On the joint impact of high-speed rail and megalopolis policy on regional economic growth in China

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Abstract

This paper quantifies multifold effects of megalopolis (MP) and high-speed railway (HSR) inaugurations on regional economic growth, in the context of MP and HSR development in China during 1996-2017. Three types of policy interventions are examined, i.e., MP inauguration, HSR introduction, and the joint intervention of MP and HSR. The difference-in-differences (DID) method is adopted to quantify these effects among different groups of prefecture-level cities in China. Specifically, we firstly examine the effects of MP and HSR inaugurations on prefectural economic output, respectively. The simultaneous and joint impact of MP and HSR is then estimated by examining the effect of their interaction. We find that while both MP inauguration and HSR induction have stimulating effects on regional economic growth, the effect of MP inauguration is dominating. Moreover, the joint intervention of MP and HSR is significantly larger than either MP or HSR, and even larger than the sum of two individual effects. Comparing the effects of HSR among different city groups, we find that MP cities are likely to benefit more from HSR service than those not in an MP. Among various MPs, the joint intervention tends to be associated with larger economic growth in MPs with better economic development foundation. These observations imply that the strategical and transport policy interventions have reinforcement effects on one another. However, the simultaneous impact may contribute to regional development disparity since the most developed regions may benefit more from the joint intervention by siphoning resources from disadvantaged regions. Overall, the results shed lights on the interactive developments of transportation infrastructure and urban agglomerations.

Keywords: High-speed rail; megalopolis; regional economic growth; joint impact; difference-in-differences.

1. Introduction

Megalopolis (MP), also known as urban agglomeration, is a spatial aggregation of cities that occurs when the relationship among them switches from competition to joint development and mutual competition. The research of MP started as early as 1920s and has been increasing over the past three decades with rapid urban development (Fang and Yu, 2017). The formation of MP is expected to enhance economic development by intensifying economic interactions among cities. Similarly, the development of large-scale transport infrastructure, particularly the high-speed rail (HSR), is known to stimulate regional economic growth through facilitating inter-city transportation efficiency (e.g., Zhang et al., 2019; Jiao et al., 2020).

In the context of recent MP and HSR developments in China, this study provides a quantitative investigation into the economic evolution in relation to MP formation and HSR inauguration. In particular, the interaction between the two types of policy interventions is studied unprecedentedly. Fang et al. (2018) suggested that the formation of MP in China has been inevitably intervened by the government since Chinese MPs are at the early stage of development or the stage of rapid growth. The planning of MPs and the associated incentive policies are supported by national strategical planning blueprints. In contrast, the urban agglomeration usually formed naturally due to geographically proximity and frequent interaction among cities without ambitious policy. Hence, MP in China has a characteristic of governmental policy-led compared with those in other countries that formed spontaneously.[1]

MP is considered as one of the most vital carriers for the socioeconomic development in China (Fang and Yu, 2017). By analyzing China's urbanization evolution, Fang (2015) suggested that MP stimulates the integration of industry infrastructure construction, marketization, urban and rural development, information sharing, science and technological development, environmental protection, through which the cities share common interest and fate. However, the previous studies on the impact of MP are mostly qualitative. Given this, the inauguration of MP in China is treated as a policy intervention in our case study, where the announcement of relevant national documentation is regarded as the milestone of MP inauguration.

Many studies suggested that the development of MP is dependent on the uplift of transportation services. For example, Fang et al. (2005) summarized that the MP centered around one large city with several metropolitans as foundations are closely connected through the high level of

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[1] For example, the emergence of London megalopolis was driven by the industrial revolution; Paris megalopolis and the megalopolis in northwest Europe emerged when the center of the world economic trading shifted to Europe in the 19th Century; megalopolis along the Atlantic coast of North America and the Great Lakes formed in the 20th century when the global trading center shifted from Western Europe to North America.

transport network, telecommunication infrastructure, and favorable incentive policies, so that the urban entity is highly spatially compacted and economically related. The importance of the connectivity among cities in a MP achieved by transport and related infrastructures was echoed by Teaford (2006) and Ni (2008). Therefore, connectivity is the basic necessity to form MP that can further improve economic development. One of the most essential ways to improve the inter-connectivity between cities is to develop HSR with less travel time than traditional railway, and with more convenience and reliability than aviation service. According to Rice et al. (2006), proximity to "economic mass" measured by travel time is an important determinant of productivity evolution. Consequently, this study is motivated to investigate the effects of HSR and MP, respectively, their interaction, and the impact of HSR on MP development.

