. Difference control in middle level region is not so good, high-income areas most affected on national gap.

5.2.2 Conditional $\beta$-convergence

Based on Equation 4.6 and Equation 4.7, inter-provincial economic growth is divided into three periods for conditional $\beta$-convergence analysis.


The following model is obtained from the MRW model,

$$\ln\left(\frac{y_{i,T}}{y_{i,0}}\right) = \beta_0 + \beta_1 \ln(y_{i,0}) + \beta_2 \ln(I/GDP) + \beta_3 \ln(n + g + \theta) + \beta_4 \ln(h) + \varepsilon_{i,0,T}$$

Equation 5.1

---

4 We get the half-life according to calculation formulas, while we have not found a reliable method to test the true difference among the beta coefficients for different quantiles, so the half-life results here are for reference only.
A second model is obtained from *Equation 5.1* by replacing two variables with a dummy variable *(dev)* which is an indicator for provinces and municipalities with a higher level of development, i.e. areas with higher level of national policy preferences, economic openness, urbanization and other factors. The value of *dev* is 1 when the data is from rich provinces. So we obtain *Equation 5.2* as

\[
\ln\left(\frac{y_{i,T}}{y_{i,0}}\right) = \beta_0 + \beta_1 \ln(y_{i,0}) + \beta_2 \ln(1/GDP) + \beta_5\text{dev} + \epsilon_{i,0,T} \tag{Equation 5.2}
\]

*Table 3. Convergence on Chinese economic growth conditions quantile regression results during 1978-1990. (Estimation of Model 5.1 and 5.2, t-values in parenthesis.)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Quantile</th>
<th><em>Equation 5.1</em></th>
<th><em>Equation 5.2</em></th>
</tr>
</thead>
</table>
| \(\beta_0\) | 0.1 | -0.1890(-0.39) | 2.9029(9.32***)
| | 0.25 | 2.1301(0.75) | 3.0932(7.16***)
| | 0.5 | 2.2856(0.93) | 3.7570(8.06***)
| | 0.75 | 0.7617(0.17) | 3.9649(5.53***)
| | 0.9 | -1.1393(-0.48) | 5.3440(21.7***)
| \(\beta_1\) | 0.1 | -0.4113(-11.01***)| -0.2813(-4.88***)
| | 0.25 | -0.3137(-2.19**)| -0.3085(-4.48***)
| | 0.5 | -0.3458(-2.47**)| -0.3897(-5.10***)
| | 0.75 | -0.2393(-1.03)| -0.3988(-3.41***)
| | 0.9 | -0.5884(-3.53***)| -0.5884(-14.38***)
| \(\beta_2\) | 0.1 | 0.1023(6.09***)| -0.1100(-1.84*)
| | 0.25 | -0.1218(-3.15***)| -0.1040(-2.35**)
| | 0.5 | -0.0780291(-1.46)| -0.0421(-0.91)
| | 0.75 | -0.0339676(-0.35)| 0.0414(0.54)
| | 0.9 | 0.121177(1.62)| 0.1317(2.8**)
| \(\beta_3\) | 0.1 | 0.0082(0.38)
| | 0.25 | 0.0378(0.59)

5 Rich provinces including: Beijing, Liaoning, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong. These provinces are selected according to per capita GDP, per capita household income, per capita government spending on education, health care and public services etc. Also reference the section about development level of China's provinces in “The western development policy”.
The regression results of both Equation 5.1 and Equation 5.2 reported in Table 3 shows that negative correlation exists between base period per capita GDP and economic growth.

In Equation 5.1, for the tenth and ninetieth quantile, investment rate has a positive correlation with economic growth; which means increasing investment in lowest and highest income areas will lead local economic growth speed up. Human capital in Equation 5.1 does not pass t-test, which indicates that it does not contribution to economic growth convergence during this period. The coefficient for employment, technological progress and other factors are -2.0164 in low-income regions and -3.1899 in high-income regions. It indicates that technological growth and depreciation have more significant effects on economic growth convergence in high-income regions than that in low-income regions.

In Equation 5.2, we replace two variables with a dummy variable (dev) that covers other factor in rich regions, the dummy variable passing significant test indicates that the high-income areas are present internal convergence. Coefficients of per capita GDP in Equation 5.2 are more significant than those in Equation 5.1. As income increases, β value dropped from -0.2813 to -0.5884 indicating high-income areas have faster convergence speed, which is conducive to reducing regional gap and also shows the existence of conditional convergence.

