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THE EFFECT OF THE GROWTH IN LENGTH OF METRO ON THE ECONOMIC GROWTH IN MAJOR BIG CITIES IN CHINA

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ABSTRACT

Urban rail transit is a widely applied mean of transportation in many cities around the world. In China, numerous cities are constructing their metro lines to improve the capability of its transportation and infrastructure. But because the investment needed in such project is colossal, the State Council in Beijing once criticized this type of investment for being wasteful and detaching from the actual demand of economic growth. Consequently, doubts on economic effects brought by metro system are also posed relentlessly. This research will try to look into the relation between the growing length of metro system and the economic growth in metropolis, finding out whether it is positive or negative and by what margin. And give out suggestions to city planners and policymakers on whether further construction of metro in mentioned cities should be carried out or approved. An econometric model that is based on the traditional Cobb-Douglas model and statistical methods including linear regression will be applied.

Contribution/Originality: This research focuses on the relationship between the total length of metro lines of big cities and the changes in economic growth respectively. The data represents the latest situation with a span of 20 years of 4 major Chinese cities and similar researches have rarely been done.

1. INTRODUCTION

Most cities in different countries around the world have their own rail transit system. Some are known as underground while others are called metro. They all serve as a crucial part in people's daily life and commute. Moreover, the new generation rail transit system is generally perceived as environmentally-friendly and efficient in operation. As a result, many cities in China have also invested in the construction of their own urban transit systems. For example, Shanghai boasts the world's largest-scaled urban rail transit network with a total length of 772 kilometers since the inauguration of Line 15 at the beginning of 2021. It consists of metro system, APM (Automatic People Mover) rail system and the maglev system. In this essay, light rail transit, underground system as well as other forms of rail transit systems will all be referred to as metro. In the past 15 years, Shanghai has witnessed a growth in length of its metro system. During this period, the economic growth of the city has been a highlight nation wide. By the end of 2021, Shanghai will complete the metro network of the central area. This means the focus of metro network construction will turn to the outskirt of the city. However, in recent years, the cost of construction of metro system, especially that of the underground section has been skyrocketing. Also, the difficulty in construction is rising, for countless buildings have to be considered. Such problem is a prevailing phenomenon that not only Shanghai suffers. Many major metropolis in China has slowed down the construction.

Worse still, some cities with smaller scales find it difficult and even impossible to make profit in running of its metro. All of these problems raise questions about the relation between the scale of metro system and the city's economic growth. In this article, statistic methods will be applied to look into this question and find out whether it is still necessary to further construct new metro lines for metropolis.

2. LITERATURE REVIEW

2.1. Relative Researches Conducted Outside China

It is widely conceived that the development in transportation can have a positive effect on economy, from the nation level to urban level. A research in Kazakhstan analyzed the development of rail transport over the past years and noted that it is in line with the growth of national economy (Erdenovich et al., 2019).

Relative researches and reports are available in the scale of urban economy and its rail and other forms of transportation. Currently, there are numerous reports suggesting a close relationship between economic growth and metro transportation in urban areas. It has been reported that due to a lack of medium-speed transportation methods in the urban area of Manila, a loss estimated at 64 million dollars are happening every single day; and as a result, the infrastructure specifically for transportation is crucial for metropolis (Cerojano, 2015). On the other hand, the investment in rail transportation has been proved to be beneficial. A report in 2014 pointed out that big companies such as GE can invest their capital and other capabilities into transportation facilities around the world. In this process, the company can form a bond with its partner and gain profit from the value chain.

Some researches have pointed out the relationship between economic growth and the urban rail transportation. Graham, Couto, Adeney, and Glaister (2003) examined the economic scales and density in urban rail transport in 17 different cities by applying the Cobb-Douglas model that contained five variables including returns on traffic density, return on network size, both constant and non-constant, and technical change. They discovered that due to the scale of the urban rail transportation system, the operation can both self-support and bring positive effect to the urban economy. The researchers then introduced the labour productivity to further prove the relationship between large urban rail systems and output levels.

2.2. Researches in China

Many researches applying the same model have been conducted in China, and some of which are based on existing metro systems in different provinces and cities. Shen, Chong, Qiangming, and Liang (2020) analyzed the data of Guangzhou and Shenzhen - two major cities in Guangdong Province - from 2006 to 2017. They applied the classic Cobb-Douglas model and included variables ranging from the traditional macroeconomic factors to variables of investments from different entities such as investment from the government and direct investment from the foreign businesses. Researchers statistically analyzed the economic growth effect of rail transit construction and came to the conclusion that the contribution rates of rail transit construction to economic growth in both cities account for over 10% and the contribution rate of income level per capita to rail transit demand is around 70%. This provided evidence that metro network can be regarded as an important factor of economic growth in major cities in China. A similar research He and Yang (2021) was conducted based on the rail system in Chongqing, where researches found that the construction and development of Chongqing rail transit has played a positive role in promoting urban economic growth. The research pointed out that fixed asset should also be considered when explaining economic growth using transportation-related factors. According to the research, rail transit construction has directly increased the GDP of the city, promoting the urban employment level and optimizing the urban spatial structure. Also, the urban rail transit system has been proved to stimulate the development of relevant industrial chains, form strong investment and consumption demand, and create a large number of employment opportunities. Moreover, the research pointed out that the rail system has contributed to the city's 20% growth in travel industry. This research further indicates the possible increase that the urban rail system can bring to economic development and it pointed out an indirect way of improving economy - traveling. Besides the impact on the macroeconomic indexes, there has been empirical evidence about the direct income that the metro system can give rise to in an area, specifically on travel industry. Hu, Zhang, and He (2021) had an insight on a new business model that develops from the metro. They took a lake scenic area in Nanjing as an example, and pointed out the direct economic effect the TOD (transit oriented development) as a development model have on the revenue of the scenic spot. It is noted that a direct connection from and to the airport or other transportation hub is a favourable factor to the area, which has considerable economic potential to boost the revenue of the tourist attraction and indeed the whole area. Different methods have been applied in reports and researches. Li (2021) studied the relationship between the urban rail system and the economic development through applying a coupling coordination model. The degree of coupling coordination is related to multiple indexes introduced by the researcher and the formula of coordination sets an example for researches with similar topic. Additionally, Tang, Zhang, and Xiao (2019) took the perspective of the economic effect that the investment driven urban rail transit project can bring to a city. They thoroughly studied the correlation between industries in response of the expansion of the urban rail system in Changsha and pointed out that the investment driven development of the rail transit had holistically boom the economy and brought benefit to all industries of the city. Similarly, Liu, Yun, and Li (2016) analyzed multiple factors such as GDP, accessibility and investment on the metro system based on Shanghai metro system. The researchers applied the system dynamic model and pointed out that the despite a long period of construction, the operation of the metro can positively affect the economy of Shanghai. Furthermore, the research estimated the future development of the metro system. However, the sample size of this research is limited, and as a result, the conclusion the research reached is, to some degree not convincing.

