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Total Differential Approach to Identify Contributors of Local Economy Growth

Qidong Cao*, Thomas E. Griffin** and Huailiu Guan***

Since the turn of the 21st century, along with in-depth economic system reform Nantong City of China has seen rapid economic development. Population and the gross domestic product (GDP) per capita are two fundamental factors determining economic development. This study presented an assessment method to evaluate the contributions of the change in population and the change in the GDP per capita to local economy growth. A total differential approach was employed to estimate the contributions of factors. The error of estimation was checked to be satisfactory. The study was based on the census data from China. This study concluded that the GDP per capita supported almost all economic growth in Nantong City while the negative effect of decreasing population was ignorable. The findings of this study provide some valuable insights and implications for the decision makers of cities like Nantong in China and other countries.

JEL Codes: B41, C65 andC82

1. Introduction

Nantong City stands on the northern bank of the Yangtze River, across the river from Shanghai. Within the Yangtze delta, the jurisdiction area of Nantong City has a coastline of more than 250 miles along the Pacific Ocean, the river bank of over 100 miles along the Yangtze River, a population of near 8 million, and a land area of 3,089 square miles.

Nantong is a city with a history over one thousand years. It is one of China's first fourteen coastal cities opened to overseas investment in 1984. The city is listed on the China's Top 100 cities, the 22nd (Zhang, 2013) for its GDP and the 30th for comprehensive strength in economy (Zhu, 2013). The GDP grew by 11.8% to RMB 456 billion (US$74.5 billions) in 2012.

By the early 2000s the population began to decrease in Nantong City, in large part due to China'sone child policy in 1980.The economic policy makers of Nantong City wanted to know the effect of population decrease and contribution of the GDP per capita growth to local economy. This study presented an assessment method to evaluate the contributions of the change in population and the change in the GDP per capita to local economy growth. A total differential approach was employed to estimate the contributions of factors.

Previous studies heavily relied on regression models to statistically estimate unknown relationships between dependent and independent variables. The relationship between the GDP and the population and the GDP per capita in this study is an Identity equation that is true no matter what value is used for the variables. The regression models are not applicable for use in this study to assess effects of population and GDP per capita on GDP.

*Dr. Qidong Cao, College of Business Administration, Winthrop University, USA, Email: caoq@winthrop.edu
** Dr. Thomas E. Griffin, H. Wayne Huizenga School of Business and Entrepreneurship, Nova Southeastern University, USA. Email: tegriffi@huizenga.nova.edu
***Prof. Huailiu Guan, School of Business, Nantong University, China, Email: ghl@ntu.edu.cn

Therefore, methodologies other than regression analysis have to been examined and carefully chosen for this study. Total differential models in this study provided an appropriate assessment method.

The remainder of this paper is organized as follows: The next section provides a review of literature. Then the total differential models are presented and explanation of the data is provided, followed by an analysis of results and discussion. Summaries conclusions are made in the final section.

2. Literature Review

There is a large literature employing regression models to investigate relationship between economic growth, GDP per capita, population, and other variables. It has been found by the linear least squares regression analysis (Frankel and Romer, 1999)that a rise of 1% in the ratio of trade to GDP increases income per person by at least 1.5%. The results from cross-country panel regressions (Barro, 2003) have shown that the GDP per capita growth rate relates to a set of quantifiable explanatory variables such as the initial level of GDP per capita, human capital (education and life expectancy), the rule of law, international openness, the ratio of government consumption to GDP, and inflation rate. Growth accelerations (Hausmann et al., 2005) have been identified by the natural logarithm of GDP per capita regressed on time t.Simple log-linear regressions of GDP on the sum of light intensity or the patterns of lights in the nighttime satellite imagery have been conducted to estimate the GDP of nations (Sutton and Costanza, 2002; Ebener et al., 2005; Sutton et al., 2007). Simple log-linear regression of GDP per Capita on the life expectation has been conducted to estimate the GDP per capita of country (Vitcu et al., 2008).Some regression results (Acemoglu et al., 2008) have showed doubt on the conventional wisdom that income per capita is a key determinant of democracy and that a general increase in income per capita will improve political systems. The GDP per capita has also been regressed on economic geography factors, and three measures of distance to markets (the sum of bilateral distances, market potential, and the weighted sum of market access and supplier access) are found to have a statistically significant effect on GDP per capita (Boulhol et al., 2008). A meta-regression analysis (Headey and Hodge, 2009) has found a significant negative effect of rapid population growth on economic growth in developing countries. Linear relationship has been found (Dao, 2012) between the response variable GDP per capita growth and the explanatory variables such as population growth, the old dependency ratio, the mortality rate, the interactions between population growth and both the young and old dependency ratios, between population growth and whether or not the rate of population growth is less than 1.2 percent per year, and between the young dependency ratio and whether or not the rate of population growth is less than 1.2 percent per year.

