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# Transport Infrastructure, Growth, and Poverty Alleviation: Empirical Analysis of China*

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Using panel data of 1994-2002, as well as time series data of 1978-2002 in China, this paper examines the effect of transport infrastructure on economic growth and poverty alleviation, and finds out that the higher growth level in East and Central China comes, to a great extent, from better transport infrastructure. It turns out by Granger-test that transport investment especially that on roads constitutes a source of growth, but not vice versa. We compare the different effect of railways and roads in different regions, and find out that public investment on road construction in poor areas is of drastic importance to growth and poverty alleviation, and therefore should be a priority of policy choice.

*Key Words*: Transport infrastructure; Economic growth; Poverty alleviation.
*JEL Classification Numbers*: O1, H5.

## 1. INTRODUCTION AND LITERATURE REVIEW

Infrastructure has been proved to be of significant effect in economic take-off and long-run growth worldwide[1]. Generally speaking, infrastructure includes permanent sets of engineering construction, equipment, and machinery and the service they provide to production and household consumption. Infrastructure can be divided as economic and social ones, the former refers to the public utilities such as electricity, telecommunications, water supply, sanitary and drainage, public engineering construction such as dam and irritation system, and the transport facilities such as railway,

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[1] A. Maddison (2001) provides description in detail how the transport infrastructure such as road system, ports, ships and boats developed and contributed to the economic take-off in Western European countries.



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road, harbor and airport; while the latter refers to education, medicare and health services (World Bank, 1999; Zhang, et al, 2007). From the viewpoint of economic infrastructure, especially the transport infrastructure, this paper analyzes the inter-provincial difference of transport investment and how it is related with growth divergence in China, finds out that more investment in road system in poor areas will contribute to economic growth and poverty alleviation.

Our focus on transport infrastructure and its relation with growth and poverty alleviation is based on the following considerations: (1) Although many researchers have tried to relate transport infrastructure and long-run growth, very few have measured the contribution of transport infrastructure to growth, and their results contradict with each other in data processing and methodology and fail to bring consistent conclusions. (2) Most poor areas in China are located in the west, where transport system is severely deficient due to underinvestment. More empirics are in urgent need to figure out the relation between transport disparity and regional, urban-rural income inequality. (3) Transport investment takes a considerable share in public expenditure, yet there are still many unanswered, unsettled questions about transport infrastructure: what is the causation between transport investment and growth? What priority in transport investment should be chosen in different areas if we try to reduce difference in growth and alleviate poverty nationwide?

Although there have been abundant research on income disparity, poverty alleviation and development in poor rural areas for decades, the research on transport infrastructure and its relation with growth did not emerge until late 1980s. Aschauer (1989) classifies non-military government spending into core infrastructure (highway, passenger transport, airport, electricity and electric power supply, water supply and drainage), public construction (government office, police, fire fighter, court house), hospital, educational buildings, and maintenance of current facilities. Core infrastructure takes the largest share in non-military spending (55%), and contributes the most to productivity (the elasticity of output is 0.24, and highly significant). The others make small and quite insignificant positive effect on productivity. Aschauer's empirical research is original and has stimulated more empirics on infrastructure investment and growth across countries.

Recently more researchers, besides Aschauer, provide evidence for significant positive relation between infrastructure and growth. Munnell (1990a) estimates that the elasticity of non-military expenditure on growth is between 0.31-0.39. Using Cobb-Douglas translog aggregate production function and data of 48 States in the U.S. in 1970-1986, Munnell (1990b) measures the positive output elasticity of development of highway, water supply, and drainage, as well as investment on government offices, hospital, and educational buildings. Using data of manufacture industry of the U.S. in 1970-1989, Morrison & Schwartz (1996) find out that the contribution of public spending to manufacture (80% of GDP) is 20%-30%. Similarly, Nadiri & Mamuneas (1994) analyze the effect of public infrastructure investment on the cost structure and performance of manufacture, and provide evidence of significant positive productivity effect. Bougheas, Demetriades & Mamuneas (2000), based on the endogenous growth model (Romer,1987), introduce infrastructure as a technology which can reduce the costs of intermediate products, and conclude that infrastructure investment is positively related with cost-reducing specialization with manufacture data, and there is robust “inverted-U shape” non-monotonic relation between infrastructure investment and economic growth with cross-section data. Fernald (1999) examines the relation between construction of interstate highway in the U.S. in 1950s and 1960s and the growth in 1970s and proves that transport investment is productive. In the same time, he also points out that the productivity effect of transport to growth is once-and-for-all, instead of a permanent one. Easterly & Rebelo (1993) use cross-section data of more than 100 countries in 1970-1988 and find out strong correlation between investment in transport and telecommunications and growth, the contribution of transport to growth is between 0.59 and 0.66. Demetriades & Mamuneas (2000) use panel data of 12 OECD countries to find out positive long-run effect of transport investment on production and demand.

However, many others find out the relation between transport investment and growth is either insignificant or even negative. Holtz-Eakin (1994) classifies public investment into four sub-groups: education, road and highway system, drainage system and public utilities, he points put that although road and highway investment takes a share of 34.5% in total public spending, there is no significant evidence of its positive effect on growth. Others researchers find out that the positive effect of transport investment on growth is tiny or even neglectable (Hulten & Schwab,1991; GarciaMila, McGuire & Porter,1996). Tatom(1991,1993) shows there is no significant productivity effect of transport investment. Evans & Karras(1994) establish their empirics with panel data of public spending of the U.S. in 1970-1986, and find out that productivity effect of transport is insignificant, which offsets the positive effect of education and results in a gross negative effect of public spending on growth.

The research of transport investment and growth in developing economies is even fewer. Demurger (2001) examines data of 24 provinces of China (excluding municipalities under direct control of central government) in 1985-1998, and points out that the inequality of transport infrastructure is one of the main factors leading to growth inequality across provinces. Nagaraj et al (2001) resort to differences in availability of physical capital and infrastructure to explain the growth disparity in 17 states in India.

Deichmann et al (2002) find out the quality of transport infrastructure makes a difference in growth performance in different areas. Dercon et al (1998) find out that there is complementary relation between physical and human capital accumulation and transport development, which in all can contribute to growth and poverty alleviation.

