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

By Shixi Kang and Jingwen Tan

The navigation of the Three Gorges is of strategic importance in improving the modern transportation network and facilitating the flow of resources within the Yangtze River basin. This paper explores the economic effects and mechanisms of the navigation of the Three Gorges permanent locks on the prefecture-level cities in the Yangtze River basin using quasi-natural experiments and satellite lighting data as a proxy variable for economic levels by means of the difference-in-differences (DID) and difference-in-difference-in-differences (DDD). The results show that: (1) the economic level of cities increased significantly after the navigation of the Three Gorges, with a certain time lag effect; (2) the navigation of the Three Gorges promoted the development of the tertiary industry and further optimised the industrial structure; (3) the navigation of the Three Gorges significantly boosted the domestic freight capacity, providing strong support for releasing land transport resources and accelerating the flow of resources between Yangtze River basin.
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Transport infrastructure has a catalytic effect on the economic growth of cities (Gospodini, 2005). 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 optimisation and upgrading of industrial structures, the needs of modern economies can no longer be met by a single land transport route (Rohács and Simongati, 2007). In this context, the expansion of waterway transport has become a real requirement to improve the transportation network.

By the end of 2021, China's inland waterways will have a navigable mileage of 128,000 km, including more than 16,000 km of high-grade waterways (CNBS, 2022a). The Yangtze River system has 64,668 kilometers of navigable mileage, accounting for about half of the total navigable mileage of China's inland waterways. The Yangtze River, the main stem of the Yangtze River system, is the longest navigable river in China, with a total length of about 6,300 kilometers and a navigable portion of 2,838 kilometers, ranking first in the world in terms of inland freight traffic (CNBS, 2022b). Before 2003, only the lower reaches of the Yangtze River waterway were eligible for navigation by large vessels. after the completion of the Three Gorges Locks in 2003, the upper reaches of the Yangtze River could be navigated by vessels of 3,000 tonnes or more (Shen and Xie, 2004). from 2017 to 2022, the annual cargo volume of the Three Gorges Locks exceeded 100 million tonnes for five consecutive years, with a cumulative cargo volume of over 730 million tonnes passing through the locks, making it an

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important logistics corridor for the high-quality development of the Yangtze River Economic Belt (CNBS, 2022b). The Yangtze River shipping system plays a vital role in the coordinated development of the economic pattern of the Yangtze River neighboring areas (Ren et al., 2022).

The Three Gorges Project was divided into three phases in total, with the first phase running from 1993 to 1997, the main project being designed to divert the Yangtze River. The second phase of the project, from 1997 to 2003, mainly completed the construction of the Three Gorges ship locks and the installation of some of the generating units. This paper uses the quasi-natural experiment of the completion of the construction of the locks in 2003 to open the Yangtze River to navigation as the object of study and analyses the impact of shipping development on the economic growth of neighboring cities on the Yangtze River (Shen and Xie, 2004). The third phase of the project ran from 2002 to 2009, a period during which the main part of the dam was constructed and additional generating units were installed (Fu et al., 2010). Inland waterway transport in China still has a large potential for development. In a time of increasingly close economic and political cooperation between cities, improving waterway transport and opening up new modes of transport are now urgent priorities in the construction of transport infrastructure.

There are many studies that show that the development of transport infrastructure can contribute to economic growth. Whether it is the development of air transport or sea, rail or road transport, the economic growth effect is clear (Deng, 2013; Hong et al., 2011; Yu et al., 2012; Achour and Belloumi, 2016; Pradhan and Bagchi, 2013). Research on the transmission mechanism of infrastructure investment on economic development can be summarised from the following perspectives: First, the reduction of transport costs brought about by improved infrastructure will directly lead to an increase in the efficiency of business operations, which in turn will contribute to regional economic development (Baum-Snow et al., 2020). Capital accumulation and technological progress are the two main factors that contribute to higher output, and public infrastructure provides the necessary conditions for a better allocation of resources, accelerating capital accumulation and industrial agglomeration, which in turn drives regional output (Mori and Smith, 2015). At the same time, the potential spillover characteristics of public infrastructure will indirectly contribute to the development of other regions (Démurger, 2001; Pereira* and Andraz, 2004).