Regression models use ranges of values for variables in the form of probability distribution while the relationship in this study is a deterministic model that produces the same result for a given input. The main purpose of regression models in the previous studies is to find relationship between the response variable and the explanatory variables while the deterministic relationship between variables of this study already exists.The total differential approach is therefore proposed for this study to assess the contributions of factors through a known relationship. The following hypotheses will be tested by the total differential models:

H1: Population decrease reduced GDP of Nantong City.
H2: GDP per capita positively affected GDP of Nantong City.

H3: Growth of GDP per capita dominated the effect of population decrease with regard to GDP of Nantong City.

3. The Methodology and Data

Regression analysis is not a panacea for economic growth data of all kinds. Previous studies heavily relied on regression models that statistically estimate unknown relationships between dependent and independent variables. As stated in Introduction, regression models are not applicable for use in this study to assess effects of population and GDP per capita on GDP.

In order to evaluate the effect of changes in population and GDP per capita, a total differential approach has been employed. We have

$z = xy$ (1)

where z = GDP, x = population, and y = GDP per capita.
The total differential (Todorova, 2011) of z = GDP is

$$dz = \frac{\partial z}{\partial x}dx + \frac{\partial z}{\partial y}dy \quad (2)$$

The total differential of z closely approximates the GDP change Δz for small Δx and Δy. We have

$\Delta z = y\Delta x + x\Delta y$ (3)

The change in GDP is explained by two components: the contribution of change in population ($y\Delta x$) and the contribution of change in GDP per capita ($x\Delta y$).

Nantong City census data for 2000 to 2011(Li, 2012) shown in Table 1 are used in Equation (3) to assess the contributions of population and GDP per capita to economy growth as follows.

$$\sum_{t=2001}^{t=2012} \Delta z_t = \sum_{t=2001}^{t=2012} y_{t-1}\Delta x_t + \sum_{t=2001}^{t=2012} x_{t-1}\Delta y_t \quad (4)$$

where $\Delta z_t = z_t - z_{t-1}$, $\Delta x_t = x_t - x_{t-1}$, and $\Delta y_t = y_t - y_{t-1}$, respectively.

Table 1: Nantong City GDP, Population, and GDP per Capita (2000 – 2011)

Year	GDP (in CNY 1,000s)	Population (in 1,000s)	GDP per capita (in CNY)
2000	71,988,472.80	7,845.30	9,176.00
2001	78,856,318.80	7,824.60	10,078.00
2002	86,398,189.80	7,802.60	11,073.00
2003	97,855,700.80	7,776.20	12,584.00
2004	119,279,728.50	7,737.90	15,415.00
2005	146,925,916.00	7,708.60	19,060.00
2006	185,773,420.70	7,697.90	24,133.00
2007	210,685,750.00	7,661.30	27,500.00
2008	250,614,718.00	7,637.20	32,815.00
2009	287,280,380.00	7,626.60	37,668.21
2010	346,567,120.00	7,629.20	45,426.40
2011	408,021,820.00	7,648.80	53,344.55

From data plotted in Figure 1, it has been seen that GDP consistently increased during 2000 to 2011 in Nantong City even though population showed a decreasing trend.

From data plotted in Figure 2, it has been seen that GDP consistently increased during 2000 to 2011 in Nantong City and the GDP per capita matched the same pattern of change.

4. Results

Using data of Nantong City in Equation (4), the results are shown in Table 2. The eleven-year change in GDP ($\sum \Delta z_t$) was CNY 336,033,347,200, the population decreased by 196,500, and the GDP per capita increased by CNY 44,168.55. The contribution to the GDP change by the population decrease was estimated as CNY -2,747,117,040, the contribution to the GDP change by the increase in GDP per capita was estimated as CNY 339,257,823,640, and the sum of two estimated numbers provided the estimated change in GDP (CNY 336,510,706,600).