**TABLE 1.**

Empirics of Infrastructure and economic growth: comparison

| authors | Production function | Samples | Estimation method | Main results |
|---|---|---|---|---|
| Aschauer(1989) | Aggregate production function | Time series data of the U.S. in 1949-1985 | OLS, including time variables | The output elasticity of non-military government spending is 39%, in which the investment on core infrastructure such as highway, electricity supply and telecommunications has a contribution share of 24%. |
| Munnell(1990b) | C-D production function and translog aggregate production function | Panel data of 48 States in the U.S. in 1970-1086. | OLS, excluding time variables | C-D function: the output elasticity of highway is 6%, while for other public capital, the elasticity is 12%. Translog production function: the output elasticity of highway is 4%, while for other public capital, the elasticity is −2%. |
| Ford & Poret(1991) | Aggregate production function | OECD, cross-section data | OLS | The average elasticity of infrastructure to TFP is 45%. |
| Hulten & Schwab(1991) | Aggregate production function | Time series data of the manufacture in the U.S. in 1951-1978 | OLS | The growth of TFP is the main source of growth. Public expenditure, labor input and capital accumulation determine the difference of growth across states. |
| Berndt & Hansson(1992) | Cost function | Time series data of Sweden in 1960-1988 | OLS, GLS | The increase in public infrastructure investment can result in decrease in cost of production and increase in profit, the contribution elasticity is 28.9%. |
| Easterly & Rebelo(1993) | Aggregate production function | Cross-section data of 1970-1988; Time-series data of 28 countries in 1970-1988 | OLS, IV | Transport and communications investment contributes positively to growth, and the correlation coefficient is between 0.59-0.66. While the coefficient of general public investment and growth is around 0.4. |
| Tatom(1993) | Aggregate production function | Time-series data of the U.S. in 1949-1991 | Granger test | The decrease in public investment results in decrease in productivity, not vice versa. |

| authors | Production function | Samples | Estimation method | Main results |
|---|---|---|---|---|
| Holtz-Eakin (1994) | Aggregate production function | Panel data of the U.S. in 1969-1986 | FE, GLS, IV | There is no productivity effect of public transport investment with region IV controlled; there is positive effect without region IV controlled. There is no inter-regional spillover effect of public spending. |
| Evans & Karras(1994) | Translog aggregate production function | Panel data of 48 States of the U.S. in 1970-1986 | REFE | There is gross insignificant negative effect of public investment on growth, in which the effect of education is positive and the effect of highway is negative. |
| Nadiri & Mamuneas(1994) | Cost function | Panel data of 12 manufacture sectors in the U.S. in 1955-1986. | OLS | In general, infrastructure investment has insignificant positive effect on cost reduction in manufacture. |
| MilaMcGuire & Porter(1996) | C-D function | Panel data of the U.S. in 1970-1983 | RE, FE | The contribution of highway to production is around 12%, higher than the effect of water supply and drainage (4-6%). There is no significant productivity effect of other public investment. |
| Pereira(2000) | VAR model | Time series data of the U.S. in 1956-1997 | Pulse reaction | Among core infrastructure, the investment return of electricity and transport is the highest, 16.1% and 9.7% respectively; both are higher than that of education and medicare. |
| Bougheas, Demetriades & Mamuneas(2000) | Aggregate production function | Cross-section data of four-digit codes of manufacture sectors in the U.S. in 1987 and 1997. | OLSIV | On the one hand, infrastructure, especially transport, contributes to specialization and long-run growth; on the other hand, infrastructure investment raises resource costs. In the end, there is non-monotone "inverted-U shape" correlation between them. |
| Demetriades & Mamuneas(2000) | Aggregate production function | Panel data of manufacture sectors in 12 OECD countries in 1972-1991 | OLS | The short-run returns of public infrastructure are between 10-20%; for longer period, the return is between 11-25%, in the very long-run, the return is between 16-36%. |
| Demurger(2001) | Aggregate production function | Panel data of 24 provinces in China in 1985-1998 | FE, RE, 2SLS | Transport and communication contribute the most to growth, second by education. |

Generally speaking, as we compare in Table 1, there is no consistent conclusion of the contribution of transport investment on growth, either in developed or developing economies. In this paper, we will use panel data of 1994-2002, together with time series data of 1978-2002 to analyze the relation between transport infrastructure and growth, and test the causation and robustness of the relation between them.

The paper is organized as follows. In Section 2, we will establish and calculate Gini coefficient, Theil coefficient, and coefficient of Variation of railway and road, through which to provide a description of transport inequality across provinces. In Section 3, we will examine the correlation between transport infrastructure and growth; specify the contribution of transport investment on growth and poverty alleviation. We will illustrate that transport, especially road investment is a main drive to economic growth, not vice versa. Section 4 concludes what we find and provides policy implications.

## 2. THE DISTRIBUTION OF TRANSPORT INFRASTRUCTURE IN CHINA

Within transport infrastructure in China, road and railway have been dominant for decades[2]. In this paper, we focus on road and railway to specify the distribution of transport, and find there is not only a huge gap in transport infrastructure between China and developed countries in many aspects such as the aggregate amount and density, but also considerable disparity and inequality across provinces.

### 2.1. Measurement of inequality of transport infrastructure

In order to measure the regional distribution and inequality of transport, we refer to the measurement of income inequality to establish Gini coefficient (Ginis), Theil coefficient (Theils) and coefficient of variation (CV) of transport. In our calculation, we add up the milages of road and railway of each province in 1978-2002, and use territory land area as weights to calculate the density of road and railway (in kilo./sq.kilo.), and then measure the Ginis, Theils and CV of road and railway (the results are listed in Table 2). Using the measurements, we can tell how unequal the distribution of transport is across provinces; the higher the coefficients, the more unequal in transport distribution.

Furthermore, we depict the dynamic trajectories of these inequality coefficients. In Figure 1,3, and 5, we can find during 1978-2002, the Ginis, Theils and CV of road density extends as "inverted N shaped" curves. Basically, from 1978 to later 1980s, with the accelerated increase of rural income and more investment in rural areas, road density was increased in

[2]Although there are five types of transport: road, railway, waterway, airlines and pipelines, most cargo and passenger transport are carried out by road and railway. For example, in 2004, 91.9% and 6.32% of passenger transport are carried out by road and railway respectively, 72.96% and 14.59% of cargo transport are carried out by road and railway respectively (China Transport Yearbook, 2005).

**FIG. 1.** The Ginis of roads density

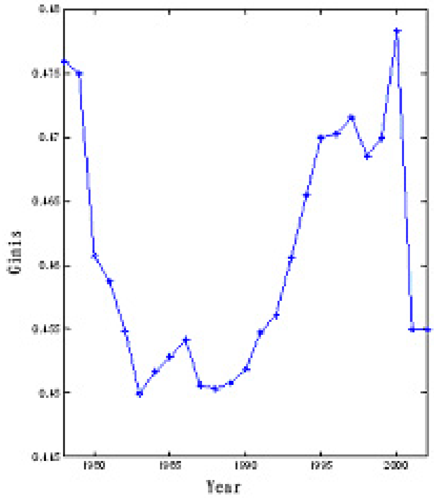
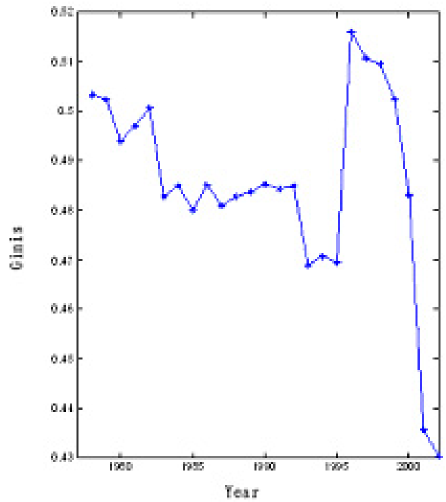



**FIG. 2.** The Ginis of railway density




poorer areas, which led to partial mitigation of the inequality of road. In the 1990s, the growth disparity between coastal and inland areas, urban and rural areas became larger, and the inequality of road density turned to rise significantly. There has been a tendency of decreasing inequality of road density since 2000, when the central government invests more heavily in infrastructure in the west and poor areas.