As research continues to improve, the issue of endogeneity of infrastructure investment is gradually gaining attention. The positive effect of infrastructure development on regional economic development has been well documented (Barro, 1990; Baxter and King, 1993). However, the fact that developed regions tend to invest more public capital also means that the likelihood of having a well-developed infrastructure system is higher. To address this issue, (**?**), 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 the reciprocal causal characteristics and thus weakening the impact of omitted variables. 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.

From the perspective of shipping transport infrastructure, there has been a considerable amount of current academic research into the economic benefits of transport infrastructure. Examples include the economic impact of the navigation of the Panama Canal, and the impact of the Suez Canal on trade due to its navigation or closure as a result of war (Feyrer, 2021; Hugot et al., 2016; Dajud et al., 2017; Maurer and Rauch, 2023). The sustainability of inland waterway shipping in relation to other modes of transport and the economics of low freight rates are also striking (Borodulina and Pantina, 2021).In terms of research methodology, DID models and panel models are the most common methods used to study related issues (Bardaka et al., 2019; Dong et al., 2022; Liang et al., 2021; Li and Chen, 2013).

It is worth noting that there is a lack of evidence in the academic community on the selected topic of inland waterway navigation and economic development in China. Against this background, the main contribution of this paper is that it fills a gap in the lack of Chinese case studies on the economic impact of inland waterway development. While many articles have analyzed the impact of railways, high-speed railways and air transport on China's economic development, no studies have been conducted on the quasi-natural experiment of Three Gorges navigation. Most existing studies are based on traditional economic indicators such as GDP per capita and industrial structure, and few 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 1994 to 2013, based on satellite nighttime average lighting, combined with double difference and interaction fixed effects models, to investigate the economic effects and mechanisms of Three Gorges navigation in urban economic development. The empirical analysis was conducted to test the robustness of the estimation results in several dimensions. The results show that Three Gorges navigation can significantly boost the economic development of cities in the Yangtze River basin by 6.57% compared to non-basin cities, and that this economic effect is more pronounced for cities at higher administrative levels. At the same time, the increase in total freight transport is the main channel through which Three Gorges navigation contributes to local economic development.

I. Methodology

A. Data

The nighttime light data was obtained from the OLS sensor (Operational Linescan System) on board the US Defense Meteorological Satellite Program (DMSP), and after reprojection of the original image data, the masking process was completed using Chinese prefecture-level city maps and radiation correction. The DMSP/OLS nighttime lighting data for the administrative regions of China from 1994-2013 were obtained by reprojecting the original image data and then masking and radiometric correction using the Chinese prefecture-level city maps.

The base data were obtained from the 1994-2013 China Urban Statistical Yearbook. 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) delete county-level cities; (2) exclude data not included in the yearbook. The final sample consists of 284 prefecture-level cities, with a total of 5680 observations.

B. Econometric Model

The DID (Differences in Differences) method is a common method to study the differences before and after policy implementation. This paper takes the permanent navigation of Three Gorges in 2003 as the policy shock point, set Yangtze River neighboring cities as the treatment group and non-Yangtze River neighboring 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 city and time effects used by (Bai, 2009) in a linear panel model.

$$Y_{it} = \alpha + \beta \mathrm{river_i} \times \mathrm{time_t} + \gamma_\mathrm{i} + \lambda_\mathrm{t} + \varepsilon_\mathrm{it} \tag{1}$$

Where Y_{it} is the average 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; $time_i$ is a time dummy variable indicating whether the Three Gorges is navigable or not, $time_i = 1$ in or after 2003 and $time_i = 0$ before 2003. The coefficient β reflects the impact of navigation on the economic development of the city.

γ_i and λ_t control for city fixed effects and time fixed effects, respectively, and controls for city fixed effects and time fixed effects by adding city dummy variables and time dummy variables to the regression, when adding treatment group dummy variables would introduce strict multicollinearity. γ_i and λ_t control for city-level and per-period time, and contains more information than the policy group dummy variables (which control to the group level) in the original model and policy time dummy variables (controlling for pre- and post-treatment period effects) are more fine-grained and contain more information. ε is the residual term. At the same time, the clustering is adjusted for standard errors at the regional level.

