Three Gorges Navigation and Urban Economic Development -- DMSP/OLS based satellite lighting data study *

Shixi Kang **Jingwen Tan**

Abstract: The navigation of Three Gorges is of strategic importance to improve the modern transportation network and promote the flow of resources in the region. This paper explores the economic effects and mechanisms of the Three Gorges permanent locks opening on the prefecture-level cities in the Yangtze River basin by using quasi-natural experiments and satellite lighting data as a proxy variable for economic level through the multiple difference method (DID) and triple difference method (DDD). The results show that (1) the economic level of cities increased significantly after the Three Gorges navigation, with a certain time lag effect; (2) the Three Gorges navigation promoted the development of the tertiary industry and further optimized the industrial structure; (3) the Three Gorges navigation significantly boosted the domestic freight capacity, providing a strong support for releasing land transportation resources and accelerating the flow of resources between regions.

Keywords: Three gorges navigation; Urban economic growth; Satellite lighting data; Interaction fixed effects

I. Introduction

The study of the impact of transport infrastructure on urban economic growth has been one of the hot topics in regional economics since the 1960s. A common view is that a well-developed transport infrastructure can indirectly contribute to local economic growth through mechanisms such as improved investment and savings (Aschauer, 1989). With the optimization and upgrading of the industrial structure, a single land transport can no longer meet the needs of modern economic development. In this context, the expansion of water transport has become a realistic requirement to improve the transport network.By the end of the Ninth Five-Year Plan, China had opened up 1,140 kilometers of inland waterways above the third level and built 351 new port berths.

In addition, the Jiangnan section of the Beijing-Hangzhou Canal has been completed with a navigation channel for 500-ton standard ships, the Shandong section has been completed with a Class III channel for 1,000-ton standard ships, and attempts to combine navigation and electricity in the Xijiang, Xiangjiang and Jialing rivers have also created significant economic benefits. The improvement of the backwardness of inland waterways has played a crucial role in the coordinated development of the economic pattern of the Yangtze River Delta and the Pearl River Delta.

The unique advantages of water transport in various transport systems have been widely recognized by the academic community.Fogel (1962) in his study of the role of railways on economic growth in the United States mentioned that the contribution of waterway networks may be more significant.Nam, et al.(2014) argued that among the different modes of transport, water transport is considered as a low cost and environmentally friendly mode of transport.Mihic, et al.(2011) outlined that the study of personalized information systems based on inland waterways will help to bring about long-term sustainable development. However, compared to other modes of transport such as railways, inland waterway transport in China is still a weak link in the transport system (Baohua, et al., 2009). For a long time, there is a serious imbalance in the proportion of inland waterways, most of the channels are still in a natural state, and the average tonnage of berths is very low, and the degree of specialization is not high (Duan, et al., 2010).

Based on the above analysis, inland waterway transport in China still has a large potential for development, and at a time when inter-city economic and political cooperation is becoming increasingly close, improving waterway transport and opening up new modes of transport have become an urgent task in the construction of transport infrastructure at present. Most existing studies are based on traditional economic indicators such as GDP per capita and industrial structure, and rarely focus on specific proxy variables that are more convenient for measuring modern economic activities. Therefore, this paper uses panel data of 284 prefecture-level cities from 1992 to 2013, based on satellite nighttime average lighting, combined with double difference and interaction fixed effects models, to target the economic effects and role of Three Gorges navigation in urban economic development The results of the study show that the economic effects and mechanisms of the Three Gorges navigation in urban economic development have been tested from multiple dimensions. The results show that the Three Gorges navigation can significantly boost the economic development in the Yangtze River basin by 6.57% compared to non-basin cities, and this economic effect is more obvious for cities with high administrative levels. Meanwhile, the boost to total freight transport is the main channel through which Three Gorges navigation acts on local economic development.

This paper is structured as follows: part II reviews the domestic and international literature; part III presents the research design and data; part IV empirically analyzes the impact of Three Gorges navigation on urban economic growth and makes robustness tests; part V further analyzes the mechanism of role in economic growth; and part VI concludes and makes recommendations.

II. Review of the literature

The impact of transport infrastructure investment on regional economic development is now becoming a hot topic in urban economics. As an important prerequisite for the promotion of national economic and social development (Rosenstein-Rodan, 1943), infrastructure investment will become a new force for reducing regional development disparities and thus for the coordinated operation of national economies.

The current findings of the academic community on the economic effects of infrastructure are still not uniform. Sun, Puyang, et al.(2019) analyzed the role of transportation construction in promoting trade opening from the perspective of tariff transmission, pointing out that perfect transportation conditions will promote high-quality economic development.Garcia-Mila, et al.(1992) used highways as a starting point to illustrate the strong contributing power of transportation construction in statewide production. Meanwhile, Aschauer (1989) suggested a positive relationship between infrastructure capital stock and productivity based on the output elasticity perspective. Accordingly, a number of scholars have presented different perspectives. Spatially, Cheng, et al. (2015) and Fujita, et al. (1999) find regional heterogeneity in the economic effects of infrastructure. The "corridor effect" of transportation construction has the potential to attract resources from neighboring regions, thereby inhibiting their economic development (Nakagawa, et al., 2007; Ortega, et al., 2012). In time, the positive relationship between infrastructure and economic development may have an inverted U-shaped characteristic (Jia, J. X.,2017). The impact of transportation infrastructure on economic development has spatial and temporal differences.