Table 4. Convergence on Chinese economic growth conditions quantile regression results during 1991-2003. (Estimation of Model 5.1 and 5.2, t-values in parenthesis.)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Quantile</th>
<th>Equation 5.1</th>
<th>Equation 5.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_0$</td>
<td>0.1</td>
<td>2.6976(0.40***)</td>
<td>0.6377(0.49)</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>2.8466(2.90)</td>
<td>1.9652(0.93***)</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0.0345(0.19)</td>
<td>2.3667 (0.54***)</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>-3.3375(3.60)</td>
<td>2.3289(0.67***)</td>
</tr>
<tr>
<td></td>
<td>0.9</td>
<td>-3.1062 (1.01***)</td>
<td>3.8429 (0.33***)</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>0.1</td>
<td>-0.0219(0.03)</td>
<td>0.1148 (0.06)</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>0.1472 (0.22)</td>
<td>-0.0566(0.13)</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0.2785(0.17)</td>
<td>-0.1015(0.07)</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>0.3590(0.26)</td>
<td>-0.0890 (0.09)</td>
</tr>
<tr>
<td></td>
<td>0.9</td>
<td>0.4421(0.04***)</td>
<td>-0.2860(0.05***)</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>0.1</td>
<td>0.0039 (0.02)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>-0.3295 (0.37)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>-0.1768(0.18)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>-0.3104 (0.34)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.9</td>
<td>-0.1925 (0.09***)</td>
<td></td>
</tr>
<tr>
<td>$\beta_3$</td>
<td>0.1</td>
<td>0.6779(0.10***)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>1.2923(0.85)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0.1761(0.72)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>-1.1468 (1.20)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.9</td>
<td>-0.9771 (0.43***)</td>
<td></td>
</tr>
<tr>
<td>$\beta_4$</td>
<td>0.1</td>
<td>0.1806(0.01**)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>0.0583(0.13)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>-0.0710 (0.12)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>-0.1436(0.19)</td>
<td></td>
</tr>
</tbody>
</table>
In Equation 5.1, all coefficients pass significant test on 0.9 quantile. $\beta_0$, $\beta_3$ and $\beta_4$ also pass the significant test on 0.1 quantile. It indicates that during second period, investment increasing is the greatest power to improve residents' income in the richest areas of China. For the poorest areas, base period income is the most important factor in determining income growth; employment, technological growth and depreciation, human capital have significant positive effects to improve residents' income.

In Equation 5.2, $\beta_0$ and $\beta_5$ pass the significant test on 0.25, 0.5, 0.75 and 0.9 quantile, $\beta_1$ pass the significant test on 0.9 quantile. It indicates that, base period income plays the largest role in promotion income; regional development level has significant positive effects for increase revenues. With the increase of quantile level, $\beta_5$ increase from 0.1050 to 0.4652 which means the development degree plays greater role in richer areas.

Generally, per capital GDP has a positive correlation with income growth, income growth rate shows gradual expansion as income increase during this period. In the other word, the income gap is widening gradually, there is no convergence in the second period.


In third period, we use Equation 5.1 and Equation 5.2 for analyze. Table 5 gives the results of regressions.

In Equation 5.1, the regressions are significant only on 0.1 and/or 0.9 quintile, our analysis focuses on low-income areas and high-income areas. Stand on the point of per capita GDP coefficient, low-income and high-income regions exist conditions $\beta$-convergence, and the convergence speed of high-income areas is faster than the low-income areas slightly. Positive correlation between investment rate and economic growth can be found in all areas, which mean in

<table>
<thead>
<tr>
<th>$\beta_5$</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.9</td>
<td>-0.2456 (0.02**)</td>
</tr>
<tr>
<td>0.1</td>
<td>0.1050 (0.11)</td>
<td></td>
</tr>
<tr>
<td>0.25</td>
<td>0.2867 (0.13**)</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>0.2805 (0.08***</td>
<td></td>
</tr>
<tr>
<td>0.75</td>
<td>0.3160(0.12****</td>
<td></td>
</tr>
<tr>
<td>0.9</td>
<td>0.4652 (0.07***</td>
<td></td>
</tr>
</tbody>
</table>
all regions, increase investment will promote economic growth. When compare the coefficients of investment rate in different areas, we found that the investment will bring much higher economic effect in high-income areas than in low-income areas. From the point of view of human capital, increase human capital can bring higher positive effects in high-income areas than in low-income areas. In addition, employ increase and technological advance push economic growth in high-income areas, while they have no obvious effect in low-income areas.