**FIG. 3.** The Theils of roads density

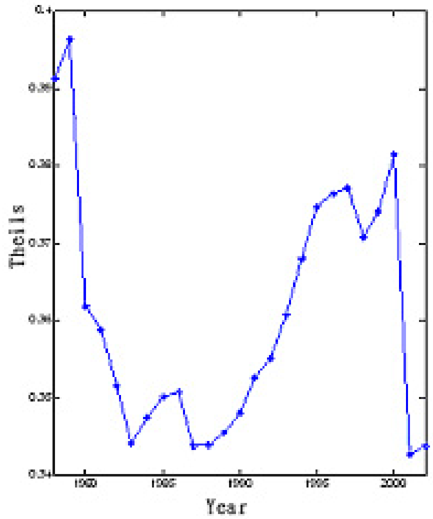
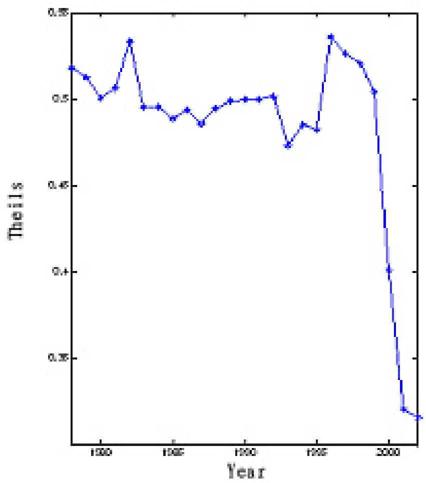



**FIG. 4.** The Theils of railway density




As for the distribution of railway in Figure 2,4, and 6, we can figure out irregular "inverted U shaped" curves overtime, in which the decreasing part after late-1990s turns out to be very significant in all the figures. We can find that before mid-1980s, although the inequality of road was decreasing, the distribution of railway was still unequal nationwide. This

**FIG. 5.** The CV of roads density

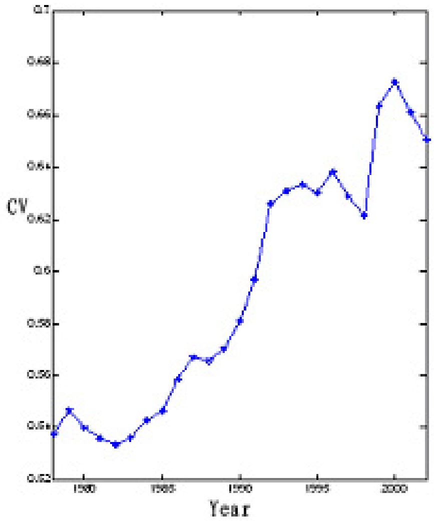
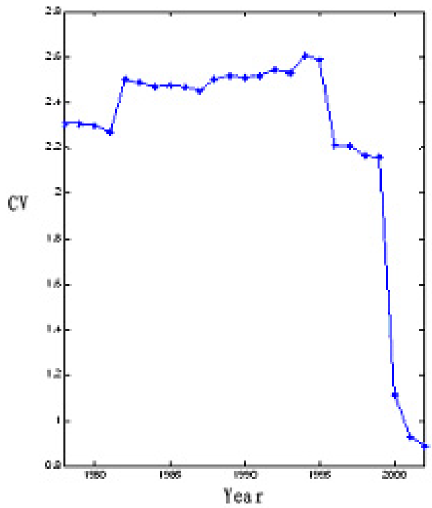



**FIG. 6.** The CV of railway density




is due to the difference in financing mechanism and management. The financing mechanism of road is much more diversified and the construction and management of lower-level road is decentralized, while the construction and financing of railway is highly centralized. Before the end of 1990s, the

**TABLE 2.**

The inequality indexes of road and railway in China

| Year | Ginis (Road) | Theils(Road) | CV(Road) | Ginis (Railway) | Theils(Railway) | CV(Railway) |
|---|---|---|---|---|---|---|
| 1978 | 0.4759 | 0.3913 | 0.5376 | 0.5033 | 0.5176 | 2.3091 |
| 1979 | 0.4750 | 0.3964 | 0.5469 | 0.5024 | 0.5127 | 2.3087 |
| 1980 | 0.4607 | 0.3620 | 0.5402 | 0.4940 | 0.5009 | 2.2997 |
| 1981 | 0.4586 | 0.3589 | 0.5360 | 0.4971 | 0.5061 | 2.2696 |
| 1982 | 0.4548 | 0.3517 | 0.5336 | 0.5006 | 0.5331 | 2.5022 |
| 1983 | 0.4499 | 0.3442 | 0.5364 | 0.4828 | 0.4949 | 2.4874 |
| 1984 | 0.4517 | 0.3475 | 0.5426 | 0.4849 | 0.4956 | 2.4705 |
| 1985 | 0.4528 | 0.3501 | 0.5464 | 0.4800 | 0.4883 | 2.4783 |
| 1986 | 0.4541 | 0.3509 | 0.5590 | 0.4851 | 0.4940 | 2.4685 |
| 1987 | 0.4506 | 0.3438 | 0.5672 | 0.4810 | 0.4857 | 2.4511 |
| 1988 | 0.4503 | 0.3440 | 0.5660 | 0.4828 | 0.4946 | 2.5002 |
| 1989 | 0.4508 | 0.3456 | 0.5702 | 0.4837 | 0.4987 | 2.5202 |
| 1990 | 0.4518 | 0.3481 | 0.5809 | 0.4853 | 0.4994 | 2.5105 |
| 1991 | 0.4547 | 0.3527 | 0.5971 | 0.4843 | 0.4997 | 2.5205 |
| 1992 | 0.4560 | 0.3551 | 0.6260 | 0.4850 | 0.5019 | 2.5431 |
| 1993 | 0.4606 | 0.3608 | 0.6308 | 0.4690 | 0.4733 | 2.5315 |
| 1994 | 0.4654 | 0.3681 | 0.6336 | 0.4707 | 0.4852 | 2.6064 |
| 1995 | 0.4699 | 0.3748 | 0.6299 | 0.4694 | 0.4825 | 2.5918 |
| 1996 | 0.4702 | 0.3765 | 0.6384 | 0.5161 | 0.5358 | 2.2124 |
| 1997 | 0.4715 | 0.3771 | 0.6288 | 0.5107 | 0.5258 | 2.2097 |
| 1998 | 0.4685 | 0.3709 | 0.6214 | 0.5096 | 0.5207 | 2.1671 |
| 1999 | 0.4699 | 0.3741 | 0.6637 | 0.5025 | 0.5044 | 2.1581 |
| 2000 | 0.4782 | 0.3815 | 0.6729 | 0.4831 | 0.4010 | 1.1161 |
| 2001 | 0.4549 | 0.3427 | 0.6612 | 0.4357 | 0.3207 | 0.9338 |
| 2002 | 0.4549 | 0.3439 | 0.6507 | 0.4304 | 0.3162 | 0.8913 |

Data source: "Comprehensive Statistical Data and Materials on 50 Years of New China" (NBS,2002); "China Statistics Yearbook" (NBS,1982-2005). Calculated by the authors.

inequality of railway was large because of the targeted investment in railway in the east areas, and it has been reduced ever since late 1990s due to the "West Development Strategy".

