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The Impact of Road Infrastructure Development on Economic Growth and Urban-Rural Income Inequality in Inner Mongolia, China

Baoligao[1]*, Motoi Kusadokoro[2] and Atsushi Chitose[2]

This study used the county-level panel data to assess the impact of road infrastructure development on regional economic growth and urban-rural income inequality in Inner Mongolia, China over the period 1999-2018. The analytical strategy involves the estimation of the dynamic equations for GDP per capita growth rate and urban-rural income inequality. The estimation results from the fixed effects model and the system generalized method of moments (S-GMM) revealed that road infrastructure quantity had a robust positive impact on economic growth while it had a robust negative impact on urban-rural income inequality across counties in Inner Mongolia during the period 1999-2018.

Key words: road infrastructure, regional economic growth, urban-rural income inequality

1. Introduction

Investment and construction of transport infrastructure are common development tools. Many governments consider the construction and maintenance of transport infrastructure an important pre-condition for sustainable economic and social development, so they have invested significant resources in this area. The role of transport infrastructure is related to the mobility of resources, productivity gains, and territorial accessibility, enhancing regional trade and employment opportunities. Thus, the development of transport infrastructure may contribute to the reduction of economic disparity and poverty in the region, particularly in developing countries. This is part of the reason that transport infrastructure is gaining increasing attention in academia.

Does transport infrastructure development lead to prosperity or inequality? To answer this question, many studies have analyzed the impact of transport infrastructure on economic development. However, few studies examined the impact of transport infrastructure development on economic growth and income inequality simultaneously in China, which is undoubtedly one of the key regions in the world economy.

Demurger (2001) used the data from a sample of 24 Chinese provinces for the period 1985-1998 and found that differences in transport infrastructure accounted for a large part of the observed variation in growth performance across provinces and the impact of transport infrastructure was diminished with its development. The similar findings were obtained from Hong *et al.* (2011), based on the data from a sample of 31 Chinese provinces from 1998 to 2007. Banerjee *et al.* (2020) investigated the effects of access to transport infrastructure on economic development during 1986-2006 in China and found that proximity to transportation networks had a moderately sized positive causal effect on per capita GDP level across sectors but no effect on per capita GDP growth. Ke *et al.* (2020) used the data for 29 Chinese provinces and autonomous regions over the period 2007-2015 and found that quality improvements in roadways, railways, and structural upgrading of the transport infrastructure significantly contributed to growth.

On the other hand, Li and Dacosta (2013) used the panel data of China from 1978 to 2007 and found that the length of transport routes via highway was highly significant and negatively related to the overall income disparity. Roberts *et al.* (2012) applied a new economic geography-based methodology to 331 prefectural-level regions and obtained the following results. First, aggregate Chinese real income was approximately 6% higher than it would have been in 2007 had the expressway network not been built. Second, there was no significant reduction in disparities across prefectures and between urban and rural areas as well. Mendoza (2017) used the China Household Income Project (CHIP) Surveys from 2005 to 2013 to examine the relationship between infrastructure development and income inequality in urban China. The results indicate that mass transit usage was positively correlated with income inequality.

[1] Graduate School of Engineering, Tokyo University of Agriculture and Technology
[2] Institute of Agriculture, Tokyo University of Agriculture and Technology
Corresponding author*: bolagtuat@gmail.com

In summary, evidence from China suggests that the impact of transport infrastructure on economic growth and income distribution varies depending on the characteristics of research approaches and the attributes of transport infrastructure. This requires more empirical studies to measure the impact of transport infrastructure in China from alternative perspectives.

This study used the county-level panel data to assess the impact of road infrastructure development on regional economic growth and urban-rural income inequality in Inner Mongolia, China over 1999-2018. Unlike most of the previous literature which focused on one specific economic outcome at the national or provincial level, our study focuses on both economic growth and income inequality, using the county-level data. The county-level data is expected to reveal the impact of transport infrastructure development on local economies because such impacts tend to become vague when more aggregate data such as province-level data are used. We have chosen roads as a representative of transport infrastructure because unlike railways or airplanes, roads with higher access to local residents bring about direct impacts on economic outcomes in local society.