During the same period of MP development, the world's largest HSR network was developed in China in the last decade (Xu et al., 2018a). Mega-investment in HSR raised questions about its significance for economic development. The impacts of HSR on economy were studied extensively over the last decades. Previous studies identified a variety of factors reflecting economic growth that relate to HSR, such as composition of population and employment (Bollinger and Ihlanfeldt, 1997), GDP and welfare (Chen et al., 2016), fixed asset investment and industrial structure (Jia et al., 2017), population, and foreign direct investment (Zhao et al., 2017). Some studies analyzed the network expansion of HSR and identified the effects of HSR in improving connectivity and accessibility (e.g., Shaw et al., 2014; Jiao et al., 2017; Wang et al., 2018; Diao, 2018; Xu et al., 2019; Jiao et al., 2020). Most of the studies that analyzed the economic impact of HSR have established a positive correlation between HSR development and regional economic growth, e.g., Zheng and Kahn (2013), Ke et al. (2017), Lin (2017), Xu et al. (2018b), Meng et al. (2018) and Diao (2018). However, the impacts can be different crossing regions, i.e., economic activities flowing from peripheral area to core area (Vickerman, 1997; Hall, 2009; Jia et al., 2017; Qin, 2017), known as 'tunnel effect'; different influences depending on the land use patterns (Chen and Haynes, 2015). Similar results are drawn in this study that the more economically developed regions are more likely to benefit from HSR development, while less effects (or even negative associations) are observed for under-developed regions.

While it is generally acknowledged that MP and HSR both may positively impact regional economic growth, the interaction between the two types of policy interventions is rarely studied. As of 2017, 131 out of 167 (78.4%) MP cities in China have been connected to the HSR network whereas the national-wide proportion is 70.0% (196 out of 280), indicating that the majority of HSR connected cities belong to MP. This phenomenon is reasonable because highly efficient transport network is an essential element for the formation of MP, which may in turn boost economic growth and travel demand for transport services. Melibaeva (2010) found that HSR has an indirect facilitation for MP formation by fusing cities linked by HSR. In addition, Venables (2004) found important links between transport and urban agglomeration that transport investment can strengthen the externalities of firm aggregation and increase productivity by raising urban densities. These effects are regarded as "wider benefits" since they are not included in a standard cost-benefit appraisal, which could substantially increase the estimated benefit of transport investment (Venables, 2004). On the other hand, the MP inauguration policies will also accelerate the construction of HSR. As the consequence, the majority of cities in one MP are connected by a same HSR line for joint development. Therefore, MP and HSR may mutually facilitate each other and promote the economy together. As suggested by Baniste and Berechman (2001), only when three conditions are present, will economic development occur, which are "positive economic externalities" (i.e., agglomeration, labor market economies, good labor force), "investment factors" (including the availability, scale, location and time of the investment) and "political factors" (any complementary policy actions). With regard to their statement, to quantify the economic growth, the three conditions should be included as far as possible. Moreover, most of the MP cities having HSR means that HSR stations might aggregate geographically. Hence, the coexistence of MP policy and HSR service is very likely to impose additive or additional influence on economic growth. Existing literature established positive correlation between economic growth and urban agglomerations led by transport investment (Graham, 2007; Melo et al., 2009; Yao and Liu, 2013; Zhou et al., 2019). However, there is a lack of understanding of how the formation of MP and HSR infrastructures as well as the combination of them impact the regional economy in China, which hinders the more informed policy-makings related to urban agglomerations and HSR infrastructure development.