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

C. Variables and Descriptive Statistics

Based on the geographical distribution of adjacent cities, this paper constructs a dummy variable (riveri) to determine whether a prefecture-level city is adjacent to the Yangtze River, i.e., if it belongs to the Yangtze River, then it is denoted as riveri=1; otherwise, it is denoted as riveri=0. At the same time, in order to remove the possible spillover influence of the adjacent cities of the adjacent cities, the dummy variable of adjacent-adjacent cities (river_neari) is set in this paper, i.e., if a city is adjacent to a city along the Yangtze River, it is denoted as river_neari=1; otherwise, it is denoted as river_neari=0.

In order to control more precisely for the potential influence 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 Three Gorges navigation on other traffic volumes, and identifies population density, the level of urbanisation, the logarithm of fixed investment, the logarithm of fiscal expenditure and the logarithm of total freight transport as control variables. To make the calculations more precise, we used the ratio of non-farm population to total population at the city level as the urbanisation rate, and the descriptive statistics of each variable are shown in Table 1.

Table 1—: Descriptive Statistics.

Variables	**N**	**mean**	**sd**	**min**	**max**
Average nighttime light DN value (light)	5680	5.2479	7.210255	0.0215	56.9627
Yangtze River city (riveri)	5680	0.0683075	0.2523078	0	1
Along the Yangtze River city(driver_neari)	5680	0.1161504	0.3204496	0	1
Population density (poprho)	5680	430.4778	334.8487	4.7	3606
Urbanization rate (urban)	5680	0.3229622	0.1775413	.0735206	1
ln (total freight) (lntrans)	5680	8.102427	0.9956511	2.944439	11.87599
ln (investment in fixed assets) (lnfixed)	5680	13.46695	1.482158	8.297544	17.69283
ln (general financial expenditure) (lnfinance)	5680	12.29635	1.227597	7.936303	17.07126

II. Empirical Analysis and Discussion

A. Basic Results

Table 2 reports the regression results for the traditional DID (model 1-4) and the DID controlling for individual, time and interaction effects (model 5). All models have net policy effect coefficients greater than 0 and are significantly correlated at least at the 10% level, providing preliminary evidence for our hypothesis of a positive economic growth effect on Three Gorges navigation.

Models 1 and 3 show that most of the variables have a significant positive effect on local light intensity. Model 2 gives a non-significant answer for the coefficient on total freight. 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 the city are weakened, thus exposing the implicit relationship between freight volumes and economic growth. Model 5 gives the results of the regression with the introduction of cross-fixed effects.

It can be seen that the Three Gorges navigation increases the average light level of the Yangtze River cities by 0.345, while the average light level of the cities from 1994 to 2013 is 5.2479, which leads to a 6.57% contribution to the economic growth of the cities in the basin compared to the non-Yangtze River cities. Unlike the two-way fixed effects model of Model 4, the interaction fixed effects further take into account time-varying city 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 and Klepper, 2016; Moretti, 2004). With regard to the insignificant coefficient on general fiscal expenditure, Agell et al. (1999) study of the insignificant correlation between public sector expenditure and economic development has amply demonstrated that controlling for urban time-varying characteristics alone is not sufficient and that adding heterogeneity analysis of non-time-varying characteristics would be more useful in revealing the deeper relationships in economic development.

Table 2—: Baseline Results.

Variables	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS
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	5680	5680	3616	5680	5680
City FE	NO	YES	NO	YES	NO
Year FE	NO	NO	YES	YES	NO
City#Year FE	NO	NO	NO	NO	YES

Note: p-values are t-test results, $***p < 0.01, **p < 0.05, *p < 0.1$..

B. 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 do not. Although the interaction fixed effects model takes into account the differences in the development of each indicator between cities 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 to other prefecture-level cities, provincial capitals are more conducive to the concentration of local resources. The results of this paper are therefore regressed separately for provincial capitals and non-capital cities, as shown in Table 3: (i) It can be seen that, in contrast to the non-capital cities where night-time light intensity is significantly related to the number of freight movements, the provincial capitals are not sensitive to its variation. This is because provincial capitals have a relatively more rational industrial structure and simply increasing the volume of bulk freight transport does not stimulate rapid economic development; (ii) The effect of fiscal expenditure is more pronounced in provincial capitals, which supports Chan and Zhao (2002) view that cities with high administrative levels are more conducive to efficient resource use. However, due to the predominance of non-capital cities, the coefficient on fiscal expenditure remains insignificant for the full sample; (iii) The models all suggest that Three Gorges access can effectively promote economic development. The pull effect of provincial capital cities is particularly prominent.