2.3. The Aim of this Research

Given the multitudinous researches mentioned, it can be deduced that in most cities, the urban metro or rail transit can have positive effect on the city's economy in both direct and indirect way. However, similar researches have rarely been conducted based on 4 major cities including Shanghai, Beijing, Guangzhou and Hong Kong metro network simultaneously. This research will focus on the relationship between the aggregated length of metro lines of these cities respectively and the changes in economic growth based on updated data over the past 21 years--from 2000 to 2021.

3. METHODOLOGY - MODEL AND VARIABLES

As mentioned above, the Cobb-Douglas model is a common approach to be applied in the topic about economic growth. In both Graham's and Liu's research, this model has been applied. On the other hand, the coupling model applied in Li's research does not suit the research as the data needed across four cities is not available and the methodology requires some indexes that have no standard. The system dynamic model may not work as expected either, because it requires some variables that has not yet been commonly acknowledged and it cannot deal with the data of four cities. In terms of variables, the dependent variable is the GDP of a city. Given the data available, the traditional variables included in the Cobb-Douglas model are selected, which are labour (L), capital and technology. To better attain data, I used the capital invested in fixed asset (F) to represent the capital. This factor appeared in He and Yang's essay, in which they focused much on the fixed asset and the house prices. As for other explanatory variables, the main explanatory variable 'the total length of metro' (M), government expense (G) are included in the model.

$$Y = AK^{a}L^{\beta}.(\alpha + \beta = 1) \tag{1}$$

Equation 1 is the basic formula of the Cobb-Douglas model.

Given the variables mentioned above, we can get the modified Cobb-Douglas function.

$$GDP = A \cdot F^{a}L^{\beta}M^{y}G^{x} \tag{2}$$

Equation 2 is the modified function in which variables are added, including labour (L), capital invested in fixed asset (F), total length of metro (M), and government expense (G).

Take logs of (2) gives:

$$lnGDP = lnA + \alpha lnF + \beta lnL + \gamma lnM + \chi lnG \quad (3)$$

Equation 3 makes the percentile change in the variables linear, which is crucial for linear regression process.

Due to the similarity in scale of Shanghai, Beijing and Guangzhou. The scale adjustment will not be done by this stage, but this also means that Hong Kong will have to be eliminated due to a mismatch of GDP per capita and some other factors. Analysis that includes Hong Kong will be introduced later. Also, given the available data, there is a lack of the index to indicate the technology factor of a city. As a result, we assume that the production technology of urban firms can be approximated by a variable that is closely related to the technology state of the city, that is yearly research and development expense (R). This replacement resembles to a proxy variable. To redeem this effect, certain error term must be added to the model to prevent a potential diminishing of the unbiasedness. The estimating equation for the modified Cobb-Douglas function is:

$$lnGDP = \delta lnR + \alpha lnF + \beta lnL + \gamma lnM + \chi lnG + v \quad (4)$$

Equation 4 presents all the continuous production function parameters that are relevant to this study.

To distinguish the effect among different cities, dummy variables are also added into the model:

$$lnGDP = \delta lnR + \alpha lnF + \beta lnL + \gamma lnM + \chi lnG + v + \varphi_1 bj + \varphi_2 gz \quad (5)$$

Equation 5 includes the dummy variables that indicates whether significant difference exists city wise.

To stress the effect of the main variable M in different city, interactions will be added to the model.

$$lnGDP = \delta lnR + \alpha lnF + \beta lnL + \gamma lnM + \chi lnG + v + \varphi_1 bj + \varphi_2 gz + \iota_1 lnM \cdot bj + \iota_2 lnM \cdot gz \quad (6)$$

Thus, the OLS regression can be applied to Equation 6.

In terms of assumptions, though the sampling is not random, given that the amount of the sample, the consistency is assumed to exist; and we assume that variables should be independent from each other. Zero conditional mean assumption, and homoskedasticity assumption is also needed to limit the residual, and if the homoskedasticity assumption is not met, then it has to be dealt with.

4. DATA ANALYSIS

4.1. Sampling Data

This research is aimed to find out whether the growth in length of the metro line can have effect on the economy. To find out the answer, 4 major cities in China--that is Shanghai, Beijing, Guangzhou and Hong Kong are chosen. The general time period is 2000-2021. There is no missing data in the current pooled cross-sectional data base. As mentioned above, in the model of this stage, Hong Kong will not be included. The main reason is that among the four cities, Hong Kong enjoyed rapid development of infrastructure mainly before the sampled time, and during the selected period, the decreasing demand of new lines means that the growth of Hong Kong metro is clearly not as fast as the rest. This also means that Hong Kong lacks representativeness because it is a different type of city whose infrastructure construction has saturated and whose growth can no longer maintain the speed it used to be at. But for Shanghai, Beijing and Guangzhou, the scale economy of major cities in mainland China has just started to bring benefits to their respective economic growth. So in this stage, there will only be data collected from 3 cities. All data regarding the macroeconomic factors are extracted from the official release of the Bureau of Statistics of each respective city. The data of the total length of metro lines are taken from the figures publishing of the metro operating company. Due to a lack of accessibility when searching for some latest data of Guangzhou. The data set of Guangzhou will not include data of 2021.

The data base covering all five explanatory variables and one dependent variable has 65 sample observations in total. The overall descriptive statistics of the data is presented in the following Table 1.