To bridge these gaps, this paper examines the economic effect of MP formation, HSR infrastructures and their simultaneous and joint impact. To compare effects at different scales, this paper considers three groups of prefecture-level cities in China, i.e., the 'Full sample' including all the sampled cities in China, the 'All-MP sample' incorporating the sampled cities that have formed MP by 2017, and 'individual MP samples' for all each individual MP formed in or before 2017 consisting of cities included in the specific MP. Firstly, with the Full sample, we focus on the average economic growth in the country due to the three types of policy interventions. In order to measure HSR impact on MP cities, we step forward to study the All-MP sample to see if the effect is different on cities with and without MP intervention. Considering that the two policies may potentially facilitate each other and cooperatively enhance the economy, the effect of the two policies that occur simultaneously is also measured on the All-MP sample. The estimation using Full sample and All-MP sample are based on the difference-in-differences (DID) method. Furthermore, as suggested by Graham (2007), it is preferable to examine the relationship between productivity and urban density separately for different economic sectors for the different levels of urbanization, where the higher ones are more likely to benefit more from urban agglomeration. The various extents of benefit may also happen in different MPs with different levels of urbanization or for other different factors. With regard to the probable difference crossing various MPs owing to differentiation in geographical location, industrial composition, other policies and so forth, individual MP samples are analyzed using the general linear regression method. The results provide new insights and policy implications regarding agglomeration policies and economy, with an emphasis on transportation infrastructure investment.

The main contributions of this paper are as follows. First, we make relevant visual analysis based on the impact of MP and HSR on the economy in China which provides an intuitive observation that both the strategical (MP inauguration) and transport (HSR induction) policy interventions have positive impacts on regional economic growth. Second, the effect of MP formation, HSR inauguration and their simultaneous impact on economic growth of normal cities and MP cities are examined and compared on account of explanatory variables related to economic growth, such as population, proportions of industries in GRP, fixed asset investments. The DID method is adopted as the econometric tool to estimate causal effect of new policy intervention and policy changes (Lechner, 2011). Third, this paper quantitively measures the stimulating effect of MP policy and the additive effect when it is combined with HSR service. Through analyzing the Full sample and All-MP sample, we establish different magnitudes of effects on cities in and out of MPs. Lastly, by comparing individual MP samples, we identify the relationship between the wealth condition of a MP and the magnitude of effect, which has implications on cross-regional disparity escalation. It is found that both of policies have similar stimulating effects on the economy, where the formation of MP has relatively larger correlation with economic growth. The coexistence of MP and HSR has the most significant effect, more than the sum of effect magnitudes associated with MP and HSR. Cities enclosed in MPs are found to benefit more from HSR service than those not belong to MPs. Among the MPs, those with better economic conditions tend to be more positively influenced by the joint intervention.

The rest of the paper is organized as follows. Section 2 introduces the data and variables. Section 3 presents an overview and descriptive data analysis of MP and HSR developments in China. Section 4 demonstrates the econometric analysis to quantify the effects of MP, HSR, and the joint impact of MP and HSR on regional economic growth. Section 5 concludes the paper.

2. Data

To measure the economic impacts of HSR and MP inaugurations, we establish a panel data including 280 prefecture-level and above cities in mainland China that have relatively complete needed data collected from the China Yearbook Full-text Database, covering the period between 1996 and 2017, starting 8 years before HSR entry. The major variables involved in this study are listed in Table 1.

As discussed, we consider three types of policy interventions in this paper, i.e., the introduction of MP policy, the connection to HSR network, and the joint impact of MP and HSR, represented by MP, HSR and MP×HSR, respectively. They are defined as dummy variables, which take the value of one if the prefecture was intervened by the policy in a particular year, and zero otherwise.

The economic-related data include the economic output GRP per capita (GRP_PC) and the variables that related to economic growth collected from the China Yearbook Full-text Database. These variables that reflect the economic condition are used to explain the economic growth to reduce specification error.

HSR data consist of the year of HSR taken into services and cities along the line, which were collected from the Yearly Train Schedule of China, complemented by descriptions of HSR stations in Baidu Entry and different media outlets. HSR services that are introduced in the last quarter of the year are regarded as opened in the next year because the effects are much likely to be produced in the following year. In other words, if one HSR was taken into operation on or after the 1st of October, its inaugural year should be the next year.