When the total differential of z is used to approximate the GDP change Δz for the annual population change Δx and the annual GDP per capita change Δy, the error is inevitable. The size of error is assessed by comparing the actual GDP increase and the GDP increase estimated by Equation (4). The error is the difference between the actual change in GDP = CNY 336,033,347,200 and the estimated change in GDP by Equation (4) = CNY (-2,747,117,040 + 339,257,823,640). The error is CNY -477,359,400, that is, -0.14% of the actual GDP increase. Based on this trivial error, it is concluded that the accuracy of the approximation by using Equation (4) is satisfactory.

Figure 1: Trend of Nantong City GDP and Population (2000 – 2011)

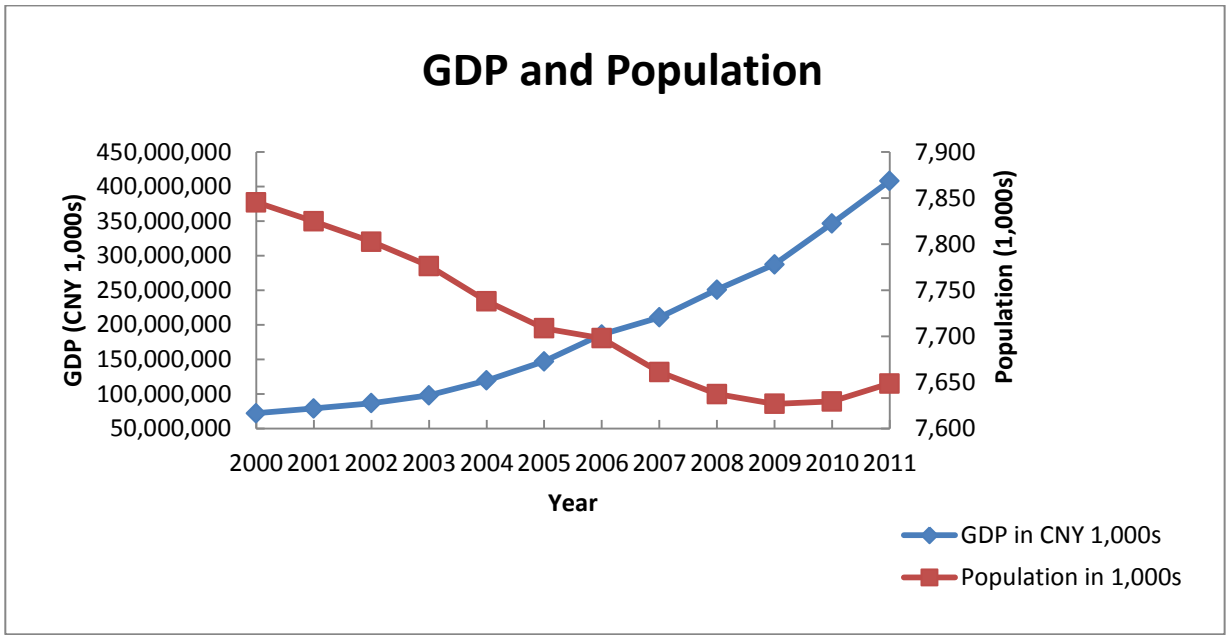


Figure 2: Trend of Nantong City GDP and GDP per Capita (2000 – 2011)