Table 1. The descriptive statistics of the data.

Variables	Obs	Mean	Std. Dev.	Min	Max
GDP (100 million yuan)	65.000	16693.340	10984.860	2505.570	40205.060
M(km)	65.000	331.559	233.138	25.990	772.000
L (10 thousand people)	65.000	964.834	266.636	496.250	1376.200
R (100 million yuan)	65.000	665.275	647.449	29.060	3037.050
F (100 million yuan)	65.000	4719.050	2482.864	923.670	9800.760
G (100 million yuan)	65.000	3160.008	2501.926	258.600	8351.540
lnGDP	65.000	9.468	0.767	7.826	10.602
lnM	65.000	5.446	0.962	3.258	6.649
lnL	65.000	6.831	0.298	6.207	7.227
lnR	65.000	5.946	1.190	3.369	8.019
lnF	65.000	8.282	0.649	6.828	9.190
lnG	65.000	7.660	0.985	5.555	9.030

4.2. Estimation Results

Firstly, the OLS regression is operated and then it is tested whether the residual meets the homoskedasticity assumption. The Breusch-Pagan / Cook-Weisberg test for heteroskedasticity is applied:

H_{01}: Constant variance

Variables: fitted values of lnGDP (1)

$chi^2 = 15.53$;

$Prob > chi^2 = 0.0001$.

Because the p-value is less than 0.01. The H_{01} is rejected, and therefore, the residual has the problem of heteroskedasticity. As a result the heteroskedasticity-robust standard error should be applied in this regression. The estimates from the Cobb-Douglas production function are shown in Table 2.

Table 2. The regression result.

R^2	0.9953	P>t
Constant	5.318***(0.6965)	0.000
lnM	0.1633**(0.0740)	0.001
lnL	-0.2527**(0.1231)	0.099
lnR	0.2684**(0.1043)	0.000
lnF	0.0958 (0.0699)	0.280
lnG	0.3453***(0.0777)	0.000
bj	-0.8623***(0.2131)	0.000
gz	0.3845***(0.1537)	0.003
lnM·bj	0.1081***(0.0293)	0.001
lnM·gz	-0.0558**(0.0267)	0.017

Notes: (1) No. of observations = 65.
(2) Standard errors in parentheses.
(3) ***—significant at 0.01, **—significant at 0.05. The significance level is presented in the third column.

The key explanatory variable, the main focus of this research, the length of metro (M) is estimated at 0.1633 and it is statistically significant at 5% level. The effect of labour (L), and research and development expense (R), are estimated at -0.2527 and 0.2684, both of which are statistically significant at 5% level. The estimate of government expense (G) is 0.3453 and significant at 1%, while the investment in fixed assets (F) is statistically insignificant.

This means that over the past 20 years, in the 3 fast developing cities chosen, given that *ceteris paribus*, whenever the total length of metro in a city increase by its 0.01, statistically, the GDP of Shanghai in this year will increase by around its 0.1633, that of Beijing will increase by 0.2714 and that of Guangzhou will increase by 0.1075. Other factors is added to the models to make the explanatory variables more complete, to avoid the omitting variables; and they also prevent the overwhelming of the main explanatory variable. In terms of the variation among different districts, with Shanghai being the basis, the difference discovered in other cities is also presented in the Table 2. For example, Beijing witnesses a difference from Shanghai that is significant at 1% level, and this means development rate in general economy of Beijing is -0.7542 compared to that of Shanghai when *ceteris paribus*; even though its metro can contribute to its GDP growth by 0.1081 more than the proportion of the growth of Shanghai. Moreover, Guangzhou boasts an advance in development by 0.3287 over Shanghai, *ceteris paribus*, in which its metro system constitute a negative part that is -0.0558.

4.3. The Elaboration of the Estimation Results

4.3.1. Metro Length

As one of the important urban infrastructure, the impact of metro system on urban economy has covered all aspects of life and it has changed the original land use nature, affected the urban spatial pattern, brought considerable benefits to commerce, and created a good brand effect for the city. The full utilization of these resources is the economic value created by metro. While optimizing the urban natural ecological environment, compared with other urban infrastructure projects, urban metro system takes longer time from planning stage to construction stage and then to operation stage, and brings different economic benefits in different stages.

In the planning stage, the land's value-added benefits in the planning area covered by rail transit are obvious. The research of Knaap, Ding, and Hopkins (2001) shows that after the rail construction plan is published, the land price increases by 31% within 0.5 miles and 10% within 1 mile. Meanwhile, the already developed metro network has gradually become an indispensable symbol of urban modernization. The construction of metro network can effectively improve the urban brand effect. uring the construction period, the construction of metro can greatly promote the technical and economic development of the construction industry in the region and increase the business volume of other industries radiated by the construction industry. At the same time, due to the characteristics of large investments and long cycle during the construction of rail transit projects, a large amount of human and material resources need to be invested, which can effectively increase employment opportunities and improve the regional employment rate. This series of chain reactions gradually expand the departments involved in the investment efficiency, so as to promote the growth of regional economy.

In the operation stage, metro system not only has its direct operating income, but also has the characteristics of large traffic volume and higher speed compared with conventional public transport, which effectively enhances the regional accessibility and increase the efficiency of people's daily commute and traveling. This improvement in efficiency means that the residential function of the central urban area will be gradually dispersed; while other functions such as commerce, finance service and other functions can be further strengthened. The bearing pressure of the urban center has been considerably reduced, which has effectively stimulated the development and utilization of land. Moreover, with the continuous development of metro system, the layout of urban transportation network will be changed and the formation of urban three-dimensional structure will be affected, making the urban spatial distribution more reasonable. These are the main explanation of the effect on economy provided by the growth of metro. In this research, total length of metro system contains all effects in planning, construction and operation up till a certain year in the chosen period, considered and aggregated into the data of this year.

4.3.2. Other factors

Certainly, other factors involved in the model should contribute to the macroeconomic growth.

The labour factor is believed to be a conventional factor in the output of the economy. The original Cobb-Douglas model take this as a crucial factor alongside capital input. In this regression result, it is significant at 5% level. In other words, this may contribute to the growth of the GDP. It is easy to understand that with the increase of the labour force, assuming the returns to scale is constant, companies can increase its production, and the aggregated demand in the society can increase. As a result, the society can experience a growth in both supply and demand, and the GDP will grow at the same time.