This study is expected to yield new insights into the impact of road infrastructure development on county-level regions and ethnic minority autonomous regions in China. This is because autonomous regions including Inner Mongolia Autonomous Region are likely to be excluded from empirical studies due to the limited availability of comparable statistics. It should be noted that in general, ethnic minority regions in China have characteristics that distinguish them from other regions such as vast land, low population density, abundant natural resources, and multi-ethnic societies. In fact, the county-level data in Inner Mongolia has larger variances in many aspects such as income level, proximity to cities, road development, and other factors due mainly to its vast land area and multi-ethnic social structure.

Our empirical results revealed that road infrastructure quantity had a robust positive impact on county-level economic growth while it had a robust negative impact on urban-rural income inequality across counties in Inner Mongolia during the period 1999-2018.

The paper is organized as follows. The data and methods are described in section 2. The results and discussion are presented in section 3, and conclusions are elaborated in section 4.

2. Methodology

1) The study area and data

Inner Mongolia is the third largest administrative region in the country, with an area of about 1.2 million km^2, accounting for 12% of China's total land area. As for its economy, Inner Mongolia ranked first among China's provincial-level administrative regions in terms of GDP growth rate for eight consecutive years from 2002 to 2009. In 2019, the annual GDP per capita was nearly $10,000, the 11th highest in China. However, rapid economic development has also caused various problems, such as an increased income gap between urban and rural residents. The ratio of urban-rural income difference to the average income in Inner Mongolia was 0.88 in 1999 and increased to 1.07 in 2003, and then showed a decreasing trend. In 2018, the ratio became 0.84. Evidence that this ratio is consistently higher than 0.8 for two decades depicts a high urban-rural income gap.

Regarding the development of road infrastructure, in 1999, Inner Mongolia ranked fifth in the country in terms of total road mileage and third in terms of road mileage per 10,000 people. The road mileage in Inner Mongolia was 59,731 km in 1999, and it increased to 202,641 km or about 3.4 times in 2018, with an average annual growth rate of 17%. Also, the overall quality of the road infrastructure had improved considerably. The percentage of graded road[1)] mileage in total road mileage was 93% in 1999, and this figure grew to 96% in 2018. In 1999, highway mileage, first-grade road mileage, and second-grade road mileage were 0 km, 15 km, and 3,070 km, respectively. All three categories had increased significantly until 2018; 6,633 km, 7,791 km, and 17,684 km, respectively.[2)] Thus, the road infrastructure in Inner Mongolia had experienced not only quantitative but also qualitative improvement over the period 1999 to 2018.

The data used to construct the county-level panel dataset in this study were all obtained from various Inner Mongolia official statistics available. Inner Mongolia is made up of 12 prefecture-level divisions, which are further divided into 103

1) Grade roads in China refer to roads with technical conditions and facilities conforming to national standards or ministry standards. The grades are divided into five technical levels from high to low, such as highway, first-grade road, second-grade road, third and fourth-grade road. The grade is categorized according to the road network planning, road function, and traffic volume. The pavement of each grade of the road consists mainly of asphalt concrete, cement concrete, asphalt gravel, and crushed stone.

2) The data used in this subsection came from various issues of the Inner Mongolia statistical yearbooks (2000-2020).

county-level divisions (counties for brevity).[3] It should be noted that Kambashi and Zalaynor districts are newly established districts in 2016 and 2013, respectively. Hence, they were not included in our panel dataset, but the data of these districts were integrated into the counties they had belonged to before the administrative division reorganization. Therefore, the econometric analysis of this study relies on the county-level panel data composed of a total of 101 counties of Inner Mongolia during the period 1999-2018.