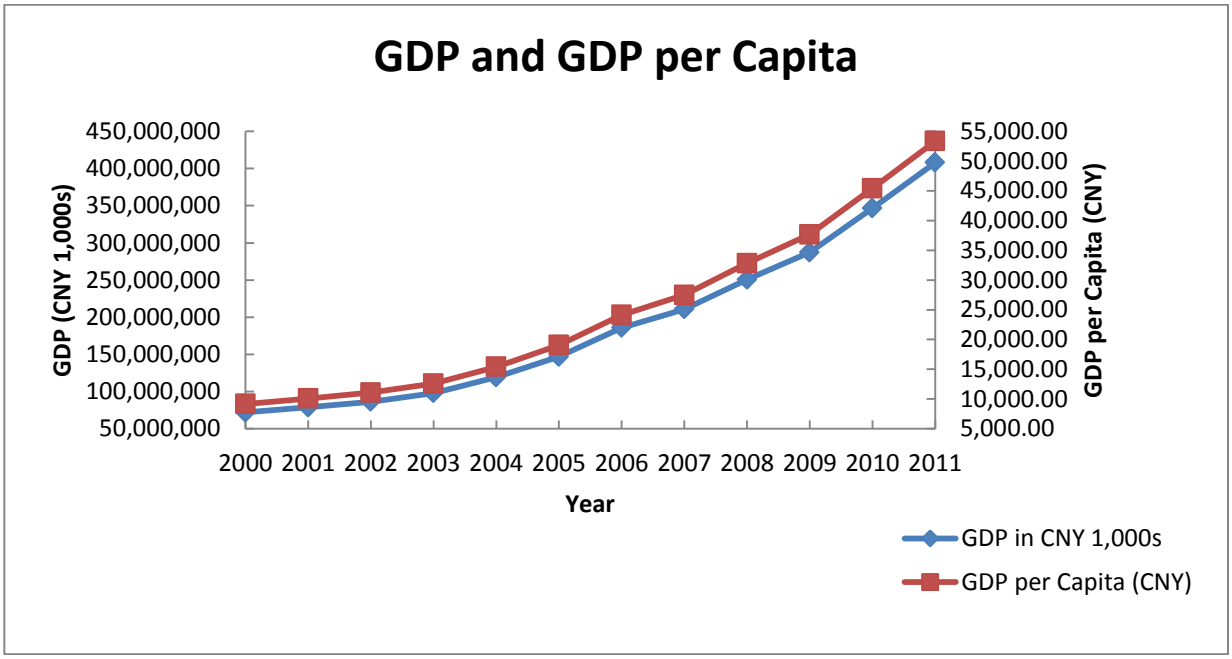


Table 2: Contributions of Changes in Population and GDP per Capita (2000 – 2011)

Year (t)	Δz_t (CNY 1,000s)	Δx_t (1,000s)	Δy_t (CNY)	$y_{t-1}\Delta x_t$ (CNY 1,000s)	$x_{t-1}\Delta y_t$ (CNY 1,000s)
2000	-	-	-	-	-
2001	6,867,846.00	-20.70	902.00	-189,943.20	7,076,460.60
2002	7,541,871.00	-22.00	995.00	-221,716.00	7,785,477.00
2003	11,457,511.00	-26.40	1,511.00	-292,327.20	11,789,728.60
2004	21,424,027.70	-38.30	2,831.00	-481,967.20	22,014,422.20
2005	27,646,187.50	-29.30	3,645.00	-451,659.50	28,204,645.50
2006	38,847,504.70	-10.70	5,073.00	-203,942.00	39,105,727.80
2007	24,912,329.30	-36.60	3,367.00	-883,267.80	25,918,829.30
2008	39,928,968.00	-24.10	5,315.00	-662,750.00	40,719,809.50
2009	36,665,662.00	-10.60	4,853.21	-347,839.00	37,064,945.04
2010	59,286,740.00	2.60	7,758.19	97,937.35	59,168,631.35
2011	61,454,700.00	19.60	7,918.15	890,357.51	60,409,146.75
Total	336,033,347.20	-196.50	44,168.55	-2,747,117.04	339,257,823.64

Using Equation (4), the contribution to the GDP change by the population was estimated as -0.82% of the estimated change in GDP (CNY 336,510,706,600) and H1 that Population decrease reduced GDP of Nantong City was supported, and the contribution to the GDP change by the GDP per capita was estimated as 100.82% of the estimated change in GDP and H2 that GDP per capita positively affected GDP of Nantong City was supported. Obviously, the GDP per capita supported almost all economic growth in Nantong City while the negative effect of decreasing population was ignorable during the period of 2000 to 2011. Therefore, H3 that Growth of GDP per capita dominated the effect of population decrease with regard to GDP of Nantong City was supported by the results of total differential models.