The research and development expense. As is proved in the regression result. The research and development expense is a decent variable to represent the technology factor of the society. Assuming that the conversion rate remains at a constant level, the research and development expense will be directly linked to the technology factor of a society. In such case, the coefficient of the ln*R* is a constant value multiplying the original coefficient of the technology factor itself. In the case of this research, there is an assumption that the research and development expense may fluctuate around a certain constant level but within a bearable scope and this is why it is selected to represent technology. The technology factor is also a conventional focus of Cobb-Douglas model. As the technology enhances, the efficiency of the labour is increased, and the output can be increased as well. As a result, more products can be produced and the sales of manufacturers rise. This provides the momentum for economy to grow.

The government expense is also an important factor that Keynes put it into his model of output ($Y=C+I+G$). The government expense is crucial because it offers funds to certain industries that are in need. This reduces the cost of their production and essentially increases their revenue, so that they can reproduction on extended scale and further increase output. In this process, more products are made possible and the transaction quantity in the market can increase. Assume that the marginal revenue is constant of increasing, for quite a part of the government expense flows to industries with potentially much higher efficiency and yet smaller scales than optimal; in this case, the company can experience a rapid increase. The market can move towards the equilibrium point, and the economy, in this process, is increasing. The investment in fixed assets, according to the regression result, is not significant in contributing to the. This also means that it may not be a proper proxy variable for the conventional capital. In He and Yang's research, they considered this variable, but it may not fit the regression model in this research. In recent years, metropolis such as Shanghai, Beijing and Guangzhou have been constructing a large number of buildings for both residential and commercial purpose. In this case, the relation of this factor and the actual capital that manufacturers put into production may be weakened. Also, the investment in fixed asset may lagged and could not convert to actual increase in the total output of a society within a year. For these reasons, this variable could not explain the economic growth as expected in this regression model.

4.4. Flaws of the Method

The model applied before does gives a regression result, but it has several problems left to be dealt with.

The difference in scale of the chosen city is an issue of the regression model. Normally, to make data collected from different cities comparable, researchers tend to use *Variable/L* to eliminate the variation of scale between cities. However, in this case, it is difficult to use a unified variable to remove the scale difference for the total length of the metro, research and development, GDP output. As a result, only three of the four cities are involved in the model for there exists similarity between their scales. Changes of the model should be made to find solution for this problem.

To tell whether there are some omitted variables, Ramsey RESET test using powers of the fitted values of ln*GDP* is applied.

H_{02}: *model has no omitted variables.*

$F\ (3, 52) = 19.62;$

$Prob > F = 0.0000.$

According to this result, the null hypothesis H_{02} should be rejected, and therefore, there are omitted variables. Moreover, this means that relation exists between the explained variables and the residual, and the zero conditional mean assumption is violated and endogenity exists in the model. Improvement is needed to ease this problem.

Multiple co-linearity is another problem to consider in this regression analysis. VIF test is applied and the result is presented in the Table 3.

The VIF value is larger than 10, and this means that there is an issue of multiple co-linearity.

Table 3. The VIF test of the regression.

Variables	VIF	1/VIF
lnM	41.670	0.024
lnL	40.370	0.025
lnR	120.030	0.008
lnF	65.110	0.015
lnG	138.370	0.007
bj	194.940	0.005
gz	69.180	0.014
lnM·bj	148.220	0.007
lnM·gz	59.940	0.017
Mean VIF	97.540	N/A

5. IMPROVEMENT AND FURTHER RESEARCH

5.1. Improvement on Model

Due to the need to remove the effect caused by the different scales. Modification is needed based on the original variables. It is reasonable to use the change rate of each variables to substitute for the original variables, that is [v_t-$v_{(t-1)}$]/[$v_{(t-1)}$]. In this way, the original scale can be eliminated by the division. The modified variables are presented in the following Table 4.

Table 4. The modified variable names and meanings.

Variable Names	Meanings
GRGDP	Growth rate of GDP
CRM	Change rate of total metro length
CRLAB	Change rate of labour popolation
CRRD	Change rate of research and development cost
CRFIX	Change rate of fixed assets investment
CRGOV	Change rate of government expense

Furthermore, another benefit of the un-scaling is resolving the mismatch of samples of Hong Kong and 19 more samples extracted from Hong Kong can be included into the model. The Equation 7 will be the new model.

$$GRGDP = \delta \cdot CRRD + \alpha \cdot CRFIX + \beta \cdot CRLAB + \gamma \cdot CRMbenefitE7 + \chi \cdot CRGOV + v + \varphi_1 bj + \varphi_2 gz + \varphi_3 hk + \iota_1 CRM \cdot bj + \iota_2 CRM \cdot gz + \iota_3 CRM \cdot hk \quad (7)$$

This model includes all continuous variables, dummy variables and interactions. In essence, the explanation is still given that *ceteris paribus*, when the total length of the metro increase by 1% the GDP increase by a certain percent. As a result, model wise, this can be regarded as a feasible twist on the original model to adapt for this research topic. As mentioned before, this model still has to fulfill several basic assumptions. The variables should be independent from each other, and given the distribution features found in figures of change rates, it can be assumed that they are identically distributed (i.i.d.). Moreover, the zero conditional mean assumption is also a basic assumption when running the regression.

5.2. Expanded Data Base

As mentioned above, due to a lack of accessibility some latest data of Guangzhou and Hong Kong. The data of these two cities will not include data of 2021. The new data base covering all five explanatory variables and one dependent variable has 82 sample observations in total. The overall descriptive statistics of the data is presented in the following Table 5.

Table 5. The descriptive statistics of the new data.