2) Methods of data analysis

Descriptive statistics and econometric models were employed to analyze the data. Economic relationships discussed in this study are likely to involve a dynamic adjustment process, so we set up a dynamic panel data model with the annual growth rate of real GDP per capita or urban-rural Theil index as the dependent variable. Also, the roadway operation mileage per 10,000 people was used as the explanatory variable to represent the road infrastructure development, with several variables controlling for other economic growth contributing factors as shown in Table 1.

We applied the fixed effects estimation and the system generalized method of moments (S-GMM) estimation for the dynamic panel data model (Arellano and Bover, 1995; Blundell and Bond, 1998). The S-GMM provides better controls for the unobserved county-specific effects and measurement errors of regressors. Before estimating this model, we conducted the F-test, Breuach-Pagan Lagrange multiplier (LM) test, and Hausman test to select the appropriate estimation model. Also, we used the Arellano-Bond test for serial correlations in the first-difference error and the Hansen test for over-identification restrictions to satisfy the criteria for using S-GMM estimations. Furthermore, in the S-GMM estimations, we referred to Roodman's (2009) approach to collapse instruments and used specific lags for instruments to alleviate the instrument proliferation problem.

3) Measuring the urban-rural income inequality

To measure the status of urban-rural income disparity within each county in Inner Mongolia, we adopted the Theil index method and decomposed the Theil index.[4] Following Theil (1967), Theil index is computed as follows:

$$Theil_{total} = \sum_i \sum_c [\left(\frac{Yic}{Y}\right) ln \left(\frac{Yic/Y}{Pic/P}\right)] \quad (1)$$

Where Y and P represent total income and total population, respectively, subscript i is urban or rural, and subscript c represents the cth county-level unit.[5] For the urban-rural income inequality within each county in Inner Mongolia, the total Theil index of equation (1) can be decomposed into within-group and between-group components, and the within-group component can be used to measure the urban-rural income inequality by the formula:

$$Theil_{ct} = \sum_{i=1}^{2} [\left(\frac{Yit}{Y}\right) ln \left(\frac{Yit/Y}{Pit/P}\right)] \quad (2)$$

Where Y and P follow the same meaning as above. For the calculation of total income, we obtained the total rural and urban income by multiplying the rural population and urban population, respectively, by the average disposable income of rural and urban residents. The subscript i takes the value of 1 and 2 for urban and rural respectively, subscript c represents the cth county-level unit, and t is a specific year.

We used the Theil index as expressed in equation (2) to capture the urban-rural income inequality at the county level. The theoretical value of the within-group Theil index ranges from 0 to +∞, but in our data, it ranges from 0.0000006 to 0.364. The average value of the weighted within-group Theil index is 0.0748 during the period 1999-2018, contributing on average to 26% of the total Theil index in Inner Mongolia.

4) Econometric model specification

We specified the dynamic model following Baltagi (2013) in a panel data context:

$$y_{i,t} = \alpha y_{i,t-1} + \beta K_{i,t} + \delta' X_{i,t} + \eta_t + \mu_i + \varepsilon_{i,t},$$
$$for\ i=1,..., N,\ t=2,...,T \quad (3)$$

Where $y_{i,t}$ is the per capita real GDP growth rate or urban-rural Theil index for county i in year t. $y_{i,t-1}$ is the lagged $y_{i,t}$. X is a set of variables possibly associated with growth or inequality, and K is the main variable of interest in this study; that is, the quantity of road infrastructure. α and β are the parameters, and δ is a vector of parameters to be estimated. The terms μ_i and η_t, respectively, denote an unobserved time-invariant county-specific characteristic, and an unobserved time effect controlling for common shocks that are assumed to be derived mainly from macroeconomic policies and institutional reforms. $\varepsilon_{i,t}$ is the idiosyncratic error term. The

3) The 103 counties in Inner Mongolia consist of 23 districts, 11 county cities, 17 counties, 49 banners, and 3 autonomous banners.
4) We also used the ratio of urban-rural income difference to the average income as an alternative measure and replicated all the regressions. Results were consistent and available upon request.
5) There is a clear administrative division with geographical boundaries between urban areas and rural areas; the urban areas include city districts and towns, and the rural areas refer to other areas outside the urban areas in Inner Mongolia.

definition and measurement of variables are described in Table 1.