Table 1. Variables and descriptions

Variable	Description	Unit
Continuous variables		
GRP	Gross Regional Product	100 000 yuan
GRP_PC	Gross Regional Product per Capita	yuan
POP	Household Registered Population at Year-end	10 000 persons
GRP_2ND	Proportion of Secondary Industry in GRP	%
GRP_3RD	Proportion of Tertiary Industry in GRP	%
FC_PRO	Number of Projects for Contracted Foreign Direct Investment	unit
FC_CAP	Amount of Foreign Capital Actually Utilized	10 000 USD
FA	Investment in Fixed Assets (Excluding Rural Households)	10 000 yuan
RE	Investment in Real Estate Development	10 000 yuan
Binary variables (equals 1 if the city qualifies the below description and 0 otherwise)		
HSR	Connected to HSR in the specific year	
HSR_TREATED	Connected to HSR in the end year	
MP	Classified to be part of a megalopolis in the specific year	
MP_TREATED	Classified to be part of a megalopolis in the end year	
MP×HSR	Classified to be part of a megalopolis and connected to HSR in the specific year	
MP×HSR_TREATED	Classified to be part of a megalopolis and connected to HSR in the end year	
HBO	Classified to be part of Hohhot-Baotou-Ordos Megalopolis in the specific year	
PRD	Classified to be part of Pearl River Delta Megalopolis in the specific year	
YRD	Classified to be part of Yangtze River Delta Megalopolis in the specific year	
CZT	Classified to be part of Chang-Zhu-Tan Megalopolis in the specific year	
SDP	Classified to be part of Shandong Peninsula Megalopolis in the specific year	

TSNS	Classified to be part of Tianshan North Slope Megalopolis in the specific year
JZ	Classified to be part of Jinzhong Megalopolis in the specific year
WH	Classified to be part of Wuhan Megalopolis in the specific year
JJJ	Classified to be part of Jing-Jin-Ji Megalopolis in the specific year
HC	Classified to be part of Harbin-Changchun Megalopolis in the specific year
CLN	Classified to be part of Central Liaoning Megalopolis in the specific year
WTS	Classified to be part of Wester Taiwan Straits Megalopolis in the specific year
JH	Classified to be part of Jianghuai Megalopolis in the specific year
PYL	Classified to be part of Poyang Lake Megalopolis in the specific year
CY	Classified to be part of Chengyu Megalopolis in the specific year
BBG	Classified to be part of Beibu Gulf Megalopolis in the specific year
DZ	Classified to be part of Dianzhong Megalopolis in the specific year
CP	Classified to be part of Central Plain Megalopolis in the specific year
MQ	Classified to be part of Mid Qian Megalopolis in the specific year

Based on the national policies of China, our analysis includes 19 MPs formed by 2017 in China, i.e., Yangtze River Delta Megalopolis (YRD), Wuhan Megalopolis (WH) Jing-Jin-Ji Megalopolis (JJJ), Chang-Zhu-Tan Megalopolis (CZT) , Shandong Peninsula Megalopolis (SDP), Jinzhong Megalopolis (JZ), Poyang Lake Megalopolis (PYL), Jianghuai Megalopolis (JH), Central Liaoning Megalopolis (CLN), Pearl River Delta Megalopolis (PRD), Dianzhong Megalopolis (DZ), Hohhot-Baotou-Ordos Megalopolis (HBO), Tianshan North Slope Megalopolis (TSNS), Central Plain Megalopolis (CP), Harbin-Changchun Megalopolis (HC), Chengyu Megalopolis (CY), Wester Taiwan Straits Megalopolis (WTS), Beibu Gulf Megalopolis (BBG), and Mid Qian Megalopolis (MQ). The detailed policy documentation and the establishment year of each MP are listed in Table 2. Since our analysis covers the period 1996-2017, the MPs established on or after 2018 is not included in the analysis.

Table 2. Megalopolises in China

Megalopolis	Inaugural year	# of cities	# of observations	National policy documentation	GRP per capita in 2017
YRD	1997	29	616	Joint Meeting of Directors of the Fourteen Cities Cooperation Office of the Yangtze River Delta	1.11×10^5
WH	2002	6	128	Fully implement the important thought of "Three Represents" and work hard to speed up the modernization of Hubei	7.79×10^4
JJJ	2004	13	279	Opinions of the Development and Reform Commission of Hebei, Tianjin, Beijing on Establishing a Coordination and Communication Mechanism to Promote the Development of the Beijing-Tianjin-Hebei Metropolitan	6.76×10^4