Research on the transmission mechanism of infrastructure investment on economic development can be summarized from the following perspectives: first, the reduction of transportation costs brought about by improved infrastructure will directly lead to an increase in the efficiency of business operations, which in turn will promote regional economic development (Baum-Snow, et al., 2020). Capital accumulation and technological progress are the two major factors that promote higher output, and public infrastructure provides the necessary conditions for a better allocation of resources, accelerating enterprise capital accumulation and industrial agglomeration, which in turn promotes increased regional output

(Mori, et al.,2015). At the same time, the potential spillover characteristics of public infrastructure will indirectly contribute to the development of other regions (Démurger, 2001; Pereira*, et al., 2004).

With the continuous improvement of domestic and international research, the endogeneity of infrastructure investment is gradually gaining attention. The positive effects of infrastructure development on regional economic development have been well documented (Barro, 1990; Baxter, et al., 1993). However, the fact that developed regions tend to invest more public capital also implies a higher likelihood of having a well-developed local infrastructure system. To address this issue, Hagedorn, et al. (2015), in a study on the impact of unemployment compensation benefits on the labor market, captures unobservable influences by using an interactive fixed effects model, while retaining the traditional fixed effects model to address reciprocal causal features, and thus weakening the impact of omitted variables.Y. Lin (2017), in a study on the impact of high speed rail on employment and market access, the DID approach was used to avoid the adverse effects of unobservables.

There are still some gaps in the research on the specific mechanism of the role of transportation infrastructure on economic development from a global perspective. This paper combines domestic and international research and makes the following extensions and additions: first, satellite lighting data is introduced as a proxy variable for output, while a panel interaction fixed effects model is used as the main regression model to mitigate endogeneity from the perspective of omitted variables and mutual causality. Second, this paper illustrates the long- and short-term and direct and indirect effects of infrastructure investment on economic development from a spatio-temporal perspective, which has important economic implications. Third, this paper improves the research related to transportation infrastructure on economic development from the waterway level based on the perspective of the Three Gorges reservoir construction, which provides a comprehensive perspective for other empirical evidence and policy formulation.

III. Introduction to the research methodology

(i) Data selection and processing

Nighttime lighting data:

The nighttime light data were obtained from the OLS sensor (Operational Linescan System) on board the Defense Meteorological Satellite Program (DMSP) of the US military weather satellite. After reprojection of the original image data, the DMSP/OLS nighttime light data within the administrative regions of China from 1992 to 2013 were obtained by using the Chinese prefecture-level city maps with radiation correction. Compared with the traditional economic measure GDP (Song, et al., 2019), which ignores institutions and specific issues to some extent, the light brightness better reflects the economic activities of modern society (Huang, et al., 2014).

Basic sample data:

The basic data were obtained from the China Urban Statistical Yearbook from 1992 to 2013. In view of the large time span of the sample, some missing data and the adjustment of administrative divisions, the following treatments were made: (1) deleting county-level cities; (2) excluding data not included in the yearbook. The final sample consists of 284 prefecture-level cities, with a total of 3616 observations.

(ii) Model design

The DID (Differences in Differences) method is a common method to study the differences before and after policy implementation. In this paper, we take the permanent opening of Three Gorges in 2003 as the policy shock point, set Yangtze River coastal cities as the treatment group and non-Yangtze River coastal cities as the control group, and introduce a fixed-effects model to mitigate the endogeneity problem. Considering that traditional fixed-effects models cannot control for unobservable variables that vary simultaneously over time and individually, this paper explores the mechanism of the role of Three Gorges navigation in regional economic development by referring to the interaction term of individual and time effects used by Bai (2009) in a linear panel model. The regression equation of this paper is.

$$y_{it} = \alpha + \beta river_i \times TG_i + \gamma X'_{it} + \lambda_i' F_t + \varepsilon_{it} \qquad (1)$$

Where y_{it} is the average nighttime light DN value of city i at time t; $river_i$ is a dummy variable representing whether city i is part of the Yangtze River is a dummy variable representing whether city i is part of the Yangtze River; TG_i is a time dummy variable indicating whether the Three Gorges is navigable or not, if $TG_i = 1$ after 2003 and vice versa, it is taken as The coefficient β reflects the impact of navigation on the economic development of the city. The coefficient β reflects the impact of navigation on the economic development of the city and is the focus of this paper; $\lambda_i' F_t$ is the one-dimensional product of the individual city effect and the year effect, i.e. the cross-fixed effect. εit is the residual term. At the same time, the clustering is adjusted for standard errors at the regional level1.

In this paper, 19 prefecture-level cities with administrative areas bordering the Yangtze River are selected as the treatment group, while the sample is located along the Yellow River of 32 prefecture-level cities were used as counterfactual tests. A list of the two groups of cities is given in Table 1.