Table 1. Defination of variables

Variables	Description / Measurment
Dependent Variables	
Growth	Economic growth / The annual growth rate of real GDP per capita (%)
Tind	Urban-rural income inequality / Within-group urban-rural Theil index
Explanatory Variable	
lRoadpc	Road infrastructure quantity / The logarithm of Roadway operation mileage per ten thousand people
Control Variables	
lgdppc	Lagged GDP per capita / The logarithm of real GDP per capita in the previous year.
LOE	Level of education / The number of primary and secondary schools per ten thousand people.
Investr	Fixed asset investment rate / The ratio of fixed asset investment formation to GDP
SOE	Investment rate of state-owned enterprises / The share of state-owned enterprises in fixed asset investment
LTE	Tertiary sector employment rate / The share of local tertiary sector employment in the total employed population
Govsize	Government size / The ratio of government expenditure over GDP
Agrshare	Agricultural output share / The ratio of Gross Output Value of Farming, Forestry, Animal Husbandry and Fishery over GDP
Urbanize	Urbanization rate / Urban population divided by total population

Note: All population data that we use are the data on the registered population year-end.

We used the fixed effects regression and S-GMM approach to estimate the dynamic model. First, we adopted a within transformation of equation (3) to eliminate μ_i. However, the fixed effects regression under the dynamic model generates a biased estimate of the coefficients because the $y_{i,\,t-1}$ is correlated with the error term. Therefore, we took the first difference of equation (3) to eliminate μ_i, the unobserved time-invariant county-specific characteristics:

$$y_{i,t} - y_{i,t-1} = \alpha(y_{i,t-1} - y_{i,t-2}) + \beta(K_{i,t} - K_{i,t-1}) + \delta'(X_{i,t} - X_{i,t-1}) + (\eta_t - \eta_{t-1}) + (\varepsilon_{i,t} - \varepsilon_{i,t-1}) \quad (4)$$

However, in equation (4), the correlation is considered to exist between the terms ($\varepsilon_{i,t}$-$\varepsilon_{i,t-1}$) and ($y_{i,t-1}$-$y_{i,t-2}$). To deal with this possible endogeneity problem, we need suitable instruments. Because there were no obviously exogenous variables, we relied primarily on internal instruments, along with the GMM estimation method proposed by Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998). More specifically, we followed their method to obtain internal instruments by utilizing orthogonality conditions while the explanatory variable *K* was treated as an endogenous variable. Then, we used the S-GMM estimator built on the first-difference GMM estimator for our dynamic model by combining the regressions in differences and in levels.

3. Results and Discussion

1) Descriptive analysis

During the twenty years from 1999 to 2018, only two counties (Erenhot and Yakeshi) among the 101 counties in Inner Mongolia had a decrease in road mileage. Guyang county had no change in road mileage, and the rest of the counties had experienced an increase in road mileage. The average road mileage per county was 699 km in 1999 and 2,083 km in 2018. The average GDP per capita across counties was 5,927 yuan, and it grew to 90,705 yuan in 2018. The average *Tind* was 0.042 in 1999 and reached its highest value of 0.084 in 2001. After 2001, the trend was decreasing and the average *Tind* reached 0.065 in 2004. Since then, there were some increases and decreases, but the average *Tind* has generally shown an increasing trend, reaching 0.083 in 2018.

Table 2 presents a summary of the descriptive statistics. Since most of the variables have missing values, our database is an unbalanced panel data. Note that there was considerable variation across counties.