Table 3—: Heterogeneity Analysis.

	(6)	(7)	(8)
Variables	Full sample	Provcapital cities	Noncapital cities
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)
City#Year FE	YES	YES	YES

Note: p-values are t-test results, $***p < 0.01, **p < 0.05, *p < 0.1.$.

C. Robustness Tests

In order to make the conclusions of the article more credible, this paper conducted robustness tests from five perspectives: parallel trend hypothesis, placebo test, introduction of alternative variables to the dependent variable, temporal randomness of the impact of Three Gorges access, and the impact of adjoining cities.

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

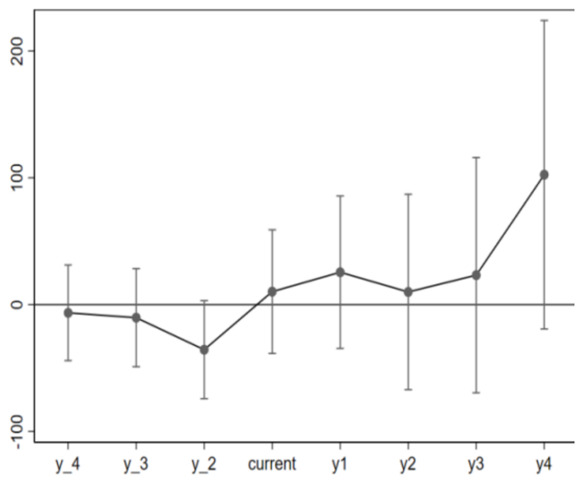

Figure 1. : Parallel trend test

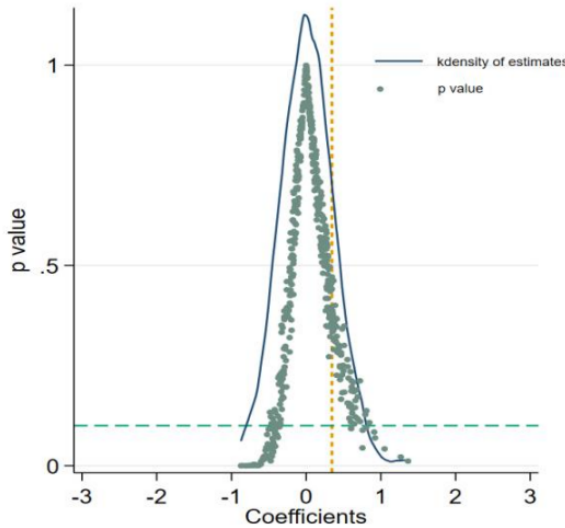

Figure 2. : Placebo test

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.

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. (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.

To demonstrate its robustness as an economic measure, the dependent variable is replaced

Table 4—: Robustness Tests.

Variables	(9) light	(10) GDP	(11) light	(12) 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)
City#Year FE	YES	YES	YES	YES

by the logarithm of GDP per capita for each prefecture, based on the traditional economic measure, given that night-time lighting in each region is strongly influenced by natural factors. The estimation results are given in model (2) in Table 4. As can be seen, the direction and significance of the variables are generally consistent with the baseline model, which is further evidence of significant economic development at the local level following the navigation of the Three Gorges.

To verify whether the policy intervention of Three Gorges navigation is time-stochastic, this paper performs a robustness check by fictitiously testing the policy time, i.e. replacing the breakpoint with 2001 and treating the sample from 1994-2001 as the ex-ante group and 2001-2013 as the ex-post group to observe whether the positive incentive effect of Three Gorges navigation on the economy persists. If the coefficient of the cross product term riveri × TGi remains significant, it indicates that the local economic development is more likely to be caused by other unobservable factors. The regression results of model (3) in Table 4 show that this coefficient is not significant, indicating that it is reasonable to consider 2003 as the policy point in time in the baseline analysis.