### 2.2. The regional and urban-rural disparity in transport infrastructure

There is sharp disparity in the density of railway and road in different areas, parrelling with the difference in economic growth levels. By the end of 2004, the railway milages in the east, central and west areas are 21037, 26311 and 27062 kilometers respectively, while the densities of railway are

**TABLE 3.**

A comparison of road milages and quality: 2004

| | Road milages (thousand kilometer) | Increase to last year (thousand kilometer) and growth rate (%) | Highway milages (kilometer) and yearly increase (kilometer) | High-level road milages (thousand kilometer) and yearly increase (kilometer) |
|---|---|---|---|---|
| East | 606.8 | 27.7 (4.8%) | 17146 (1445) | 142.1 (11650) |
| Central | 642.3 | 18.5 (3%) | 10152 (1837) | 104.3 (11560) |
| West | 621.6 | 14.7 (2.4%) | 6991 (1262) | 53.1 (4740) |

Data source: "China Transport Yearbook", calculated by the authors. High-level roads include road with technical standard of Class II or higher.

198158 and 40 kilo/sq. kilo. Although the railway milage in the west has surpassed other areas, the density of railway in the west lagged far behind others. At the same time, the road milages in the east, central and west areas are 606.8, 642.3 and 621.6 thousand kilometers, taking shares of 32.44%, 34.33% and 33.23% in national road milages. Similarly, although the gap in absolute milages is not large, the difference in road density is significant, 9.23 kilo/sq.kilo in the west compared with 57.02 in the east and 38.46 in the central. Furthermore, there are much fewer highways and high-level roads in the west areas, which show a big gap in road quality in addition to density (see Table 3 for detail).

There is significant difference in financing mechanism of transport investment, which in turn, reinforces the gap in milages and quality. For high-level roads, especially highways, the returns of investment come from tolls and fees. In the east areas with higher per capita vehicle possession rate, and higher road density, it is much easier to attract investment at home and abroad to finance the road construction. While in poorer areas where more roads are in urgent need, it is difficult for the local government to finance road construction due to the low road density and few vehicles, which in turn, results in a vicious cycle of "income poverty and transport poverty". The regional difference in road construction has been enlarged because more financing has been targeted to the richer east areas. During 1998-2001, the east areas take an average share of 50% in total road construction (see Table 4). Noteworthyly, more transport investment has been moved to the central and west poorer areas in recent years with the implementation of "Big West Development" strategy.

The rural area is even more lagged behind in road construction. On the one hand, the complex geographical condition makes construction costs higher, on the other hand, the return of road investment is lower and the payback period is much longer. Due to the survey of transport in 2002[3],

[3]The Second Nationwide Road Survey Bulletin, National Bureau of Statistics (NBS): http://www.stats.gov.cn/tjgb/qttjgb/qgqttjgb/t20020331_15498.htm

**TABLE 4.**

The share of road investment in different areas

| Years | East (%) | Central (%) | West (%) |
|---|---|---|---|
| 1998 | 54.8 | 23.9 | 21.2 |
| 1999 | 52.1 | 25.2 | 22.6 |
| 2000 | 49.2 | 26.8 | 24.0 |
| 2001 | 45.2 | 30.6 | 24.3 |
| average | 50.0 | 26.8 | 23.1 |

Data source: "China Transport Yearbook" (2005). Numbers calculated by the authors

the rural road milages take 47.66% in national road system, and most rural roads are of lower technical levels. There are still a great amount of villages without availability to any paved road in the northwest and southwest.

## 3. TRANSPORT, GROWTH AND POVERTY ALLEVIATION: EMPIRICAL ANALYSIS

### 3.1. Regression model

Based on Demurger (2001), and taking the road construction as a key factor in regional income disparity, we construct the regression model as follows:

$$y_{it} = \alpha_i + \beta X_{it} + \gamma Z_{it} + \phi W_{it} + \mu_{it} \quad (1)$$

Where $i = 1, \ldots, 28$, represents different provinces; subscript $t$ represents 9 time series between 1994 and 2002, 252 samples in total. We choose the starting year of 1994 after fiscal decentralization to take into account systematic policy adjustment so that we can focus on the effect of transport on growth and poverty alleviation. In our model, we measure $y$ as log (per capita GDP) instead of the growth rates as in Demurger(2001), and by this means, we combine all the effect of path-dependence and regional specific characteristics into parameter $\alpha_i$. $X$ represents neo-classical production factors, which are measured by the growth rate of labor force and the ratio of physical accumulation to GDP. $Z$ represents the initial condition of growth, which is measured by log of real per capita GDP in 1990 ($y_0$) and the share of people with schooling of 9 years or more in the total population (hc). We use $W$ to depict the difference in market scale and transport in different areas, measured by population density, road density and railway density in different regions. Besides, we add quadratic indexes to test the scale effect or congestion effect of transport (column 1 in Table 5). We also compare different regression results to figure out whether there is substitution effect or complementary effect between road and railway networks (column 2 and 3 in Table 5).

### 3.2. Sample description

All data we use in this paper are complied from "Comprehensive Statistical Data and Materials on 50 Years of New China" (NBS,2002); "China Statistics Yearbook" (NBS,1982-2005); "China Population Statistics Yearbook", and "China Education Yearbook". The per capita GDP for different provinces have been adjusted with provincial GDP deflator. The statistical description of all samples is listed in Appendix 1.

**FIG. 7.** The standard deviation of log real GDP per capita

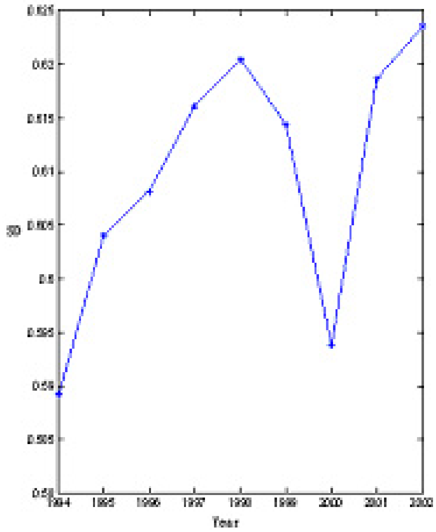



Figure 7 depicts the dynamic change of standard deviation of per capita real GDP overtime. We can find that the disparity of per capita real GDP is enlarging during 1994-1998, and turns to temporary decrease during 1998 and 2000. However, the disparity rises again after 2000 and surpasses the summit level in 1998. Although physical capital investment is regarded as an important factor in growth, the standard deviation of investment (Figure 10) does not show similar change as what we find in Figure 7.