Variables	Obs.	Mean	Std. Dev.	Min	Max
GRGDP	82.000	0.099	0.059	-0.067	0.243
CRM	82.000	0.113	0.156	0.000	0.822
CRLAB	82.000	0.029	0.041	-0.052	0.227
CRRD	82.000	0.146	0.115	-0.009	0.954
CRFIX	82.000	0.095	0.156	-0.302	0.857
CRGOV	82.000	0.127	0.110	-0.072	0.519

5.3. Regression Analysis and Comparison

The OLS regression is applied. The result of Breusch-Pagan / Cook-Weisberg test for heteroskedasticity is $Prob > chi^2 = 0.2977$ and consequently, the null hypothesis (constant variance) cannot be rejected, and therefore, it fulfills the homoskedasticity assumption. The result of this regression as well as the previous regression is presented in the following Table 6.

In the regression result of the second model, the R-square is realistically lower than that of the first model. The factor that stands for the total length of metro is still significant at 1% level, which is a good sign showing that the effect of the metro might be statistically reliable. However, the labour, research and development costs are no longer significant, while the previously insignificant fixed asset investment has become significant at 1% level. In terms of the differences among cities, the variation has been much more smaller than in the previous model, which is closer to the reality situation. One phenomenon is that Hong Kong, as expected, has a much lower speed in its economic growth compared with the other 3 cities. This can be explained by a limit of its natural resource endowment, and chiefly, its space. The limit of space means there can be no more possibility to construct more metro lines, and nor is it possible to shelter more people than it already has.

Table 6. Regression results of both models.

Variables	Model 1	P>t	Variables	Model 2	P>t
R^2	0.9953	N/A	R^2	0.6209	N/A
Constant	5.318***(0.7983)	0.000	Constant	0.0493***(0.0130)	0.000
lnM	0.1633***(0.0473)	0.001	CRM	0.1541***(0.0545)	0.006
lnL	-0.2527*(0.1504)	0.099	CRLAB	0.0714 (0.1305)	0.586
lnR	0.2684***(0.0650)	0.000	CRRD	0.0518 (0.043)	0.238
lnF	0.0958 (0.0877)	0.280	CRFIX	0.0812***(0.0292)	0.007
lnG	0.3453***(0.084)	0.000	CRGOV	0.1520***(0.0465)	0.002
bj	-0.8623***(0.2066)	0.000	bj	0.0296*(0.0159)	0.066
gz	0.3845***(0.1245)	0.003	gz	0.0146 (0.0169)	0.389
			hk	-0.030*(0.0156)	0.056
lnM·bj	0.1081***(0.0312)	0.001	CRM·bj	-0.0918 (0.0800)	0.255
lnM·gz	-0.0558**(0.0227)	0.017	CRM·gz	-0.0887 (0.0720)	0.222
			CRM·hk	-0.4914 (0.7072)	0.489

Note: (1) No. of observations = 82.
(2) Standard errors in parentheses.
(3) ***—significant at 0.01, **—significant at 0.05, *—significant at 0.1. The significance level is presented in the third and sixth column.

Apart from Hong Kong, the result also suggests that the fixed asset investment might be positive to the economic growth as well. In recent years, the construction speed of China has been outstanding. This means the construction cycle is largely shortened and the time during which an investment can create job opportunities is shortened as well. This can also cause an increase in the demand for investment in fixed assets, to maintain its effect that it used to possess. Despite that, the investment in construction of fixed assets still can have effect on the economic growth for the simple fact that it creates value. Especially in big cities such as Shanghai, where the price of the land has been skyrocketing since several years ago, thousands of resident purposed buildings can facilitates families and whenever the transaction is active, the economic growth is power.

The new model indeed gives a new insight into this research question, and the new result provides that reminds city planner and relevant officials who are involved in enacting macroeconomic policies of paying attention to these factors that otherwise would have been neglected.

5.4. Discussion and Limitations

It is true that the new model gives out a more realistic result, and if we look into the multiple co-linearity, the VIF test, we can find that in this model, there is no significant multiple co-linearity. As shown in the Table 7.

However, it does not mean this model is unexceptionable. The variable omitting problem is still not settled (Prob > F = 0.0296, taking the 5% level as the standard).

Table 7. The VIF test of the new regression.

Variable	VIF	1/VIF
CRM	3.890	0.257
CRLAB	1.550	0.646
CRRD	1.350	0.740
CRFIX	1.110	0.904
CRGOV	1.410	0.707
bj	2.610	0.383
gz	2.870	0.348
hk	2.440	0.409
CRM·bj	2.890	0.346
CRM·gz	3.840	0.260
CRM·hk	1.470	0.680
Mean VIF	2.310	N/A

Further researches can focus on finding out some more variables or indexes in order to better explain the growth of the economy. This also leads to another problem. That is the endogenity is still not eased. As a result, further research can try to find instrument variables for the secondary variables, or introduce lagged variables to ease this problem. Apart from this problem of the new model, there are also some other issues that remains in this research. The database of this research bears certain similarities with the panel data. In this research, it is regarded as pooled cross-sectional data, and therefore, the fixed effects of each cities are not eliminated statistically, even with dummy variables distinguishing the four cities. Further researches can try to expand the database and use panel data methods. For the selected secondary variables, they do not necessarily achieve the desired effect. For example, the investment in fixed assets may contain the capital that is invested into the construction of metro, and this means the correlation between explanatory variables exists, which violates the basic assumption of the OLS regression. Some modification is definitely needed to improve the independence of variables.

The causality is another problem that this research cannot completely settle. It is only common sense that a build-up area should have experienced some development before the demand for transportation with a larger capacity and higher speed exists. Also, the government could not provide enough fund to build metro lines unless the urban area is developed and the fiscal revenue can partially or completely support the huge expense. As a result, the two-way causality issue exists and this also indicates the existence of endogenity.

Furthermore, as is claimed in the assumption, the sampling is not random. The focus of this research is mainly on the metropolis of China, whereas smaller-scaled cities are not considered. Also, the effect of different stages - as mentioned before, planning, construction and operation - of metro construction up till a certain year is all combined in the data of this single year, and more detailed distinguish can be done to further identify the effect of each stage.