Table 1 List of "Yangtze River Group" and "Yellow River Group"

Yangtze River Group	Yellow River Group
Yibin, Chongqing, Yichang, Jingzhou, Yueyang, Wuhan, Huanggang, Ezhou, Huangshi, Jiujiang, Anqing, Chizhou, Tongling, Wuhu, Nanjing, Zhenjiang, Nantong, Shanghai, Ma'anshan	Lanzhou, Baiyin, Zhongwei, Wuzhong, Yinchuan, Shizuishan, Wuhai, Erdos, Bayannur, Baotou, Hohhot, Xinzhou, Yulin, Luliang, Yan'an, Linfen, Weinan, Yuncheng, Sanmenxia, Luoyang, Jiaozuo, Zhengzhou, Kaifeng, Xinxiang, Puyang, Liaocheng, Tai'an, Dezhou, Jinan, Zibo, Binzhou, Dongguan

(iii) Selection of variables

Based on the geographical distribution of coastal cities, this paper constructs a dummy variable ($river_i$) to discriminate whether a prefecture-level city is adjacent to the Yangtze River, i.e., if it belongs to the Yangtze River, it is denoted as $river_i$=1; conversely, it is denoted as $river_i$=0.

At the same time, in order to strip the possible spillover effects of the coastal cities of their neighboring cities, the dummy variable of neighboring cities (river_neari) is set in this paper, i.e., if it is in the neighboring cities of the Yangtze River coastal cities, it is noted as $river\_near_i$=1; conversely, it is noted as $river\_near_i$=0.

In order to control more precisely for the potential impact of other factors in economic development, this paper refers to the economic growth model proposed by Kaldor (1957), while considering the crowding-out effect of the Three Gorges opening on other traffic volumes, and identifies population density, urbanization level, log of fixed investment, log of fiscal expenditure and log of total freight transport as control variables. To make the calculation results more accurate, we used the ratio of non-farm population to total population at the city level as the urbanization rate, and the descriptive statistics of each variable are shown in Table 2.

Table 2 Descriptive statistics

variable name	N	mean	sd	min	max
Average nighttime light DN value (light)	3,616	5.2479	7.210255	0.0215	56.9627
Is it a Yangtze River city (riveri)	3,616	0.0683075	0.2523078	0	1
Proximity to cities along the Yangtze River(driver_neari)	3,616	0.1161504	0.3204496	0	1
Population density (poprho)	3,616	430.4778	334.8487	4.7	3606
Urbanization rate (urban)	3,616	0.3229622	0.1775413	.0735206	1
ln (total freight) (lntrans)	3,616	8.102427	0.9956511	2.944439	11.87599
ln (investment in fixed assets) (lnfixed)	3,616	13.46695	1.482158	8.297544	17.69283
ln (general financial expenditure) (lnfinance)	3,616	12.29635	1.227597	7.936303	17.07126

IV. Analysis of the empirical results

(i) Basic results

Table 3 reports the regression results for the traditional DID model and the baseline model controlling for individual, time, and interaction effects in turn.The net policy effect coefficients for all five models are greater than 0 and significantly correlated at least at the 10% level, providing preliminary evidence for our hypothesis of a positive economic growth effect for Three Gorges navigation. Models 1 and 3 show that most of the variables show a significant effect on local light brightness.

The positive effect of the coefficient on total freight is significant. Model 2, on the other hand, gives the answer that the coefficient on total freight is not significant. Freight demand and capacity tend to move in the same direction as city size. With the introduction of individual fixed effects, the differences between the economic environment and political status of cities are weakened, thus exposing the implicit relationship between freight volume and economic growth. Model 5 gives the results of the regression with the introduction of the interaction fixed effects. It can be

to see that the Three Gorges navigation increases the average light intensity of prefecture-level cities along the Yangtze River by 0.345, while the average light intensity of prefecture-level cities from 1992 to 2013 is 5.2479, thus it is not difficult to obtain that the Three Gorges navigation contributes 6.57% to the economic growth of prefecture-level cities in the basin compared to non-Yangtze River city groups. Unlike the two-way fixed effects model of Model 4, the interaction fixed effects further take into account city characteristics with time-varying characteristics. Clearly, under the assumption that cities are static, population density can no longer positively affect economic growth through dynamic pathways such as human capital externalities and attracting firms to the city (Golman, et al., 2016; Moretti, 2004). As for the insignificant coefficient on general fiscal spending, Agell, et al.'s (1999) study on the insignificant correlation of public sector spending on economic development has amply demonstrated that controlling for urban time-varying characteristics alone is not sufficient and that the inclusion of heterogeneity analysis of non-time-varying characteristics would be more useful in revealing the deeper relationships in economic development.

Table 3 Baseline regression results table

	(1)	(2)	(3)	(4)	(5)
VARIABLES	light	light	light	light	light
riveri × TGi	1.078*	0.458**	1.083**	0.455**	0.345**
	(12.67)	(36.12)	(13.52)	(48.87)	(35.85)
poprho	0.008**	-0.002**	0.007*	-0.002**	-0.001**
	(13.34)	(-18.68)	(9.94)	(-20.03)	(-26.07)
urban	11.286**	11.013**	11.225**	10.796**	3.044**
	(46.79)	(49.86)	(41.17)	(44.32)	(18.74)
lntrans	-0.051	-0.238*	-0.455	-0.209	-0.146
	(-0.95)	(-6.72)	(-4.42)	(-5.45)	(-5.90)
lnfixed	1.843*	0.618*	2.056*	0.593*	0.315**
	(10.12)	(9.13)	(9.47)	(9.28)	(54.71)
lnfinance	0.385**	0.516*	1.174*	0.335	0.010
	(27.95)	(6.49)	(7.00)	(3.80)	(1.35)
Constant	-29.668**	-6.458*	-30.388*	-2.254	1.532***
	(-21.47)	(-9.64)	(-12.18)	(-2.74)	(904.53)
Observations	3,616	3,616	3616	3,616	3,616
City FE	NO	YES	NO	YES	NO
Year FE	NO	NO	YES	YES	NO
City#Year FE	NO	NO	NO	NO	YES

Note: t-values in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

(ii) Heterogeneity analysis

This section focuses on the regional heterogeneity of the impact of Three Gorges access on economic development between cities along the Yangtze River and those that are not. Although the interaction fixed effects model takes into account the inter-city differences in the development of each indicator from year to year, it still ignores to some extent the impact of economic heterogeneity based on non-time-varying indicators.