Table 2. Descriptive statistics

Variables	Obs.	Mean	S.D.	Min	Max
Growth (%)	2010	13.5	10.1	-23.4	87.2
Tind	1784	0.072	0.052	$6*10^{-7}$	0.36
lRoadpc	1988	1.72	0.50	0.108	3.23
lgdppc	2007	4.34	0.53	3.25	5.67
LOE	2020	2.42	1.77	0.39	13.7
Investr	1898	0.61	0.42	0.002	6.69
SOE	1860	0.47	0.23	0.001	1
LTE	1883	0.34	0.16	0.061	0.96
Govsize	1995	0.18	0.11	0.013	0.98
Agrshare	1877	0.34	0.25	0	1.12
Urbanize	1913	0.47	0.28	0.072	1

Source: Inner Mongolia statistical yearbooks (2000–2019) and relevant provincial and municipal statistical yearbooks (2000–2019).

2) Estimation results

The estimated results from the fixed effects regression and S-GMM estimation method are shown in Table 3. Note that "*L*" is appended to the lagged variable of *Growth* and *Tind*. All standard errors were corrected for heteroskedasticity, and year dummies were included in all regressions. Table 3 suggested that our S-GMM estimations were valid. There was no instrument proliferation problem because the number of instruments ranged between 45 and 53. The insignificance of the Hansen test results confirmed orthogonal conditions. The insignificance of the Arellano-Bond test results implied that there was no second-order serial correlation of the error term in equation (4) for the S-GMM estimations.[6)]

Table 3. The estimation results

Estimation	FE		S-GMM	
Dependent Variable	Growth	Tind	Growth	Tind
L.Growth	.104*		.16*	
	(.061)		(.081)	
L.Tind		.571***		.721***
		(.053)		(.057)
lRoadpc	4.109**	-.014**	9.446***	-.018***
	(1.569)	(.006)	(3.134)	(.005)
lgdppc	-29.234***	.004	-10.859**	.05***
	(3.578)	(.01)	(5.071)	(.011)
LOE	1.063**	.002	.602	-.002*
	(.436)	(.001)	(.655)	(.001)
Investrate	5.72***	-.003	1.474	-.001
	(.926)	(.003)	(1.321)	(.002)
SOE	-2.365	-.003	-2.203	-.002
	(1.66)	(.003)	(1.383)	(.004)
LTE	-.523	.004	18.715**	-.049**
	(4.078)	(.017)	(8.806)	(.021)
Govsize	-38***	.013	-15.093*	.093***
	(8.846)	(.023)	(8.584)	(.024)
Agrshare	-8.122**	-.051***	-20.34***	.042***
	(3.836)	(.018)	(5.621)	(.011)
Urbanize	1.459	.001	-8.382**	-.022*
	(2.006)	(.01)	(4.225)	(.013)
_cons	140.2***	.053	42.268*	-.181***
	(16.86)	(.048)	(21.81)	(.046)
Obs.	1690	1569	1690	1569
R Squared	.4779	.4079		
No. of Ins.			53	45
Hansen test			.217	.160
AR (2)			.504	.116

Note: 1) Robust standard errors are in parentheses.
2) R squared of FE within regression is derived from within-group R-square.
3) Year dummies are included in all estimations.
4) *, **, *** indicate significance at the levels of 10%, 5% and 1%, respectively.

The main findings from fixed effects estimation are as follows. First, a percentage change in roadway operation mileage per 10,000 people (*lRoadpc*), a variable of interest, is associated with a 4.1% increase in GDP per capita growth rate (*Growth*) and with a 0.014 decrease in urban-rural Theil index (*Tind*). The coefficients are significantly different from zero at the 5% level. Second, *Investr* and *LOE* have significant, positive impacts while *lgdppc*, *Govsize*, and *Agrshare* have significant, negative impacts on *Growth*. Third, *Agrshare* has a significant, negative impact on *Tind*.