Figure 8 depicts the standard deviation of road density during 1994-2002, which is increasing continuously overtime. While the standard deviation of railway density (Figure 9) in the same period is quite stable during 1994-1998 period, and decreasing significantly thereafter. Furthermore, we find out there is significant "inverted U shape" relation between railway density and growth of per capita GDP (Figure 11). In Figure 12, road density is

**FIG. 8.** The standard deviation of road density

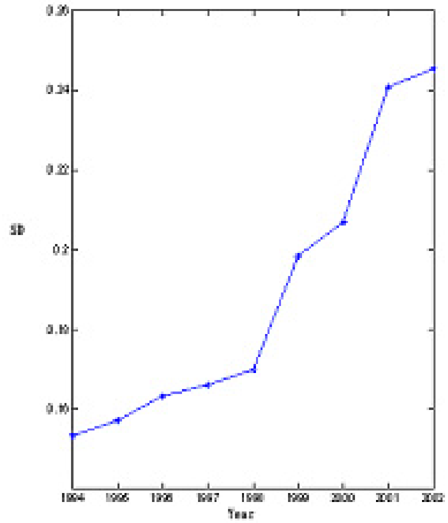
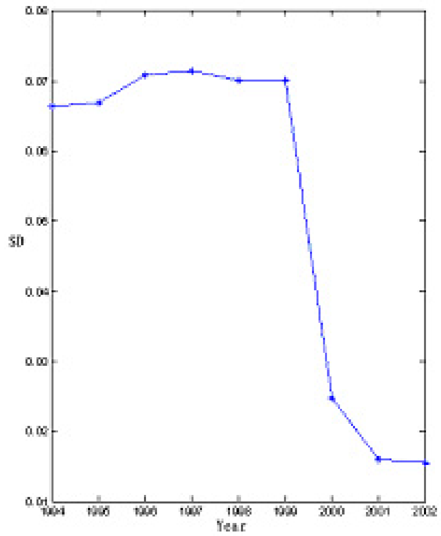



**FIG. 9.** The standard deviation of railway density




consistently related with economic growth because of the increasing returns of network effect. In summary, there is close, complex, non-linear relation between transport construction and growth. Why significant disparity and

**FIG. 10.** Growth ratio of investment

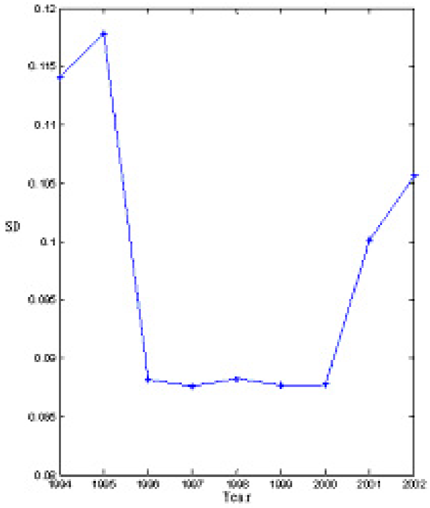
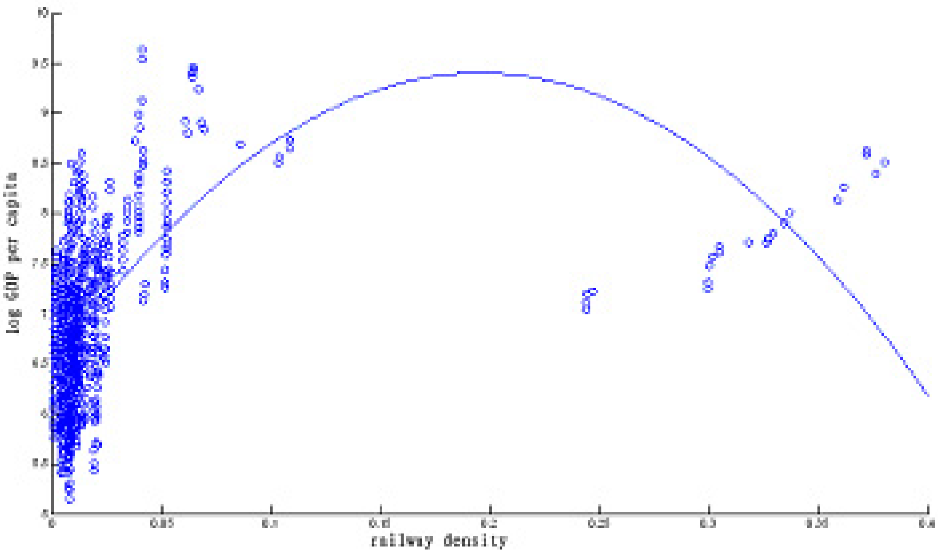
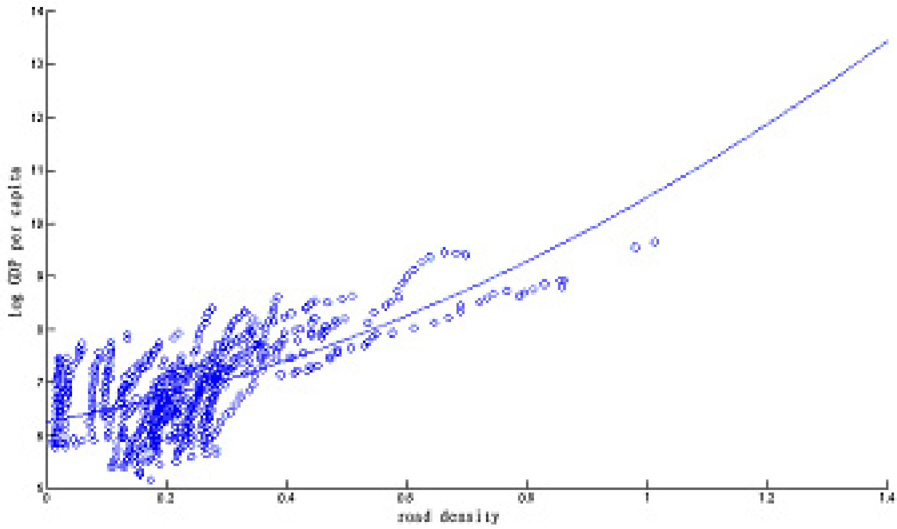



**FIG. 11.** Relationship of railway and GDP per capita




stratification in income distribution has been evidenced across provinces? The examination of difference in transport infrastructure will provide us a new viewpoint of explanation.