As a long-term political status and symbol, provincial capitals can be approximated as non-time-varying indicators. Compared with other prefecture-level cities, provincial capitals are more conducive to the concentration of local resources. Therefore, the regressions are conducted separately for provincial capitals and non-capital cities, and the results are shown in Table 4.

(i) It can be seen that, in contrast to non-capital cities where nighttime lighting is significantly correlated with the amount of freight transported, capital cities are not sensitive to its changes. This is because the industrial structure of provincial capitals is relatively more rational, and simply increasing the volume of bulk freight transport does not stimulate rapid economic development; (ii) the effect of fiscal spending is more pronounced in provincial capitals, which supports Chan, et al.'s (2002) view that cities with high administrative levels are more conducive to efficient resource use. However, the coefficient on fiscal spending remains insignificant for the full sample due to the predominance of non-capital cities. (iii) The models all indicate that the Three Gorges access can effectively promote economic development. The pull effect of provincial capital cities is particularly prominent.

Table 4 Table of heterogeneity regression results

	Full sample	**Provincial capital city**	**Non-provincial cities**
VARIABLES	**(1)**	**(2)**	**(3)**
riveri × TGi	0.345***	1.146***	0.215*
	(3.10)	(2.66)	(1.95)
poprho	-0.001***	-0.000**	-0.001***
	(-6.26)	(-2.01)	(-6.30)
urban	3.044***	3.698***	3.261***
	(7.59)	(4.72)	(7.32)
lntrans	-0.146***	-0.129	-0.145***
	(-3.45)	(-1.36)	(-3.39)
lnfixed	0.315***	0.457***	0.317***
	(8.67)	(2.99)	(8.22)
lnfinance	0.010	0.640***	0.003
	(0.21)	(3.10)	(0.06)
Constant	1.532***	-8.514***	1.482***
	(3.08)	(-4.69)	(2.79)
Observations	3,616	346	3,270

(iii) Robustness tests

Parallel trend hypothesis testing

In practice, the average nighttime lights are often biased due to various climatic factors and differences in the natural environment between regions, thus making the sample not obey the parallel trend hypothesis and biasing the DID estimation results. Therefore, the following parallel trend test will be conducted in this paper: i.e., using the year before navigation as the base group, the interaction term between the year dummy variable and the treatment group dummy variable will be generated and used as the explanatory variable in the regression to determine whether there is a significant difference between the treatment group and the control group in the year of Three Gorges navigation. A visual representation of the test results is given in Figure 1. From the results of the parallel trend test, there is no significant difference between the treatment group and the control group before the navigation point, which is consistent with the parallel trend hypothesis; the coefficients after the point are still around the 0 line, but show an upward trend in general, indicating that there is a certain time lag effect of Three Gorges navigation on the economic impact, and the direction of the effect is positive.

Placebo test: randomly generated experimental groups

Although in the baseline analysis we verified that the Three Gorges Passage can promote urban economic development, it is also possible that this development is largely attributable to other policies in the same year. To ensure that the statistical significance of the indicators above is not derived from some random factor, this paper refers to Cantoni, et al.'s (2017) approach of conducting a placebo test by randomly generating experimental groups. Thirty-two randomly selected experimental groups were generated as policy dummy variables, matched to the original data, and the placebo outcome coefficients and t-values were extracted after 500 replications as shown in Figure 2. it can be seen that the estimated coefficients are clustered around zero and most of the p-values are greater than 0.1, indicating that our results are not significant at the 10% level and that the estimated results are not by chance and are less likely to be influenced by other policies or random factors.

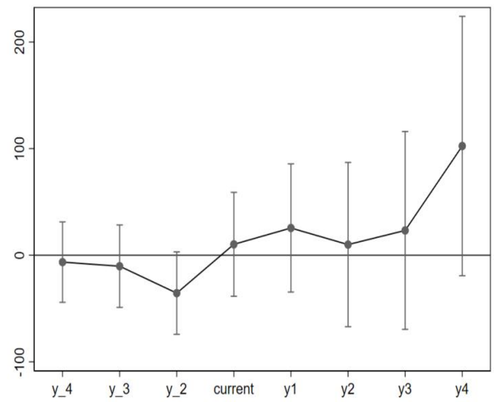

Figure 1 Parallel trend test graph

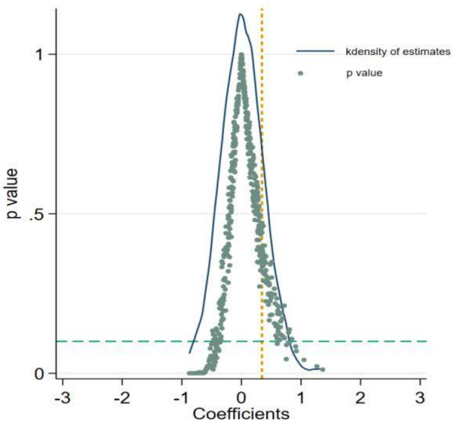

Figure 2 Placebo test

Introduction of alternative variables to the dependent variable

In order to demonstrate its robustness as an economic measure, the dependent variable is replaced by the logarithm of GDP per capita of each prefecture-level city based on the traditional economic measure, considering that nighttime lighting in each region is strongly influenced by natural factors. The estimation results are given in model (2) in Table 5. It can be seen that the direction of action and significance of the variables are basically consistent with the benchmark model, which further proves that the local economies have been developed significantly after the opening of the Three Gorges.