The results from the S-GMM estimation for which the two step approach was applied are qualitatively consistent for the impact of a variable of interest but inconsistent for those of some control variables, with the results from the fixed effects estimation. The main findings from the S-GMM are summarized as follows. First, a percentage change in roadway operation mileage per 10,000 people is associated with a 9.4% increase in GDP per capita growth rate and with a 0.018 decrease in urban-rural Theil index. The coefficients are significant at the 1% level. Second, *LTE* has a significant, positive impact on *Growth*, while *lgdppc*, *Govsize*, *Agrshare*, and *Urbanize* have significant, negative impacts on it. Third, *LTE*, *LOE,* and *Urbanize* have significant, negative impacts on *Tind*, while *lgdppc*, *Govsize*, and *Agrshare* have significant, positive impacts on it.

Both the fixed effects regression and the S-GMM estimations revealed that the quantity of road infrastructure has a significant, positive impact on economic growth while it has a significant, negative impact on urban-rural income inequality across counties during 1999-2018. Although the estimation results for the control variables are not necessarily consistent between the two estimation models, we obtained the following robust results. First, the lagged GDP per capita has a negative impact on economic growth while having a positive impact on urban-rural income inequality. This result suggests that convergence existed in GDP per capita across counties over the years and that road infrastructure development can possibly increase income inequality through an indirectly lagged effect. Second, government size has a negative impact on economic growth and a positive impact on urban-rural income inequality. This implies that the public sector was overwhelmed by the private sector in contributing to economic growth, and it was more likely to widen urban-rural income inequality due possibly to public investment policy in favor of economically promising areas.

4. Conclusion

This study has used the county-level panel data to assess the impact of road infrastructure development on regional economic growth and rural-urban income inequality in Inner Mongolia, China, over the period 1999-2018. During the two decades, the overall economy of China had dramatically developed. The Inner Mongolia Autonomous Region had contributed to this development, including a fifteenfold increase in average county-level GDP per capita and a threefold increase in average county-level road mileage.

6) For the sake of brevity, we skipped the introduction about the choice of instrumenting variables and lags used in our S-GMM estimations. However, results still hold and are available upon request.

However, during this period, urban-rural income inequality at the county level did show an expanding trend.

The empirical results of this study indicate as follows. First, it appeared that road infrastructure quantity had a robust positive impact on economic growth. This result is consistent with the findings of Demurger (2001) and Hong *et al*. (2011).

Second, road infrastructure quantity had a robust negative impact on urban-rural income inequality. This result is consistent with the finding of Li and Dacosta (2013). These two results combined suggest that the development of road infrastructure can enhance the economic growth and can lead to a more equitable distribution of income between urban and rural residents across counties in Inner Mongolia.

However, it is important to note that there may be a potential channel through road infrastructure that could have increased income inequality. Road infrastructure development could increase GDP per capita growth rate, and higher GDP per capita can lead to an increase in income inequality. Moreover, if we combine our results with the finding of Mendoza (2017), we can make the following inference. A small rise in the urban-rural income inequality in Inner Mongolia during the past two decades might be due to the fact that the benefits of the reduced urban-rural income inequality from road infrastructure development were diluted by the effects of the development of the mass transit that have not been equitably accessed or uniformly distributed either across or within counties.

This study enhances our understanding of road infrastructure impacts on economic growth and urban-rural income inequality across counties in China and can provide some policy implications for regional transport infrastructure development. The results are specific to the case of Inner Mongolia but are useful for policymakers in other ethnic minority autonomous regions in China and developing countries that have experienced similar patterns of economic and infrastructure development. However, due mainly to the limited data, this study has several limitations. First, because we restricted the measurement of road infrastructure to its quantity, we could not examine how improvements in the quality of road infrastructure affect economic outcomes. For example, highways and other lower-grade roads may have different impacts. Second, the causal mechanism that road infrastructure development enhanced economic growth and reduced income inequality remains unclear. Third, road infrastructure may have direct and indirect effects on income inequality. Identifying these causal relationships requires the structural models built on microeconomic foundation. Fourth, our S-GMM estimation used only internal instruments requiring strong assumptions to be valid (Bond *et al*., 2001); thus, the results were likely subject to the endogeneity problem. Dealing with this problem requires the instrument set including appropriate external instrument variables. Further research is required to resolve these issues.

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