				Area	
CZT	2005	3	66	Regional Planning of Chang-Zhu-Tan Megalopolis	9.86×10^4
SDP	2005	9	184	Shandong Peninsula Megalopolis Master Plan	9.59×10^4
JZ	2005	2	36	Opinions of the CPC Jinzhong Municipal Committee on building Jinzhong into the most dynamic economic belt and urban agglomeration in central Shanxi	7.99×10^4
PYL	2006	6	126	Planning of Poyang Lake Economic Circle (2006-2010)	4.39×10^4
JH	2007	6	131	The 5th meeting of the 10th Anhui Provincial People's Congress	5.03×10^4
CLN	2008	8	171	Central Liaoning Megalopolis Development Plan	5.84×10^4
PRD	2009	9	197	Outline of the Pearl River Delta Region Reform and Development Plan (2008-2020)	2.04×10^5
DZ	2009	3	61	Regional Coordinated Development Plan of the Yunnan Dianzhong Urban Economic Circle (2009-2020)	3.55×10^4
HBO	2010	5	89	Hohhot-Baotou-Ordos Megalopolis Development Plan	2.07×10^5
TSNS	2012	2	38	Development plan of the economic belt on the northern slope of Tianshan	9.18×10^4
CP	2016	25	525	Central Plain Megalopolis Development Plan	3.49×10^4
HC	2016	5	106	Harbin-Changchun Megalopolis Development Plan	6.76×10^4
CY	2016	15	302	Chengyu Megalopolis Development Plan	4.01×10^4
WTS	2017	19	407	Wester Taiwan Straits Megalopolis Development Plan	5.19×10^4
BBG	2017	8	168	Beibu Gulf Megalopolis Development Plan	3.70×10^4
MQ	2017	2	42	Mid Qian Megalopolis Development Plan	3.00×10^4
LX	2018	/	/	Lanzhou-Xining Megalopolis development plan	/
GZP	2018	/	/	Guanzhong Plain Megalopolis Development Plan	/

Figure 1 presents the geographical distribution of MPs in China as of 2017. The MPs shown in slash texture represent those with HSR services. It shows that most MPs have been connected to the HSR network except the Beibu Gulf, Lanzhou-Xining and Guanzhong Plain MPs. Given the substantial overlap between the coverage of HSR and MP, we are motivated to analyze their interactions and joint impact on regional economic growth.

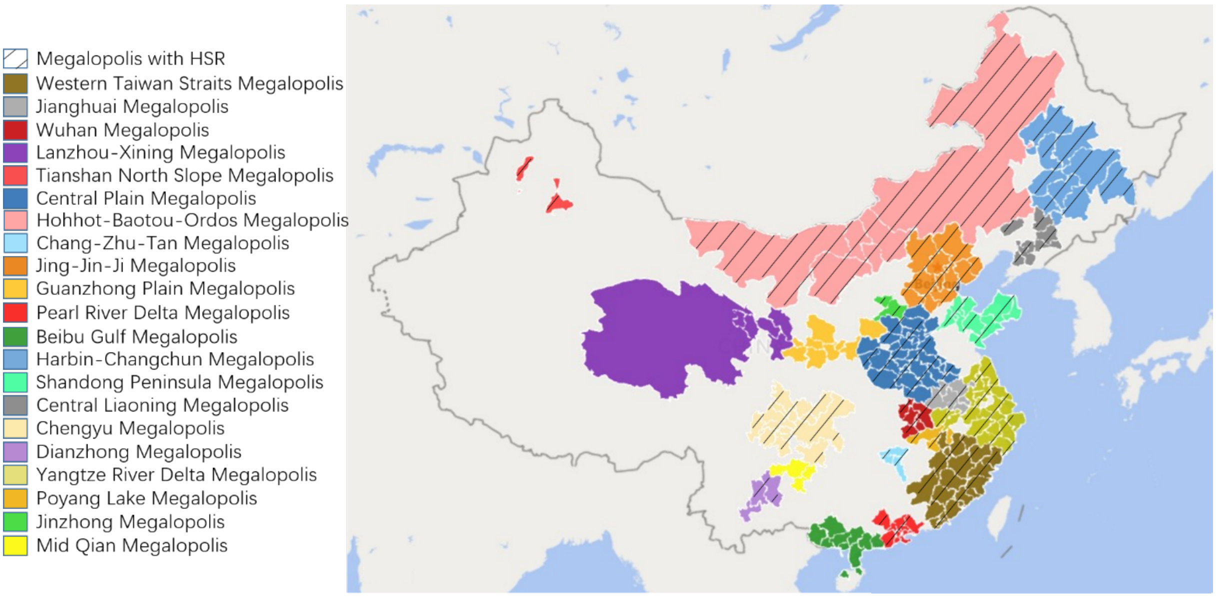

Figure 1. Geographical Distribution of MPs in China

3. Descriptive analysis of MP and HSR developments

To envision the overall effect of strategical policy and HSR infrastructure development on local economy, this section introduces the development of MPs in China and discusses the variations in GRP growth following MP and HSR inaugurations.