Consider the temporal stochasticity of the impact of the Three Gorges opening

To verify whether the policy intervention of Three Gorges Passage is time-random, this paper performs a robustness test by fictitious policy time, i.e., replacing the breakpoint with 2001, considering the sample from 1992-2001 as the ex-ante group and 2001-2013 as the ex-post group, viewing

Check whether the positive incentive effect of Three Gorges navigation on the economy remains. If the cross product term riveri × TGi coefficient remains significant, it indicates that the local economic development is more likely to be caused by other unobservable factors. The regression results from model (3) in Table 5 can be

As seen, this coefficient is not significant, which justifies the consideration of 2003 as the policy point in the baseline analysis.

Table 5 Robustness tests

	base model	**Replacing the dependent variable**	**Replacement policy time**	**Exclusion of adjacent cities**
VARIABLES	light	lngdp	light	light
riveri × TGi	0.345***	0.094*	0.017	0.632***
	(3.10)	(1.67)	(0.14)	(5.62)
poprho	-0.001***	0.000***	-0.001***	-0.001***
	(-6.26)	(3.44)	(-6.47)	(-7.66)
urban	3.044***	1.987***	3.243***	2.946***
	(7.59)	(10.94)	(8.30)	(8.91)
lntrans	-0.146***	-0.170***	-0.165***	-0.065**
	(-3.45)	(-8.31)	(-3.99)	(-2.37)
lnfixed	0.315***	0.311***	0.374***	0.200***
	(8.67)	(13.95)	(10.64)	(6.89)
lnfinance	0.010	0.307***	-0.019	0.632***
	(0.21)	(10.94)	(-0.40)	(5.62)
Constant	1.532***	1.670***	1.286**	2.546***
	(3.08)	(10.33)	(2.57)	(8.04)
Observations	3,616	2,652	3,616	3,904
City#Year FE	YES	YES	YES	YES

Removal of the impact of adjoining cities

This paper focuses on the impact of Three Gorges navigation on regional economic development. And other regions may also have spillover effects or indirect effects on it, thus biasing the estimation of the baseline results. Therefore, this paper excludes the adjoining cities that are most likely to affect the region from the regression, and the results have been given in model (4) in Table 5. The results show that the estimated coefficients and significance after excluding the spillover sample interference do not differ significantly from the baseline model, and the baseline regression results in this paper are reliable.

Counterfactual test

To make the causal analysis in this paper more rigorous in terms of theoretical logic, we refer to Jia, et al. (2021) in their counterfactual analysis of regional decentralization in Chongqing and Sichuan, and select cities along the Yellow River outside the policy scope as a new reference group for analysis to explore whether there is a policy effect. Since there exists the Xiaolangdi project in the Yellow River basin, which only strips the navigation function and is otherwise similar to the Three Gorges project, the selection of the Yellow River basin is of greater reference significance in studying the economic effects of navigation or not. If there are policy effects in the Yellow River group, the baseline analysis is not reliable.

Table 6 Balance test

variable	Yangtze River, or Chang Jiang	Yellow River or Huang He	Mean difference (s.e)
	(1)	(2)	(3)
Fiscal revenue per capita (10,000 yuan)	8518.368	5776.781	2741.587
			(2087.101)
GDP per capita (million yuan)	78035.68	69826.06	8209.628
			(11499.59)
Average wage ($)	68020.68	63648.81	4371.872
			(4082.878)
Share of employment in the tertiary sector (%)	49.2	54.11875	-4.91875
			(3.196366)
observed value	19	32	

In this paper, 32 prefecture-level cities are selected for regression based on administrative division and geographical distance, while the significance of the mean differences between the two groups is examined by a balance test (see Table 6). It can be seen that the economic environment of the cities along the two rivers is basically similar, indicating that the Yellow River basin is a sufficient counterfactual to the Yangtze River basin.

The regression results are given in Table 7. It is clear that the cross product term river_yellowi for the Yellow River group × TG_i is not significant, further validating the exogenous nature of Three Gorges access itself for the economic development of cities in the Yangtze River basin.