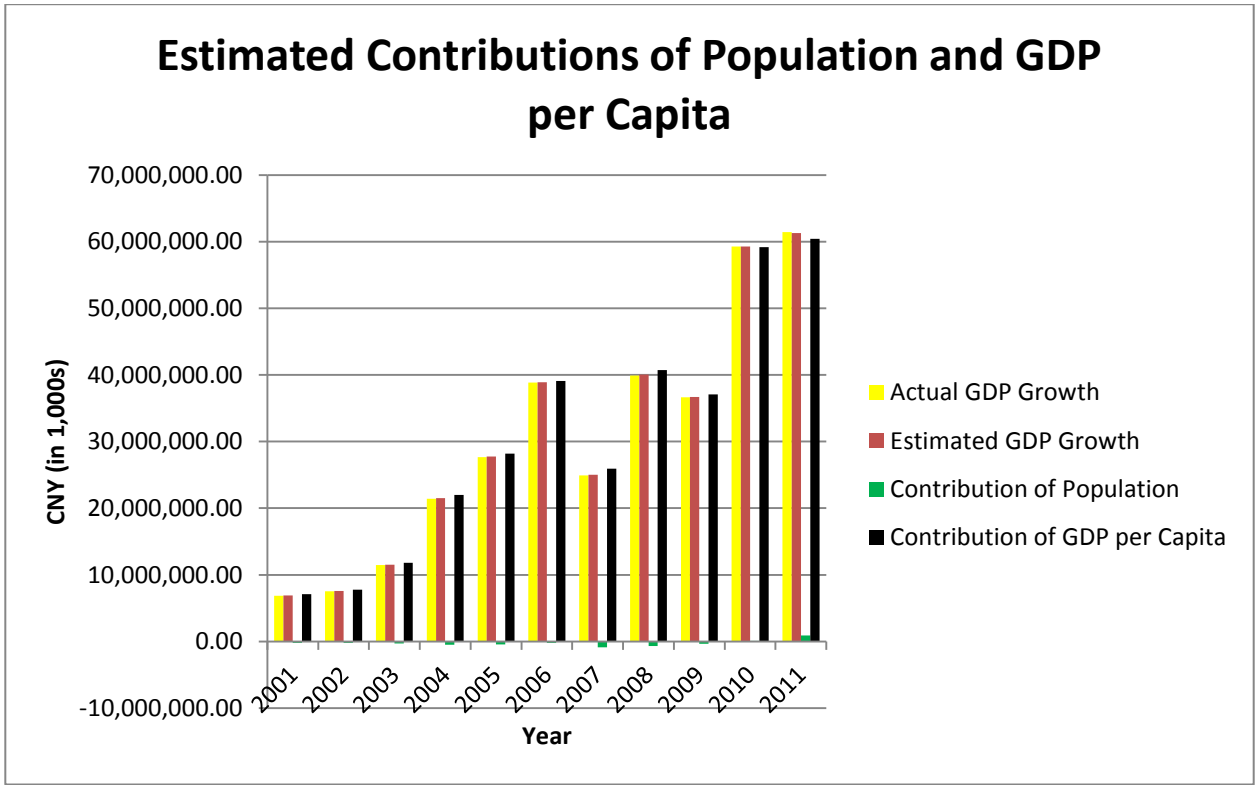
The actual GDP growth, the estimated GDP growth, the contribution of change in population, and the contribution of change in GDP per capita were plotted in Figure 3. Figure 3 again indicates that the estimation error of the GDP growth is trivial, and the GDP per capita supported almost all economic growth and the negative effect of decreasing population was ignorable.

5. Summary and Conclusions

In Table 1, Nantong City had a population of 7,648,800 in 2011, a decrease of 196,500 or 2.5% from 2000. In the same time period, Jiangsu Province saw a population increase of 7.35%. The population growth rate of Nantong City was 9.85% lower than the provincial averages. In Table 1, the GDP of Nantong City was CNY 408,021,820,000 in 2011, an increase of CNY 336,033,347,200 or 466.79% from 2000 while the GDP per capita was CNY 53,344.55, an increase of CNY 44,168.55 or 481.35% from 2000.

The total differential approach provided a satisfactory estimation for the contributions of the population change and the increase in the GDP per capita. For economic growth in the period of 2000 to 2011, the estimation results showed that the population growth contributed -0.82% while the GDP per capita contributed 100.82%. Obviously, the GDP per capita supported almost all economic growth in Nantong City while the negative effect of decreasing population was ignorable.

Figure 3: Actual and Estimated GDP Growth and Estimated Contributions of Population and GDP per Capita (2000 – 2011)



As the population began to decrease in Nantong City due to China's one child policy, the economic policy makers of Nantong City wanted to know the effect of population decrease and contribution of the GDP per capita growth to local economy. This study developed total differential models to assess the contributions of the change in population and the change in the GDP per capita to local economy growth.

The effect of the growth of GDP per capita supported fast economic growth after population growth rate turned negative. It has been commonly accepted that the GDP per capita is a comprehensive index for characterizing the level of economic development and efficiency. It is often determined by factors such as level of technology, status of management, resource utilization, nature of economic system, and structural efficiency. In conclusion, there has been strong evidence that since the turn of new century the fast economic growth can be attributed to economic efficiency from technology updates, improvement of management, reform of economic system, and optimization of economic structure, which has offset the effect of negative population growth on economic development.

The limitation of this study is that the GDP per capita is only a comprehensive index for the economic development and efficiency. To find out which of the above factors have been improved and how much each of factors has contributed to the economic growth, more sophisticated models are suggested for the future research.

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