6. CONCLUSION

The metro system in big cities has been proved to have an effect on the economic growth of the city, but to achieve this, the city itself should have the momentum to further develop. If the construction of the city has saturated, the effect might be much limited. Also, a largely developed city with complete infrastructure may not step into further construction of new metro lines in the first place. Median-speed metro system is undoubtedly an important infrastructure that speeds up the transportation in urban area and this facilitates the increase of efficiency and ultimately, the growth of economy. There are also numerous researches focusing on the profit of loss in the operation of metro itself. If the metro system is actually making profit, there would certainly be less vacillation when government or other entities decides to invest in metro construction. Besides, in China, the promoting policies and the constraining policies on metro construction have been inextricably alternating over the past decades. Those policies that have constrained the construction might not necessarily be a result of policymakers' shortsightedness; instead, at that time, the fiscal situation might not be optimal and did not permit a colossal amount of fund being spent on a project with relatively long cycle, not to mention that the metro system may not be able to balance the book. Still, it has been guaranteed that big cities have the priority when it comes to the this type of investment due to a demand increasing in all likelihood. To sum up, for metropolis that is currently experiencing rapid growth and promises further possibility to keep growing space, natural resource and demography wise. Furthermore, to better match the construction of the metro system. Other facilities, such as residential or commercial purposed buildings, should follow the effect of the enhancement of transportation. This can ensure the area is fully utilized and start to create value in return of the convenience factor provided by metro lines.

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APPENDIX

Appendix presents the data and regression results. Because there are two stages in the research using different from of the original data, the appendix directly presents the calculated figures. In terms of regression results, Stata orders are also presented for readers' reference.

1. Data

1. Log data in the first model.

Year	lnGDP	lnM	lnL	lnR	lnF	lnG	SH	BJ	GZ
2000	8.479	4.174	6.614	4.340	7.534	6.434	1	0	0
2001	8.567	4.174	6.623	4.478	7.598	6.588	1	0	0
2002	8.665	4.174	6.675	4.628	7.690	6.777	1	0	0
2003	8.825	4.401	6.701	4.859	7.805	7.005	1	0	0
2004	9.000	4.530	6.730	5.137	8.034	7.241	1	0	0
2005	9.127	4.782	6.761	5.365	8.173	7.415	1	0	0
2006	9.269	5.137	6.786	5.556	8.275	7.503	1	0	0
2007	9.463	5.612	6.932	5.728	8.403	7.697	1	0	0
2008	9.584	5.616	6.960	5.892	8.482	7.870	1	0	0
2009	9.664	5.757	6.970	6.048	8.570	8.003	1	0	0
2010	9.793	6.108	6.995	6.177	8.579	8.103	1	0	0
2011	9.904	6.135	7.007	6.393	8.531	8.273	1	0	0
2012	9.967	6.147	7.017	6.521	8.567	8.339	1	0	0
2013	10.052	6.261	7.222	6.655	8.639	8.418	1	0	0
2014	10.137	6.357	7.219	6.759	8.702	8.502	1	0	0
2015	10.199	6.426	7.216	6.842	8.757	8.731	1	0	0
2016	10.305	6.431	7.219	6.956	8.818	8.842	1	0	0
2017	10.402	6.431	7.224	7.094	8.888	8.929	1	0	0
2018	10.492	6.516	7.227	7.215	8.939	9.030	1	0	0
2019	10.549	6.573	7.227	7.329	8.989	9.009	1	0	0
2020	10.564	6.573	7.209	7.378	9.087	9.000	1	0	0
2021	10.602	6.649	7.227	7.426	9.190	8.933	1	0	0
2000	8.095	4.189	6.429	5.048	7.168	6.094	0	1	0
2001	8.259	4.317	6.444	5.143	7.333	6.326	0	1	0
2002	8.418	4.499	6.521	5.392	7.503	6.443	0	1	0
2003	8.569	4.594	6.556	5.546	7.677	6.600	0	1	0
2004	8.741	5.078	6.750	5.759	7.835	6.800	0	1	0
2005	8.875	5.078	6.778	5.939	7.947	6.964	0	1	0
2006	9.034	5.078	6.824	6.071	8.123	7.168	0	1	0
2007	9.252	5.234	6.849	6.267	8.286	7.408	0	1	0
2008	9.377	5.346	6.888	6.430	8.255	7.580	0	1	0
2009	9.465	5.650	6.906	6.505	8.488	7.749	0	1	0
2010	9.613	5.888	6.939	6.712	8.611	7.907	0	1	0
2011	9.752	6.078	6.975	6.842	8.685	8.085	0	1	0
2012	9.853	6.149	7.010	6.969	8.774	8.212	0	1	0
2013	9.959	6.217	7.040	7.078	8.858	8.337	0	1	0
2014	10.040	6.280	7.053	7.146	8.931	8.417	0	1	0
2015	10.118	6.328	7.078	7.233	8.986	8.655	0	1	0

2016	10.205	6.375	7.107	7.303	9.043	8.765	0	1	0
2017	10.305	6.420	7.128	7.365	9.099	8.828	0	1	0
2018	10.407	6.492	7.121	7.534	8.995	8.919	0	1	0
2019	10.476	6.560	7.067	7.711	8.971	8.910	0	1	0
2020	10.494	6.560	7.138	7.752	8.992	8.870	0	1	0
2021	10.588	6.589	7.113	8.019	9.059	8.822	0	1	0
2000	7.826	3.258	6.207	3.369	6.828	5.555	0	0	1
2001	7.958	3.258	6.220	3.486	6.886	5.753	0	0	1
2002	8.078	3.553	6.229	3.551	6.917	5.858	0	0	1
2003	8.238	3.610	6.256	3.618	7.069	5.980	0	0	1
2004	8.407	3.610	6.293	3.796	7.207	6.103	0	0	1
2005	8.554	4.210	6.353	3.856	7.326	6.166	0	0	1
2006	8.720	4.453	6.396	3.939	7.436	6.327	0	0	1
2007	8.882	4.648	6.436	4.609	7.530	6.745	0	0	1
2008	9.032	4.811	6.481	4.861	7.652	6.906	0	0	1
2009	9.121	5.080	6.521	5.142	7.886	6.966	0	0	1
2010	9.272	5.296	6.567	5.260	8.091	7.305	0	0	1
2011	9.409	5.472	6.639	5.473	8.135	7.492	0	0	1
2012	9.488	5.472	6.678	5.572	8.232	7.494	0	0	1
2013	9.619	5.561	6.716	5.677	8.402	7.733	0	0	1
2014	9.689	5.561	6.774	5.811	8.495	7.834	0	0	1
2015	9.761	5.713	6.833	5.941	8.595	7.879	0	0	1
2016	9.829	5.846	6.888	6.126	8.649	7.954	0	0	1
2017	9.897	5.965	6.944	6.277	8.686	8.156	0	0	1
2018	9.952	6.132	7.005	6.397	8.689	8.281	0	0	1
2019	10.079	6.275	7.026	6.519	8.842	8.402	0	0	1
2020	10.127	6.275	7.054	6.653	8.937	8.529	0	0	1