Table 7 Counterfactual Tests

	Yangtze River, or Chang Jiang	Yellow River or Huang He
VARIABLES	(1)	(2)
riveri × TGi	0.345***	
	(3.10)	
river_yellowi × TGi		-0.078
		(-0.71)
poprho	-0.001***	-0.001***
	(-6.26)	(-6.01)
urban	3.044***	3.024***
	(7.59)	(7.43)
lntrans	-0.146***	-0.147***
	(-3.45)	(-3.46)
lnfixed	0.315***	0.316***
	(8.67)	(8.71)
lnfinance	0.010	0.020
	(0.21)	(0.41)
Constant	1.532***	1.423***
	(3.08)	(2.82)
Observations	3,616	3,616

V. Further analysis

The above studies have shown that the Three Gorges navigation has a significant positive impact on regional economic growth, and this impact is more pronounced in the provincial capitals. At the same time, another question deserves attention: what is the specific mechanism of the Three Gorges navigation in this economic pulling effect? The study of this question will help to fully grasp the entire process from the improvement of waterway transportation to economic growth and to identify the main agents of the effect. In this section, we first propose the hypothesis that the opening of the Three Gorges can effectively release the secondary industry and promote the development of the tertiary industry, thus promoting the transformation and upgrading of the industrial structure. Therefore, we select the share of value added of secondary and tertiary industries in GDP as the main proxy for industrial structure, and use a triple difference model (Difference-in-Difference-in-Difference, DDD) for regression. The regression model was set up as follows.

$$Y_{industry} = \alpha + \beta river_{it} \times TG_t + \gamma X_{it}' + \lambda_i + \delta_t + \varepsilon_{it} \quad (2)$$

where $Y_{industry}$ is a proxy variable for the industrial structure, including the share of value added in the secondary sector in GDP and the share of value added in the tertiary sector in GDP. Consistent with the previous benchmark model design, $river_{it}$ is taken as 1 when the city is located along the Yangtze River and 0 vice versa, and TG_t is taken as 1 when $t \geq 2003$ and 0 vice versa. The estimated coefficient β of $river_{it} \times TG_t$ indicates the net policy effect of Three Gorges navigation on regional economic development. Control variables X' In this paper, the logarithm of per capita GDP , logarithm of fixed asset investment, urbanization rate, and logarithm of general fiscal expenditure are selected. Also in this paper, urban fixed effects λ_i and Year fixed effects σ_t, and standard error clustering at the prefecture-level city level in the Yangtze River basin are included in the regression.

Table 8 Impact of the Three Gorges opening on the industrial structure

	(1)	(2)
VARIABLES	secondary sector of industry	tertiary sector of industry
riverit × TGt	-1.946**	0.639**
	(-44.22)	(31.25)
lngdp	8.913**	-3.036**
	(16.73)	(-14.04)
lnfixed	3.271***	-0.932***
	(110.04)	(-138.84)
urban	0.521	3.103
	(0.59)	(2.82)
lnfinance	-0.529	-1.472
	(-1.21)	(-4.71)
Constant	-73.026*	92.817**
	(-7.35)	(15.53)
Observations	2,178	2,178
Number of cities	284	284
R-squared	0.514	0.135

The regression results are given in Table 8. It can be seen that when the secondary industry is the dependent variable, the coefficient of the cross term riverit × TGt is significantly negative, indicating that the share of the secondary industry in Yangtze River coastal cities decreases by 1.946 percentage points after the Three Gorges navigation.

Similarly, for the tertiary sector, its share increases after the Three Gorges navigation, at 0.639%.The explanation proposed by B. Lin, et al. (2015) is that the tertiary sector is positively related to transport energy consumption. The emergence of new waterway transport modes has enabled the tertiary sector, which has a high demand for transport consumption, to flourish.

Next, we turn to a more in-depth question: what specifically mediates the pull effect of Three Gorges navigation on the regional economy? Many scholars have already argued that there is a clear positive correlation between transport capacity and national economy. For example, Sun, et al. (2017) found that road freight can promote the rapid economic development of major industries through Granger causality experiments and impulse response functions.Chen, et al. (2007) also talked about a two-way causal relationship between the regional economy and local railway freight transport in their study of the railway system in Henan Province, which jointly promotes

From this, this paper introduces the total amount of freight (lntransit) in equation (2), as well as its triple cross term and two-two cross product term with riverit and TGt. The regression model is as follows.

$$\mathrm{Y_{industry}} = \alpha + \beta_1 \mathrm{river}_{it} \times \mathrm{TG}_t + \beta_2 \mathrm{river}_{it} \times \mathrm{TG}_t \times lntrans_{it} + \beta_1 \mathrm{river}_{it} \times lntrans_{it} + \beta_1 \mathrm{TG}_t \times lntrans_{it} + \lambda_i + \sigma_t + \varepsilon_{it} \quad (3)$$

where total freight $\mathrm{lntrans}_{it}$ is meant to be the sum of the traffic volume of the $_i$th city in year t for all modes of transportation. The coefficient β_2 of the variable $\mathrm{river}_{it} \times \mathrm{TG}_t \times \mathrm{lntrans}_{it}$ is the focus of attention in this section, indicating how much of the impact of Three Gorges access on the industrial structure of Yangtze River coastal prefecture-level cities comes from an increase in total freight traffic. If this coefficient is positively significant with the sign of Table 8, it indicates that the Three Gorges navigation promotes local economic development mainly by raising the total amount of freight transported. The other variables have the same meaning as in equation (2).

Since above we have demonstrated that the administrative rank of a city creates heterogeneity in the estimates of the economic effects of navigation through the Three Gorges, the following section will additionally consider the role played by provincial capitals versus non-capital cities in the mechanism of action.

Table 9 reports the regression results for the triple difference. In particular, columns (1)(2) show the results of the estimation of the share of the secondary and tertiary sectors by the cross product term in the full sample case. It can be concluded that the improved total freight transport promotes the development of the secondary sector while allowing the share of the tertiary sector to decrease, which is contrary to the hypothesis above, so we include the analysis of heterogeneity between provincial and non-capital cities in order to uncover the hidden deeper effects behind it.