**FIG. 12.** Relationship of road and GDP per capita



### 3.3. The relation between transport and growth: regression results

Based on equation (2), we establish regression to figure out the correlation between transport and growth (results listed in Table 5).

From regression (1), we find that the effects of the initial human capital level (hc) and initial real per capita GDP ($y_0$) are quite insignificant (low T-statistics). The growth of labor force (lab) has insignificant negative effect on economic growth, which means what matters is not the quantity, but quality, of labor. The population density (dpop), representing market scale, has tiny effect on growth with a very small coefficient (0.0005). Both capital accumulation (k) and transport (road, railway) exhibit very significant effect on growth, and the output elasticity of capital is as high as 0.65.

We also find that the coefficients of quadratic items of road and railway are both negative (−2.067 and −23.482 respectively), showing “inverted U shape” relation between transport and growth. We can calculate that the increasing return effect of road will turn to decreasing return when the road density reaches 1.02 kilo/sq.kilo., and the railway density of 0.48 kilo/sq.kilo.remarks a turning point, after which there will be decreasing returns to scale of railway construction. For railway, the results are consistent with what we find in Figures 11. The construction of railway should have very significant positive effect since the current railway densities are

0.0198, 0.0158 and 0.040 respectively in the east, central and west areas of China, all quite below the turning point. As for road, the national road density is by far below the turning point, and we can only find out positive relation between road construction and growth in Figure 12. However, the regional disparity in road density is enormous. The road density in Shanghai is 1.01 in 2002, which is very close to the turning point; while it is 0.88 and 0.86 respectively in Beijing and Tianjin, 0.56 for Guangdong, and on average it is less than 0.50 in central areas, and even less than 0.18 in the west. Therefore more investment in road system in the east, especially the coastal metropolitan cities will be subject to congestion effect in the near future, while more investment in road in poorer central and west areas will be exhibiting continuous economy of scale.

In regression (2) and (3), we consider road and railway separately. It turns out that the coefficient of quadratic road is −3.32, and satiation point of road density is 0.765 kilo/sq. kilo, after which more investment in road will result in congestion effect. Similarly, the coefficient of quadratic railway is −25.96, and the satiation point of railway density is around 0.2 kilo/sq. kilo. Compared with the result in regression (1), the satiation points of density become lower in regression (2) and (3). We can conclude that there is complementary effect between road and railway construction, and the accommodation of different transport facilities can result in higher network effect.

From the fixed effect of different areas, we find that when the initial conditions and transport infrastructure have been controlled, the average fixed effect coefficients are 7.368, 7.22 and 7.126 for the west, central and east areas respectively (regression 1), from which we can conclude that there is significant advantage coming from transport infrastructure in the relatively developed areas. Furthermore in regression (3) when only railway is taken into account, we find that advantage of east area is much larger than that of other areas, while when only road is taken into account (regression 2), the advantage in the east is less significant.. So we can conclude that the development in the west should have been much higher if the transport situation were better, and in order to improve development in poorer areas, the priority should be put on road construction.

### 3.4. Causation test and robustness analysis

Although we find out significant positive relation between transport and the returns of physical capital, human capital and growth level from the above regressions, it is a puzzling and disputing question of whether transport is the cause of growth or vice versa (Aschauer,1989; Tatom,1991; Fernald,1999). Zhang (2007) regards the increase in per capita GDP as a main drive for better transport infrastructure in the east. However, we cannot tell the causation before we try Granger-test using national data. Besides,

**TABLE 5.**

Transport infrastructure and economic growth: regression

| $\ln y$ | Regression (1) | Regression (2) | Regression (3) |
|---|---|---|---|
| Fixed effect (east)* | 7.126 | 5.841 | 6.565 |
| Fixed effect (central) | 7.22 | 6.041 | 6.563 |
| Fixed effect (west) | 7.368 | 6.225 | 6.472 |
| dpop | 0.0005 (2.058) | 0.001 (3.326) | 0.001 (4.85) |
| road | 4.224 (10.343) | 5.079 (12.427) | |
| road$^2$ | −2.067 (−4.512) | −3.322 (−7.45) | |
| railroad | 11.258 (4.512) | | 10.418 (3.11) |
| rr$^2$ | −23.28 (−4.067) | | −25.960 (−3.35) |
| lab | −0.04 (−0.14) | −0.235 (−0.84) | −0.333 (−0.90) |
| $k$ | 0.656 (3.39) | 0.293 (3.30) | 0.848 (3.30) |
| hc | 0.217 (2.83E-15) | | |
| $y_0$ | $-0.493\ (-1.74E-14)$ | | |
| $R^2$ | 0.997 | 0.997 | 0.979 |
| Adjusted-$R^2$ | 0.996 | 0.996 | 0.976 |
| F | 7999 | 19472 | 2600 |

* The fixed effects in this table are average effects of the provinces in the East, Central and West areas. For the specific fixed effect of each province, see Appendix 2 for detail.
Note: Due to the insignificant effect of hc and $y_0$ in regression (1), we ignore these two variables in regressions (2) and (3). The numbers in parentheses are T-statistics.

we need to test the robustness of our results through using time series data from longer period or different indicators for transport situation and economic growth.

*3.4.1. Causation: transport and economic growth.*

Ever since Ashauer(1989)'s research on transport and growth with time series data in U.S., there has been criticism about the "common trends" in his econometric model (Eisner,1991; Grimlich,1994). Tatom (1993) introduces a test of a series of lagged variables and finds that the decrease of investment in infrastructure should be the result of the decrease of productivity, not vice versa. Ashauer (1993) points out that the output elasticity of infrastructure is positive, but the output elasticity of other public spending is tiny or negative, thus there is no consistent causation as Tatom shows. Fernald (1999) finds that as the increase of investment in transport, the industries with higher intensity of vehicle usage turn to grow faster, which indirectly proves that investment in transport infrastructure is the reason of growth.

We use Granger test to examine the causation between transport infrastructure and growth. Because it is improper to use panel data for Granger test, we establish time series data of economic growth and transport development during 1978-2002 instead. We use the standard deviations of logarithm of real per capita GDP (sdlnrjgdp), Ginis of road (ggini) and Ginis of railway (tgini), remove the time inconsistency with first differentiation, and make Granger test. Through the above measurement of variables, we can not only test the causation relation, but also establish a direct correlation between transport inequality and income inequality across provinces overtime.