3.1. The MPs in China

As introduced in Section 1, the MP refers to the huge and multi-level urban group formed by the aggregation of several large cities that are distributed geographically. MPs are important carriers for countries to participate in global competition and shift the focus of the world economy (Fang et al., 2018). With the continuous development of urbanization, China has invested both financially and academically to facilitate the formation and growth of MPs (Fang et al., 2017). The National Five-Year Plan Outlines of "Eleventh Five-Year", "Twelfth Five-Year" and "Thirteenth Five-Year" regard MPs as the main body of space for promoting new urbanization for 15 consecutive years. Moreover, the nation is gradually building its MPs as shown in 'Opinions of the Central Committee of the Communist Party of China on Establishing a More Effective New Mechanism for Coordinated Regional Development' which indicates a new model of regional development driven by the construction of MPs in China. The aim is to promote the economic growth through clustering effect. MPs expect to promote the development of the connections among cities which facilitate trade and resource exchange within the MP. The clear division of labor in different cities promotes industrial development.

In details, Fang et al. (2011) summarized 23 MPs in China in 2010 including 5 national-level large MPs, 9 regional-level medium-sized MPs, and 6 sub-regional-level small-sized MPs. However, due to the different development situations in various regions, some of them have not been endorsed by formal governmental documentation and have been lacking associated policy support. Thus, according to the standard of MP introduced by Wang et al. (2013)[2] and the relevant documents issued by the government of China, 21 formal MPs are included in our analysis as listed in Table 2.

To illustrate the evolution of MPs, we present the changes in the amount of MPs from 1997 to 2018, which are shown in Figure 2. As can be seen, the amount of MPs and cities included in MPs increase in consistent trends, which verifies that China is vigorously accelerating the planning and construction of MPs. As of 2018, 218 prefecture-level cities in China have been classified in MPs, which means the MPs are acting as the main body of China's new urbanization.

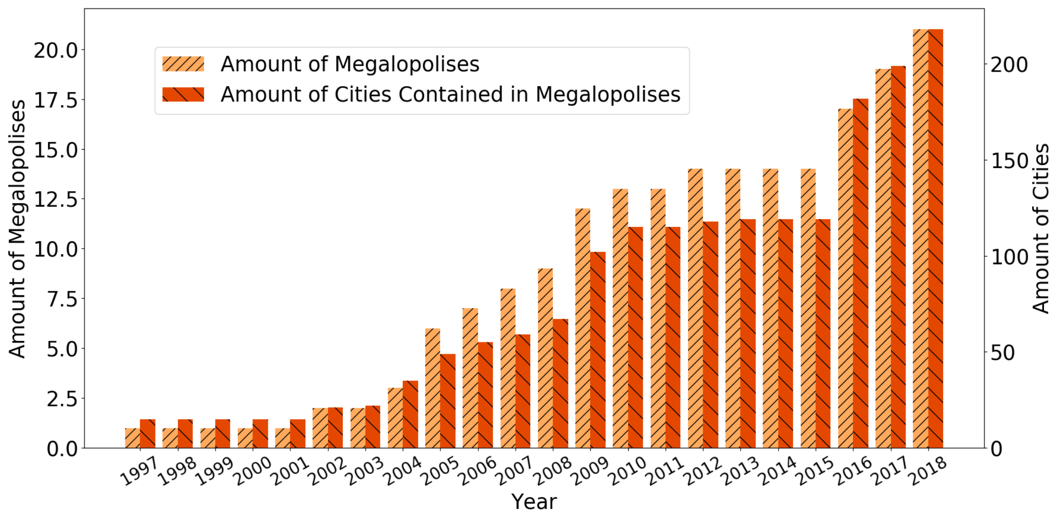

Figure 2. The numbers of MPs and cities classified in MPs

3.2. Impact of MPs on economic development

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[2] According to Wang et al. (2013), the standard of MP includes three conditions: 1) the cities in MP should have developed economic levels, admirable traffic conditions, high population size, and good urbanization level; 2) the cities in one MP should be closely connected which means the hinterland of the areas are connected or the cities gravity values are large; 3) the development strength of the core city is powerful.