Column (3)(4) of Table 9 gives the estimation results for the share of secondary and tertiary industries under non-capital cities. It can be seen that both sets of coefficients of the cross product term $\mathrm{river}_{it} \times \mathrm{TG}_t \times \mathrm{lntrans}_{it}$ are significantly positive, indicating that the increase in total freight transported by the Three Gorges Passage to non-provincial cities can promote a simultaneous increase in the output shares of secondary and tertiary industries.

In the regression results table of the share of secondary and tertiary industries under the provincial capital cities in column (5)(6), we can again see that the coefficient of the triple cross product term is negative in the secondary industry and positive in the tertiary industry, which fits our previous hypothesis. Also, this situation is consistent with the conclusion of Ma (2005) that central cities play an important role in driving regional economic development.

Table 9 Results of the triple difference regression

	full sample		Non-provincial cities		provincial capital city	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	secondary sector of industry	tertiary sector of industry	secondary sector of industry	tertiary sector of industry	secondary sector of industry	tertiary sector of industry
riverit × TGt	-9.172**	0.646	-8.669**	-7.519***	57.407*	-163.394**
	(-18.25)	(2.31)	(-38.70)	(-102.10)	(12.59)	(-58.53)
$river_{it}$ × TGt ×$lntrans_{it}$	0.912**	-0.008	0.855**	1.019***	-5.761*	16.758**
	(14.88)	(-0.24)	(26.70)	(75.52)	(-12.19)	(58.00)
$river_{it}$×$lntrans_{it}$	-1.344*	0.094	-1.528**	-0.748**	3.739	-15.050**
	(-7.94)	(3.76)	(-33.29)	(-22.37)	(6.03)	(-38.89)
TG_t×$lntrans_{it}$	-0.809*	0.245*	-0.772*	0.237**	-0.811**	0.559**
	(-9.34)	(10.17)	(-9.14)	(13.81)	(-19.40)	(32.83)
lngdp	8.916**	-3.034**	9.880**	-3.912**	1.677	3.237**
	(15.39)	(-13.42)	(15.98)	(-26.50)	(4.93)	(16.60)
lnfixed	3.405**	-0.973***	3.740**	-1.120***	0.802*	-0.453
	(61.27)	(-80.07)	(42.49)	(-219.75)	(6.53)	(-5.89)
urban	1.465	2.807	5.091	-0.137	-4.993**	9.750**
	(1.41)	(2.38)	(3.29)	(-0.10)	(-14.06)	(42.66)
lnfinance	-0.205	-1.564	-0.818	-1.010	2.922	-4.248*
	(-0.43)	(-4.92)	(-1.87)	(-3.52)	(4.99)	(-12.08)
Constant	-78.357*	94.530**	-83.684*	97.087**	-22.741	85.937**
	(-7.34)	(15.51)	(-8.33)	(19.17)	(-3.50)	(21.15)
Observations	2,178	2,178	1,973	1,973	205	205
City	284	284	257	257	27	27
R-squared	0.520	0.136	0.552	0.147	0.339	0.371

In addition, it is easy to see in the full sample regression results that the significance of the coefficient on the cross product term $river_{it}$ × TG_t has decreased compared to that in Table 8, which indicates that total freight does play an important role in the mechanism of the role of Three Gorges navigation on the regional economy.

In summary, we conclude through empirical analysis based on the hypothesis proposed at the beginning of this section that the Three Gorges navigation can effectively release the effectiveness of the secondary industry, promote the development of the tertiary industry, and then promote the transformation and upgrading of the industrial structure, and this positive effect is more significant in cities with high administrative levels.

VI. Summary and recommendations

This paper assesses the impact of Three Gorges navigation on regional economic development based on a panel of 284 prefecture-level cities in China from 1992 to 2013, using average nighttime light as a proxy variable for economic level, and using multiplicative difference and interactive fixed effects. The study finds that: first, the economic impact of Three Gorges navigation on the Yangtze River cities is 6.57%, and the impact is more significant in the provincial capitals, with a certain time lag; second, Three Gorges navigation promotes the development of the tertiary industry and further optimizes the industrial structure; third, Three Gorges navigation significantly boosts the domestic freight capacity, which provides a strong support for releasing land transportation resources and accelerating the flow of resources between regions. Third, the opening of the Three Gorges has significantly boosted domestic freight capacity, providing strong support for releasing land transport resources and accelerating the flow of resources between regions. This conclusion provides a new policy perspective for China's transportation infrastructure. With the rapid development of the logistics industry, the modern economy has placed higher demands on the transportation network. In the face of this situation, opening up new modes of transport has become the rational choice to maximize the use of transport resources. Although the Three Gorges has a certain lagging effect on the economic level, it will bring continuous economic benefits in the long run. Therefore, how to maximize the advantages of Three Gorges navigation to the regional economy and provide sufficient policy support will be the focus of governments and academics at all levels in the future.

Bibliography

Aschauer. Is public expenditure productive? [J]. Journal of monetary economics, 1989, 23(2): 177-200.

Fogel. A quantitative approach to the study of railroads in American economic growth: a report of some preliminary findings [J]. The Journal of Economic History, 1962, 22(2): 163-97.

Nam, Win. Competitiveness between road and inland water transport: the case of Myanmar [J]. Transport problems, 2014, 9.