**TABLE 6.**

Transport inequality and income inequality across provinces: Granger test

| Null Hypothesis: | F-Statistics | Probability |
|---|---|---|
| sdlnrjgdp is NOT the Granger causation of ggini | 5.2572 | 0.0323 |
| ggini is NOT the Granger causation of sdlnrjgdp | 0.7343 | 0.4012 |
| Null Hypothesis: | | |
| tgini is NOT the Granger causation of sdlnrjgdp | 2.0887 | 0.1632 |
| sdlnrjgdp is NOT the Granger causation of tgini | 0.0196 | 0.8899 |

From Table 6, we find that unequal distribution of road (ggini) is the reason of income inequality, not vice versa. However, as for the unequal distribution of railway and income inequality, we find causation effects on both directions, i.e. each one is the causation for the other. The finding is consistent with the above regression in that the investment of road system in poorer areas will be quite effective in eliminating disadvantage and poverty. We also prove from the Granger test that it is correct to explain the regional disparity in growth with the inequality in transport infrastructure (especially inequality in road investment), not vice versa.

*3.4.2. Adjustment of time periods and variables.*

Based on the tested causation effect, we use the Ginis of road as independent variable to explain the income disparity. Because the coefficients of human capital (hc) and initial income ($y_0$) are insignificant as we find in Table 5, we eliminate these variables in regression. The adjusted econometric model is as follows:

$$y_t = \alpha + \beta k_t + \gamma lab_t + \lambda dpop_t + \tau rgini_t + \mu \tag{2}$$

where $t$ represents the year between 1978 and 2002. $y_t$ measures the income inequality, which is calculated as the logarithm of standard deviation of real per capita GDP. $k_t$ and $lab_t$ are physical capital and labor force respectively, the former is calculated by the average of the percentage of capital formation in GDP in different years and provinces, the later is the average growth rate of labor force. *dpop* , the average density of population, *rgini* is used to measure market size. is Ginis of transport, including Ginis of road and Ginis of railway. The regression results are listed in Table 7.

In regression 1 in Table 7, the inequality of investment in road is positively related to income inequality across provinces, but the relation is insignificant. In other words, more investment in road in poorer areas may help poverty alleviation only to a certain extent, or the improvement in road facilities in poor areas is a necessary, but not a sufficient condition for growth and poverty alleviation. The increases in labor force and physical capital tend to enlarge regional income disparity because more physical capital and labor have been mobilized to relatively developed areas. We also find that the increase of population density and market size contributes to reducing income inequality because of the trickling-down effect.

Because there is bilateral causation between railway and growth based on Granger test, we establish regressions 2 and 4 to estimate how each factor affects the other. We find that although inequality of railway and income inequality have negative effect on each other, income equality is a less significant explaining variable for railway inequality in that the F-test of regression 4 is nearly unacceptable. Generally speaking, during the period considered, the more inequality of railway distribution is favorable for reducing economic inequality. It seems to be a puzzling result; however it is consistent with what we have analyzed above. There is "inverted U shape" relation between railway construction and growth, the railway densities in most areas are much below the satiation point (nationally, 0.48 kilo/sq.kilo), more investment in railway construction is needed to explore the economy of scale.

Comparing the effect of growth of labor force and capital investment on economic growth, the contributions differ significantly in different regressions. We can find that if we only take into account Gini coefficient of road, which is quite unequal, then labor growth and capital investment cannot help to reduce regional income inequality (regression 1). When we take railway into account, then labor increase and capital investment can help to reduce income inequality, mostly through providing facilities of mobility of labor and capital, and through spillover effect and trickling-down effect (regression 2 and 3).

It turns out from a comparison between Table 6 and 7 that there is consistent relation between transport infrastructure and economic growth,

**TABLE 7.**

Inequality of transport and income inequality across provinces

| | (1) | (2) | (3) | (4)* |
|---|---|---|---|---|
| sdlnrjgdp | | | | −0.7271 (−1.7456) |
| c | 0.0099 (3.1776) | 0.0095 (3.8416) | 0.0117 (3.9532) | 0.0051 (0.8050) |
| dpop | −0.0018 (−3.3996) | −0.0018 (−4.4203) | −0.0023 (−4.2946) | −0.0014 (−1.2944) |
| ggini | 0.01238 (0.0375) | | 0.4821 (1.3079) | |
| tgini | | −0.1901 (−1.7456) | −0.2890 (−2.2068) | |
| lab | 1.80E-05 (0.0010) | −0.0070 (−0.4244) | −0.0069 (−0.4262) | −0.0365 (−1.1650) |
| k | 0.0130 (0.1756) | −0.0074 (−0.1108) | −0.0500 (−0.6819) | −0.1017 (−0.7892) |
| $R^2$ | 0.4847 | 0.5559 | 0.5944 | 0.2050 |
| Adjusted $R^2$ | 0.3762 | 0.4624 | 0.4817 | 0.0376 |
| F | 4.4673 | 5.9447 | 5.2757 | 1.2246 |
| F (P) | 0.0103 | 0.0028 | 0.0037 | 0.3335 |
| DW | 1.5226 | 1.2488 | 1.6946 | 1.5128 |

* The first three regressions consider the effect of transport on economic growth. The fourth regression considers the effect of income inequality on inequality of railway distribution, as a test of the bilateral relation between these two variables. The numbers in parentheses are t-statistics.

whether we use panel data of 1994-2002 or time series data of 1978-2002, whether we consider the relation of per capita GDP level and public investment on transport, or the relation of standard deviation of per capita GDP and Gini coefficients of road and railway. More investment in road and railway will be very supportive for regional growth, especially more investment in road and railway in poor areas can expect higher economic returns of scale and is in urgent need for poverty alleviation.

## 4. CONCLUSIONS AND POLICY IMPLICATIONS

This paper considers the correlation between transport construction and economic growth across provinces in Chinese economy using panel data of 1994-2002, and time series data of 1978-2002. We also implement Granger test to check the causation between transport and economic growth. The main results are as follows:

Firstly, the disparity in income level and growth rate in the east, central and west areas is closely related with the difference of transport investment. When we control the variable of transport (especially that of road), the advantage of the east and central areas over the west will be significantly reduced. It turns out that the lack of transport infrastructure is a key reason of economic underdevelopment in the west, rural areas. Once the bottleneck of transport is broken, the mobility of production factors such as labor, capital and information, will provide opportunity for economic growth and poverty alleviation in poor areas.

Secondly, the externality of transport infrastructure is of great importance for regional growth. As a quasi-public good, transport infrastructure has strong network effect. According to our research, the road density is by far below the satiation point except in very few cities such as Shanghai. The railway density is much lower than the satiation point in all provinces. More investment in road and railway is urgently needed and can be expected to explore more economy of scale.

Thirdly, the inequality of transport is a reason for income inequality. According to Gini coefficients of road and railway, there is significant inequality of transport across provinces in China. The transport network is more densely distributed in the east than in the poorer central and west areas, the quantity and quality of transport system are both much better in urban than in rural area. In order to reduce regional inequality, more investment in transport should be targeted to poorer inland provinces, especially to rural areas.

Fourthly, the priority should be put on road instead of railway construction for poor area. As we find from the analysis, the reduction of road inequality will help the reduction of income inequality more directly. In most rural area, both the quantity of road milage and the quality of road are rather low, which has been a huge hindrance for regional development. More investment in a classified rural road network will be a drive for growth and poverty alleviation.