a. Growth/Change rates in the second model

Year	GRGDP	CRM	CRLAB	CRRD	CRFIX	CRGOV	SH	BJ	GZ	HK
2001	0.093	0.000	0.009	0.148	0.067	0.166	1.000	0.000	0.000	0.000
2002	0.102	0.000	0.053	0.162	0.096	0.209	1.000	0.000	0.000	0.000
2003	0.174	0.256	0.027	0.259	0.121	0.256	1.000	0.000	0.000	0.000
2004	0.191	0.138	0.029	0.321	0.258	0.266	1.000	0.000	0.000	0.000
2005	0.135	0.286	0.032	0.255	0.148	0.190	1.000	0.000	0.000	0.000
2006	0.152	0.427	0.026	0.211	0.108	0.092	1.000	0.000	0.000	0.000
2007	0.215	0.608	0.157	0.188	0.136	0.214	1.000	0.000	0.000	0.000
2008	0.129	0.004	0.028	0.178	0.083	0.189	1.000	0.000	0.000	0.000
2009	0.083	0.151	0.011	0.169	0.092	0.142	1.000	0.000	0.000	0.000
2010	0.138	0.421	0.025	0.138	0.008	0.105	1.000	0.000	0.000	0.000
2011	0.117	0.027	0.012	0.241	-0.047	0.185	1.000	0.000	0.000	0.000
2012	0.065	0.011	0.010	0.137	0.037	0.069	1.000	0.000	0.000	0.000
2013	0.089	0.121	0.227	0.143	0.075	0.082	1.000	0.000	0.000	0.000
2014	0.089	0.101	-0.002	0.110	0.065	0.087	1.000	0.000	0.000	0.000
2015	0.064	0.072	-0.003	0.086	0.056	0.258	1.000	0.000	0.000	0.000
2016	0.112	0.005	0.003	0.121	0.063	0.117	1.000	0.000	0.000	0.000
2017	0.102	0.000	0.005	0.149	0.073	0.091	1.000	0.000	0.000	0.000
2018	0.094	0.088	0.002	0.128	0.052	0.107	1.000	0.000	0.000	0.000
2019	0.060	0.059	0.000	0.122	0.051	-0.021	1.000	0.000	0.000	0.000
2020	0.014	0.000	-0.018	0.049	0.103	-0.009	1.000	0.000	0.000	0.000
2021	0.039	0.079	0.019	0.049	0.109	-0.065	1.000	0.000	0.000	0.000
2001	0.178	0.136	0.016	0.099	0.180	0.262	0.000	1.000	0.000	0.000
2002	0.172	0.200	0.080	0.283	0.185	0.124	0.000	1.000	0.000	0.000
2003	0.164	0.099	0.035	0.167	0.189	0.169	0.000	1.000	0.000	0.000
2004	0.187	0.622	0.214	0.237	0.172	0.222	0.000	1.000	0.000	0.000
2005	0.144	0.000	0.028	0.198	0.118	0.178	0.000	1.000	0.000	0.000
2006	0.173	0.000	0.047	0.141	0.193	0.225	0.000	1.000	0.000	0.000
2007	0.243	0.169	0.025	0.217	0.177	0.272	0.000	1.000	0.000	0.000
2008	0.133	0.119	0.041	0.177	-0.030	0.188	0.000	1.000	0.000	0.000
2009	0.092	0.354	0.018	0.078	0.262	0.184	0.000	1.000	0.000	0.000
2010	0.160	0.268	0.033	0.229	0.131	0.172	0.000	1.000	0.000	0.000