Mihic, Golusin, Mihajlovic. Policy and promotion of sustainable inland waterway transport in Europe - Danube River [J]. Renewable and sustainable energy reviews, 2011, 15(4): 1801-9.

Baohua, Quanxin, Shaokuan. Structural analysis on 2008 intercity transport system of China [J]. Journal of Transportation systems engineering and information technology, 2009, 9(1): 10-8.

Duan, Yu, Xing, et al. Inland Waterway Transport in China: Situation and Problems [M]. ICLEM 2010: Logistics For Sustained Economic Development: Infrastructure, Information, Integration. 2010: 379-85.

Rosenstein-Rodan. Problems of industrialisation of eastern and south-eastern Europe [J]. The economic journal, 1943, 53(210/211): 202-11.

Sun, Pu-Yang, Zhang, Tian-Tan, Yao, Shu-Jie. Tariff transmission, domestic transportation costs and retail prices - a theoretical and empirical study based on the construction of high speed rail [J]. Economic Research, 2019, (03): 135-49.

Garcia-Mila, McGuire. The contribution of publicly provided inputs to states' economies [J]. Regional science and urban economics, 1992, 22(2): 229-41.

Cheng, Loo, Vickerman. High-speed rail networks, economic integration and regional specialisation in China and Europe [J]. Travel Behaviour and Society, 2015, 2(1): 1-14.

Fujita, Krugman, Venables. The spatial economy: cities, regions, and international trade [M]. MIT press, 1999.

Nakagawa, Hatoko. Reevaluation of Japanese high-speed rail construction: recent situation of the north corridor Shinkansen and its way to completion [J]. Transport Policy, 2007, 14(2): 150-64.

Ortega, López, Monzón. Territorial cohesion impacts of high-speed rail at different planning levels [J]. Journal of Transport Geography, 2012, 24: 130-41.

Jia Junxue. Public infrastructure investment and total factor productivity:a theoretical analysis based on a heterogeneous entrepreneurial model [J]. Economic Research, 2017, (02): 4-19.

Baum-Snow, Henderson, Turner, et al. Does investment in national highways help or hurt hinterland city growth? [J]. Journal of Urban Economics, 2020, 115: 103124.

Mori, Smith. on the spatial scale of industrial agglomerations [J]. Journal of Urban Economics, 2015, 89: 1-20.

Démurger. Infrastructure development and economic growth: an explanation for regional disparities in China? Journal of Comparative economics, 2001, 29(1): 95-117.

Pereira*, Andraz. Public highway spending and state spillovers in the USA [J]. Applied Economics Letters, 2004, 11(12): 785-8.

Barro. government spending in a simple model of endogeneous growth [J]. Journal of political economy, 1990, 98(5, Part 2): S103-S25.

Baxter, King. Fiscal policy in general equilibrium [J]. The American Economic Review, 1993: 315-34.

Hagedorn, Manovskii, Mitman. The impact of unemployment benefit extensions on employment: the 2014 employment miracle? [R]: National Bureau of Economic Research, 2015.

Lin. Travel costs and urban specialization patterns: Evidence from China's high speed railway system [J]. Journal of Urban Economics, 2017, 98: 98-123.

Song B-T, Pan M-W. Civilization Measurement, Governance Performance and the Shared Characteristics of the Public Economy-An Essay on the Logical Flaws of Western Quantitative Historiography [J]. Economic Research, 2019, 11.

Huang, Yang, Gao, et al. Application of DMSP/OLS nighttime light images: a meta-analysis and a systematic literature review [J]. Remote Sensing, 2014, 6(8): 6844-66.

Bai. Panel data models with interactive fixed effects [J]. Econometrica, 2009, 77(4): 1229-79.

Kaldor. A model of economic growth [J]. The economic journal, 1957, 67(268): 591-624.

Golman, Klepper. spinoffs and clustering [J]. The RAND Journal of Economics, 2016, 47(2): 341-65.

Moretti. Workers' education, spillovers, and productivity: evidence from plant-level production functions [J]. American Economic Review, 2004, 94(3): 656-90.

Agell, Lindh, Ohlsson. Growth and the public sector: A reply [J]. European journal of political economy, 1999, 15(2): 359-66.

Chan, Zhao. The relationship between administrative hierarchy position and city size development in China [J]. GeoJournal, 2002, 56(2): 97-112.

Cantoni, Chen, Yang, et al. Curriculum and ideology [J]. Journal of Political Economy, 2017, 125(2): 338-92.

Jia, Liang, Ma. Political hierarchy and regional economic development: Evidence from a spatial discontinuity in China [J]. Journal of Public Economics, 2021, 194: 104352.

Lin, Du. How China's urbanization impacts transport energy consumption in the face of income disparity [J]. Renewable and Sustainable Energy Reviews, 2015, 52: 1693-701.

Sun, Jing. study on the Relationship Between Highway Freight Volume and Industrial Structure in China on VAR Model; proceedings of the International Conference on Green Intelligent Transportation System and Safety, F, 2017 [C]. Springer.

Chen, Zhang, Qin. Study on the relation of local railroad freight transportation and regional economic growth; proceedings of the 2007 IEEE International Conference on Automation and Logistics, F, 2007 [C]. IEEE.

Ma. Urban administrative restructuring, changing scale relations and local economic development in China [J]. Political Geography, 2005, 24(4): 477-97.