In Equation 5.2, base period income and investment rate have significant effects to income growth; both of the two factors have greater effect in low and middle income areas than higher income areas. Coefficient of development level passes t-test only on 0.1 quantile indicates that under the promise of immovable natural resource endowment, policy support direction may transfer from rich areas (in second period) to poorest areas (in third period).

Table 5. Convergence on Chinese economic growth conditions quantile regression results during 2004-2011. (Estimation of Model 5.1 and 5.2, t-values in parenthesis.)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Quantile</th>
<th>Equation 5.1</th>
<th>Equation 5.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_0$</td>
<td>0.1</td>
<td>1.177628(6.27***</td>
<td>3.7144(0.46***</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>1.2386(1.48)</td>
<td>4.2293(1.33***</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>1.0375(1.10)</td>
<td>4.0021(0.79***</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>1.7746(1.56)</td>
<td>2.4549(0.51***</td>
</tr>
<tr>
<td></td>
<td>0.9</td>
<td>3.5261(9.67***</td>
<td>1.1717(1.43)</td>
</tr>
<tr>
<td>$\beta_1$</td>
<td>0.1</td>
<td>3.4311 (1.23**)</td>
<td>-0.3053 (0.05**</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>-0.0542(-0.79)</td>
<td>-0.3457 (0.15***</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>-0.0571(-0.73)</td>
<td>-0.3126(0.09***</td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>-0.0826(-0.65)</td>
<td>-0.1337 (0.06***</td>
</tr>
<tr>
<td></td>
<td>0.9</td>
<td>-0.1377(-3.07***)</td>
<td>0.0201(0.16)</td>
</tr>
<tr>
<td>$\beta_2$</td>
<td>0.1</td>
<td>0.2193(4.8***)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>0.2835(1.45)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>0.2067(1.01)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>0.3952(1.3)</td>
<td></td>
</tr>
</tbody>
</table>
### Conclusion

In this thesis, quantile regression approach is applied to analyze China's household income convergence. China's household income convergence is divided into three phases due to the variation in coefficients found. From 1978 to 1990, China’s household income shows $\sigma$-convergence, absolute $\beta$-convergence and conditional $\beta$-convergence successively. High-income areas in the first period show fastest convergence, its fastest divergence in the second period has the greatest impact in household income differences; in third period, the household income in rich regions shows absolute $\beta$-convergence. Regions with lower economic development level have better performance than other regions in controlling economic gap during the three periods. However, the investment rate, human capital and technological advances in quantile regressions do not display significant role in income growth.

<table>
<thead>
<tr>
<th>Phase</th>
<th>$\beta_3$</th>
<th>$\beta_4$</th>
<th>$\beta_5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>-0.1551(-1.89*)</td>
<td>0.0056(0.6)</td>
<td>0.1663(0.06*)</td>
</tr>
<tr>
<td>0.25</td>
<td>0.0491(0.23)</td>
<td>0.0171(0.56)</td>
<td>0.0988 (0.14)</td>
</tr>
<tr>
<td>0.5</td>
<td>-0.0107(-0.03)</td>
<td>0.0333(0.78)</td>
<td>0.0595 (0.09)</td>
</tr>
<tr>
<td>0.75</td>
<td>0.0889(0.16)</td>
<td>0.0240(0.58)</td>
<td>-0.0488(0.09)</td>
</tr>
<tr>
<td>0.9</td>
<td>0.5127(2.33**)</td>
<td>0.0599(4.07***)</td>
<td>-0.2016 (0.21)</td>
</tr>
</tbody>
</table>
Theoretically, the variables like investment rate, human capital and technological advances should have an effect on household income increasing, but we do not find the effect on some quantile levels and periods. Given China is not a market-oriented economic system, political factors may play more important role in promoting regional development. Resource endowments differences, openness level, government regulation, policy preferences and some other factors may significant impact on regional income growth; while their characteristics of unquantifiable lead us have to exclude them from being variables in model, even lead greater bias from actuals.

Reference:


Wei, H., Chinese Regional Economic Growth and Convergence, *China Industrial Economy*, (March 1997), 31-37. (Chinese)