Fifthly, improvement of transport infrastructure is the necessary but not sufficient conditions for regional growth and poverty alleviation. However, with better transport facilities, there will be more opportunities for people living in remote rural areas to receive education, training, information and technology, more non-agricultural jobs provided to rural residents, more mobility of labor, capital and resources. Thus, transport investment is of great importance in establishing sustainable growth and reducing poverty.

Lastly, the inequality of transport infrastructure in China is impressive, and the situation is getting worse after the fiscal decentralization in 1994. Most local governments in poor areas cannot afford transport construction with public spending, while most private investment in transport is targeted at coastal developed areas. In order to reduce the inequality of transport, the central government is responsible to mobilize more resource to inland poor areas and provide more public investment in transport infrastructure.

Appendix 1 Sample description of provincial panel data

| | Logarithm of real per capita GDP | Lagged logarithm of real per capita GDP | Population density (people/sq.km) | Road density (km./sq.km) | Squared road density density | Railway density (km./sq.km) | Squared railway | Growth rate of labor force | Ratio of investment to GDP | Human capital | Initial endowment |
|---|---|---|---|---|---|---|---|---|---|---|---|
| mean | 7.5674 | 7.4793 | 355.8129 | 0.2915 | 0.1227 | 0.0255 | 0.0039 | 0.0039 | 0.4482 | 0.7471 | 2.9761 |
| medium | 7.4332 | 7.3516 | 256.2946 | 0.2647 | 0.0701 | 0.0124 | 0.0002 | 0.0062 | 0.4375 | 0.7617 | 2.9318 |
| maximum | 9.6371 | 9.5404 | 2699.1460 | 1.0136 | 1.0273 | 0.3802 | 0.1446 | 0.2690 | 0.9006 | 0.8319 | 3.7088 |
| minimum | 6.3054 | 6.2383 | 6.7553 | 0.0186 | 0.0003 | 0.0013 | 0.0000 | −0.2300 | 0.2965 | 0.5728 | 2.6111 |
| Standard deviation | 0.6356 | 0.6353 | 437.5944 | 0.1946 | 0.1671 | 0.0570 | 0.0209 | 0.0383 | 0.0969 | 0.0706 | 0.2332 |
| Skewness | 0.9100 | 0.9283 | 3.3648 | 1.1636 | 2.6908 | 5.3474 | 6.1950 | −0.3181 | 1.4177 | −1.0422 | 1.2554 |
| Kurtosis | 3.7348 | 3.7894 | 15.9908 | 4.5346 | 11.0728 | 32.1867 | 39.7228 | 22.7665 | 5.7632 | 3.0274 | 4.9154 |
| J-B test | 40.4528 | 42.7365 | 2247.5160 | 81.5922 | 988.3867 | 10145.5500 | 15771.7900 | 4106.7300 | 164.5854 | 45.6314 | 104.7091 |
| probit | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

Note: Data in the table include 28 provinces during 1994-2002 (excluding Tibet and Hainan, data of Chongqing is mergered with that of Sichuan), 252 samples in total.

Appendix 2 The fixed effect of different provinces in regression 1,2,3 of Table 5

| (1) | | (2) | | (3) | |
|---|---|---|---|---|---|
| Beijing-(East) | 6.5347 | Beijing-(East) | 5.7623 | Beijing-(East) | 6.3218 |
| Tianjin-(East) | 6.7604 | Tianjin-(East) | 5.9085 | Tianjin-(East) | 6.5460 |
| Hebei-(East) | 7.1183 | Hebei-(East) | 5.8562 | Hebei-(East) | 6.6167 |
| Liaoning-(East) | 7.5984 | Liaoning-(East) | 6.3618 | Liaoning-(East) | 7.0203 |
| Shanghai-(East) | 7.0256 | Shanghai-(East) | 5.0600 | Shanghai-(East) | 5.2428 |
| Jiangsu-(East) | 7.6559 | Jiangsu-(East) | 6.1102 | Jiangsu-(East) | 6.7297 |
| Zhejiang-(East) | 7.5046 | Zhejiang-(East) | 6.1105 | Zhejiang-(East) | 7.0060 |
| Fujian-(East) | 7.2288 | Fujian-(East) | 5.9304 | Fujian-(East) | 6.9923 |
| Shandong-(East) | 6.8744 | Shandong-(East) | 5.5555 | Shandong-(East) | 6.3869 |
| Guangdong-(East) | 7.3378 | Guangdong-(East) | 5.9313 | Guangdong-(East) | 7.1637 |
| Guangxi-(East) | 6.7470 | Guangxi-(East) | 5.6649 | Guangxi-(East) | 6.1841 |
| Shanxi-(Central) | 6.8875 | Shanxi-(Central) | 5.7903 | Shanxi-(Central) | 6.4691 |
| Neimenggu-(Central) | 8.0896 | Neimenggu-(Central) | 6.9716 | Neimenggu-(Central) | 6.8997 |
| Jilin-(Central) | 7.6319 | Jilin-(Central) | 6.5004 | Jilin-(Central) | 6.8508 |
| Heilongjiang-(Central) | 8.0570 | Heilongjiang-(Central) | 6.8688 | Heilongjiang-(Central) | 7.0430 |
| Anhui-(Central) | 6.6973 | Anhui-(Central) | 5.4511 | Anhui-(Central) | 6.1416 |
| Jiangxi-(Central) | 7.0830 | Jiangxi-(Central) | 5.9188 | Jiangxi-(Central) | 6.4995 |
| Henan-(Central) | 6.7087 | Henan-(Central) | 5.5045 | Henan-(Central) | 6.2718 |
| Hubei-(Central) | 7.1183 | Hubei-(Central) | 5.8562 | Hubei-(Central) | 6.6167 |
| Hunan-(Central) | 6.7087 | Hunan-(Central) | 5.5045 | Hunan-(Central) | 6.2718 |
| Sichuan-(West) | 7.1454 | Sichuan-(West) | 5.9521 | Sichuan-(West) | 6.4320 |
| Guizhou-(West) | 6.4939 | Guizhou-(West) | 5.3860 | Guizhou-(West) | 5.8398 |
| Yunnan-(West) | 6.9188 | Yunnan-(West) | 5.7019 | Yunnan-(West) | 6.4206 |
| Shaanxi-(West) | 7.0827 | Shaanxi-(West) | 5.9194 | Shaanxi-(West) | 6.3650 |
| Gansu-(West) | 7.8165 | Gansu-(West) | 6.6567 | Gansu-(West) | 6.7309 |
| Qinghai-(West) | 7.9072 | Qinghai-(West) | 6.8076 | Qinghai-(West) | 6.6059 |
| Ningxia-(West) | 7.3908 | Ningxia-(West) | 6.2975 | Ningxia-(West) | 6.4985 |
| Xinjiang-(West) | 8.1877 | Xinjiang-(West) | 7.0811 | Xinjiang-(West) | 6.8869 |

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