2011	0.149	0.209	0.037	0.140	0.076	0.194	0.000	1.000	0.000	0.000
2012	0.107	0.074	0.035	0.135	0.093	0.136	0.000	1.000	0.000	0.000
2013	0.111	0.070	0.030	0.114	0.088	0.133	0.000	1.000	0.000	0.000
2014	0.085	0.065	0.014	0.071	0.075	0.084	0.000	1.000	0.000	0.000
2015	0.081	0.050	0.025	0.091	0.057	0.268	0.000	1.000	0.000	0.000
2016	0.091	0.047	0.029	0.073	0.059	0.117	0.000	1.000	0.000	0.000
2017	0.105	0.046	0.022	0.064	0.057	0.065	0.000	1.000	0.000	0.000
2018	0.108	0.075	-0.007	0.184	-0.099	0.095	0.000	1.000	0.000	0.000
2019	0.071	0.070	-0.052	0.194	-0.024	-0.008	0.000	1.000	0.000	0.000
2020	0.019	0.000	0.074	0.042	0.022	-0.039	0.000	1.000	0.000	0.000
2021	0.099	0.029	-0.025	0.305	0.069	-0.047	0.000	1.000	0.000	0.000
2001	0.141	0.000	0.013	0.124	0.059	0.218	0.000	0.000	1.000	0.000
2002	0.128	0.344	0.008	0.067	0.032	0.112	0.000	0.000	1.000	0.000
2003	0.172	0.059	0.028	0.069	0.164	0.129	0.000	0.000	1.000	0.000
2004	0.184	0.000	0.038	0.194	0.148	0.130	0.000	0.000	1.000	0.000
2005	0.159	0.822	0.062	0.062	0.126	0.065	0.000	0.000	1.000	0.000
2006	0.180	0.275	0.044	0.086	0.117	0.175	0.000	0.000	1.000	0.000
2007	0.176	0.215	0.040	0.954	0.098	0.519	0.000	0.000	1.000	0.000
2008	0.161	0.178	0.047	0.287	0.130	0.174	0.000	0.000	1.000	0.000
2009	0.093	0.308	0.040	0.324	0.263	0.062	0.000	0.000	1.000	0.000
2010	0.163	0.241	0.047	0.125	0.227	0.404	0.000	0.000	1.000	0.000
2011	0.147	0.192	0.075	0.237	0.046	0.206	0.000	0.000	1.000	0.000
2012	0.082	0.000	0.039	0.104	0.101	0.002	0.000	0.000	1.000	0.000
2013	0.141	0.092	0.038	0.111	0.185	0.271	0.000	0.000	1.000	0.000
2014	0.072	0.000	0.060	0.144	0.098	0.106	0.000	0.000	1.000	0.000
2015	0.075	0.165	0.061	0.138	0.106	0.046	0.000	0.000	1.000	0.000
2016	0.070	0.142	0.056	0.203	0.055	0.077	0.000	0.000	1.000	0.000
2017	0.071	0.127	0.058	0.164	0.038	0.225	0.000	0.000	1.000	0.000
2018	0.057	0.182	0.063	0.127	0.003	0.133	0.000	0.000	1.000	0.000
2019	0.135	0.154	0.021	0.129	0.165	0.129	0.000	0.000	1.000	0.000
2020	0.049	0.000	0.029	0.143	0.100	0.135	0.000	0.000	1.000	0.000
2001	0.005	0.030	0.016	0.140	-0.134	0.026	0.000	0.000	0.000	1.000
2002	0.023	0.054	0.018	0.064	-0.038	0.001	0.000	0.000	0.000	1.000
2003	-0.067	0.014	-0.006	0.133	0.022	0.035	0.000	0.000	0.000	1.000
2004	0.046	0.009	0.014	0.112	0.857	-0.021	0.000	0.000	0.000	1.000
2005	0.070	0.004	0.006	0.149	0.124	-0.038	0.000	0.000	0.000	1.000
2006	0.067	0.003	0.011	0.094	-0.203	-0.016	0.000	0.000	0.000	1.000
2007	0.095	0.000	0.016	0.039	0.668	0.024	0.000	0.000	0.000	1.000
2008	0.038	0.000	0.005	-0.009	-0.214	0.342	0.000	0.000	0.000	1.000
2009	-0.011	0.013	0.003	0.044	0.248	-0.072	0.000	0.000	0.000	1.000
2010	0.071	0.006	-0.008	0.037	0.337	0.030	0.000	0.000	0.000	1.000
2011	0.089	0.006	0.020	0.047	-0.147	0.208	0.000	0.000	0.000	1.000
2012	0.053	0.000	0.022	0.063	0.112	0.036	0.000	0.000	0.000	1.000
2013	0.050	0.006	0.019	0.054	-0.302	0.149	0.000	0.000	0.000	1.000
2014	0.055	0.000	0.005	0.071	0.200	-0.064	0.000	0.000	0.000	1.000
2015	0.063	0.012	0.007	0.092	0.002	0.073	0.000	0.000	0.000	1.000
2016	0.038	0.000	0.004	0.079	-0.029	0.061	0.000	0.000	0.000	1.000
2017	0.068	0.000	0.007	0.079	0.363	0.019	0.000	0.000	0.000	1.000
2018	0.066	0.014	0.008	0.150	0.021	0.129	0.000	0.000	0.000	1.000
2019	0.003	0.009	-0.003	0.076	-0.066	0.146	0.000	0.000	0.000	1.000
2020	-0.055	0.000	-0.020	0.078	-0.093	0.339	0.000	0.000	0.000	1.000

2. Regression Results

1. Stata order: regress lngdp lnm lnl lnr lnf lngov c.lnm#i.bj c.lnm#i.gz bj gz, robust.

Source	SS	df	MS
Model	37.472	9.000	4.164
Residual	0.175	55.000	0.003
Total	37.647	64.000	0.588
Number of obs =	**65.000**		
F (9, 55) =	1306.350		
Prob > F =	0.000		
R-squared =	0.995		
Adj R-squared =	0.995		
Root MSE =	0.056		

lnGDP	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
lnM	0.163	0.047	3.450	0.001	0.069	0.258
lnL	-0.253	0.150	-1.680	0.099	-0.554	0.049
lnR	0.268	0.065	4.130	0.000	0.138	0.399
lnF	0.096	0.088	1.090	0.280	-0.080	0.272
lnG	0.345	0.084	4.100	0.000	0.176	0.514
bj	-0.862	0.207	-4.170	0.000	-1.276	-0.448
gz	0.385	0.125	3.090	0.003	0.135	0.634
lnM·bj	0.108	0.031	3.460	0.001	0.045	0.171
lnM·gz	-0.056	0.023	-2.460	0.017	-0.101	-0.010
_cons	5.318	0.798	6.660	0.000	3.718	6.918

2. Stata order: regress grgdp crm crlab crrd crfix crgov bj gz hk c.crm#i.bj c.crm#i.gz c.crm#i.hk

Source	SS	df	MS
Model	0.173	11.000	0.016
Residual	0.106	70.000	0.002
Total	0.279	81.000	0.003
Number of obs =	**82.000**		
F(11, 70) =	10.420		
Prob > F =	0.000		
R-squared =	0.621		
Adj R-squared =	0.561		
Root MSE =	0.039		

GRGDP	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
CRM	0.154	0.055	2.820	0.006	0.045	0.263
CRLAB	0.071	0.131	0.550	0.586	-0.189	0.332
CRRD	0.052	0.044	1.190	0.238	-0.035	0.139
CRFIX	0.081	0.029	2.780	0.007	0.023	0.140
CRGOV	0.152	0.047	3.260	0.002	0.059	0.245
bj	0.030	0.016	1.870	0.066	-0.002	0.061
gz	0.015	0.017	0.870	0.389	-0.019	0.048
hk	-0.030	0.016	-1.940	0.056	-0.062	0.001
CRM·bj	-0.092	0.080	-1.150	0.255	-0.252	0.068
CRM·gz	-0.089	0.072	-1.230	0.222	-0.232	0.055
CRM·hk	-0.491	0.707	-0.690	0.489	-1.902	0.919
_cons	0.049	0.013	3.770	0.000	0.023	0.075