This paper focuses on the impact of the Three Gorges navigation on regional economic development. Other regions may also have spillover effects or indirect effects on it, thus biasing the estimation of the benchmark 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 4. The results show that the estimated coefficients and significance after excluding the interference of spillover samples do not differ significantly from the baseline model, and the baseline regression results in this paper are reliable.

D. *Competing Assumptions and Counterfactual Design*

Many civilisations were born along rivers, so this paper needs to exclude the competing hypothesis of 'River Valley Civilization'. Historically and in terms of civilizational development, rivers provide civilizations with fertile land, easy access to irrigation and industrial water resources, so cities along rivers tend to grow faster.

To make the causal analysis in this paper more logically rigorous, we refer to (Jia et al., 2021). (2021) in their counterfactual analysis of regional decentralisation in Chongqing and Sichuan, and select cities along the Yellow River outside the policy context as a new reference group for analysis to explore the existence of policy effects. The choice of the Yellow River region is more informative in examining the economic effects of navigation or not, due to the existence of the Xiaolangdi Project, which only strips away the navigation function and is otherwise similar to the Three Gorges Project. If there are policy effects in the Yellow River group, the baseline analysis is not reliable.

In this paper, 32 prefecture-level cities were selected for regression based on administrative division and geographical distance, while the significance of the mean difference between the two groups was examined through a balance test (see Table 5). It can be seen that the economic environment of the cities along the two rivers is largely similar, indicating that the Yellow River basin is a sufficient counterfactual to the Yangtze River basin. The regression results are given in Table 6. It is clear that the cross product term river_yellowi for the Yellow River group × TGi is not significant, further validating the exogeneity of Three Gorges access itself on the economic development of cities in the Yangtze River basin.

Table 5—: Balance Test.

Variables	(13) Yangtze River	(14) Yellow River	(15) Mean difference
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 tertiary (%)	49.2	54.11875	-4.91875
			(3.196366)
Observed value	19	32	

E. *Mechanism Analysis*

The above studies have shown that the Three Gorges navigation has a significant positive impact on regional economic growth, and that this impact is more pronounced in provin-

Table 6—: Counterfactual Test.

Variables	(16) Yangtze River	(17) Yellow River
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	5680	5680

cial 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 transport to economic growth and to identify the main agents of this effect. This section begins with the hypothesis that navigation through the Three Gorges can effectively unlock the effectiveness of the secondary sector, promote the development of the tertiary sector, and thus facilitate the transformation and upgrading of the industrial structure. Therefore, we select the value added of the secondary and tertiary industries as a proportion of GDP as the main proxy variable of the industrial structure and use the DDD model (Difference-in-Difference-in-Difference) for regression. The regression model was set as follows:

$$Y_{\text{industry}} = \alpha + \text{ river }_{\text{it}} \times TG_t + \gamma X'_{it} + \lambda_i + \delta_t + \varepsilon_{it} \tag{2}$$

In this case, Y_{industry} is a proxy variable for 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. In line with the previous benchmark model design, river $_{\text{it}}$ is 1 when the city is located along the Yangtze River and 0 otherwise, and TGt is 1 when $t \geq 2003$ and 0 otherwise. The estimated coefficient α of river $_{\text{it}}$ $\times TG_t$ indicates the net policy effect of Three Gorges navigation on regional economic development. The control variables selected in this paper are the log of GDP per capita, the log of fixed asset investment, the urbanisation rate and the log of general fiscal expenditure. City fixed effects λ_i and year fixed effects δ_t are also included in this paper, and standard error clustering at the prefecture-level city level in the Yangtze River basin is performed in the regression.

The regression results are given in Table 7. As can be seen, when the secondary sector is the dependent variable, the coefficient of the cross-sectional term river $_{\text{it}}$ $\times TG_t$ is significantly negative, indicating that the share of the secondary sector in Yangtze River cities decreases by 1.946 percentage points after the navigation of the Three Gorges. This is explained by (Lin and Du, 2015), who suggest that the tertiary sector is positively related to transport energy consumption. The emergence of new modes of waterway transport has enabled the tertiary sector, which has a high demand for transport consumption, to flourish.

Table 7—: Impact of Three Gorges Navigation on Industrial Structure.

	(18)	(19)
Variables	Secondary Sector	Tertiary Sector
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

Next we turn to a more in-depth question: what specifically mediates the pull effect of Three Gorges access to navigation on the regional economy? Many scholars have already argued that there is a clear positive correlation between transport capacity and the national economy. For example, Sun and Jing (2019) 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 was jointly promoted. Thus, this paper introduces the total freight volume (lntransit) in equation (2), as well as its interaction terms with riverit and TGt. The regression model is as follows:

$$
\begin{aligned}
(3) \qquad \mathrm{Y}_{\text{industry}} &= \alpha + \beta_1 \text{ river }_{\text{it}} \times \mathrm{TG}_{\mathrm{t}} + \beta_2 \text{ river }_{\text{it}} \times \mathrm{TG}_{\mathrm{t}} \times \text{ lntrans }_{it} \\
&+ \beta_1 \text{ river }_{\text{it}} \times \text{ lntrans }_{it} + \beta_1 \mathrm{TG}_{\mathrm{t}} \times \text{ lntrans }_{it} + \lambda_i + \delta_t + \varepsilon_{it}
\end{aligned}
$$

where total freight $lntrans_{it}$ is meant to be the sum of the transport volumes of all modes of transport in year t in the i city. The coefficient β_2 of the variable $\text{river}_{\text{it}} \times TG_{\text{t}} \times lntrans_{it}$ is the focus of attention in this section, indicating how much of the impact of Three Gorges navigation 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 contributes to local economic development mainly by raising the total amount of freight transported. The other variables have the same meaning as in equation (2).

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

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

Columns (3) and (4) of Table 9 give the results of the estimation of the share of secondary and tertiary industries in non-capital cities. It can be seen that both sets of coefficients of the cross product term $\text{river}_{\text{it}} \times TG_{\text{t}} \times lntrans_{it}$ 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 the secondary and tertiary industries. In the regression results table for the share of secondary and tertiary industries under 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. At the same time, this situation is also consistent with Ma (2005) conclusion that central cities play an important role in driving regional economic development.

Furthermore, it is easy to see in the full-sample regression results that the significance of the coefficient on the cross product term $\text{river}_{\text{it}} \times TG_{\text{t}}$ has decreased compared to that in Table 8, suggesting that total freight transport does play an important role in the mechanism of the role of Three Gorges navigation on the regional economy.

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

Table 8—: Results of DDD Regression.

	full sample		Nocapital cities		provcapital city	
	(20)	(21)	(22)	(23)	(24)	(25)
Variables	secondary	tertiary	secondary	tertiary	secondary	tertiary
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)
riverit × TGt ×lntransit	0.912**	-0.008	0.855**	1.019***	-5.761*	16.758**
	(14.88)	(-0.24)	(26.70)	(75.52)	(-12.19)	(58.00)
riverit×lntransit	-1.344*	0.094	-1.528**	-0.748**	3.739	-15.050**
	(-7.94)	(3.76)	(-33.29)	(-22.37)	(6.03)	(-38.89)
TGt×lntransit	-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

III. Conclusion

Based on a panel of 284 prefecture-level cities in China from 1994 to 2013, this paper assesses the impact of Three Gorges navigation on regional economic development using the DID and interactive fixed effects, using average nighttime lighting as a proxy variable. The study found that: Firstly, the economic impact of Three Gorges navigation on Yangtze River cities was 6.57%, and the impact on provincial capitals was more significant, with a certain time lag; Secondly, Three Gorges navigation promoted the development of the tertiary industry and further optimised the industrial structure; Thirdly, Three Gorges navigation significantly boosted the domestic freight transport capacity, providing strong support for releasing land transport resources and accelerating the flow of resources between regions. Third, the navigation 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 transport infrastructure. With the rapid development of the logistics industry, the modern economy is placing higher demands on transport networks. In the face of this situation, opening up new modes of transport has become the rational choice to maximise the use of transport resources. Although the economic impact of the Three Gorges will be delayed, it will bring continuous economic benefits in the long term. Therefore, it is important for governments and academics at all levels to maximise the benefits of Three Gorges navigation to the regional economy and to provide adequate policy support.

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