In order to obtain a preliminary understanding of the impacts of the MP policies on economy, this subsection discusses the economic growth associated with the expansion of MPs.

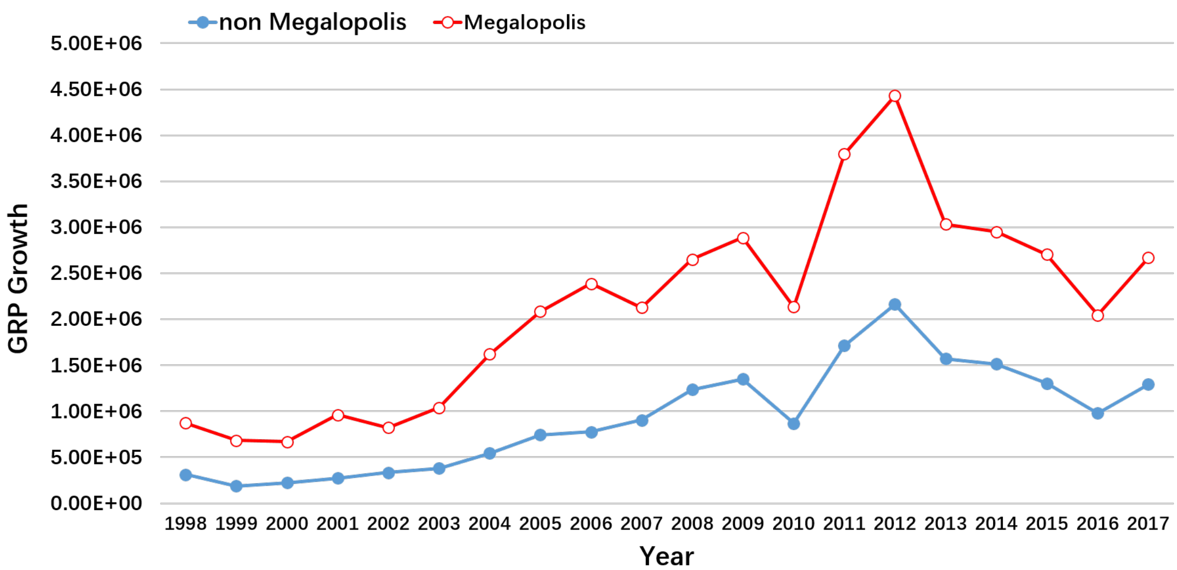

Figure 3. The average GRP Growth of prefecture-level cities in/out of MPs

In Figure 3, we present the average values of GRP growth from 1998 to 2017 (e.g., growth in 1998 means the growth value between 1997 and 1998) for the prefecture-level cities in China. The red line and blue line represent the growth of cities included in MPs and cities not included, respectively. The years on y-axis represent the statistical years. The specific average growth and standard deviations are relayed to Table 5 in Appendix A. The results show that the average GRP growth of all cities have parallel trends in early years (before 2003). Afterwards, the amplitude of MP growth accelerates and the gap between MP and non-MP cities are enlarged. Obviously, cities classified in MPs have larger GRP growth than those not contained in MPs, indicating the potential contribution of MP establishment to regional economic development since MPs facilitate mutual cooperation and complementarity among cities.

3.3. Impact of HSR on MP Economic Development

Previous studies often focused on the impact of either MP or HSR on various cities, few studies examined their interactions. As shown in Figure 3, most MPs are connected to HSR; this section further analyzes the GRP growth of MPs, intending to obtain a primary understanding of the impacts of HSR on MP.

We present the average GRP growth of MP cities with and without HSR during 1998-2017 in Figure 4. The specific mean and standard deviation values are relayed to Table 5 in Appendix A. The red curve represents the average GRP growth of MP cities connected to HSR network (in the specific year) and the blue curve represents that of the MP cities without HSR. It shows that in the early years of HSR development (2005-2007), the coverage of HSR system is extremely limited while the construction of HSR infrastructure entails large amount of investment. During this period, the MP cities with HSR have an average of lower economic growth rate. An upsurge of red curve occurred in 2008 when the vast of HSR infrastructure launched in service and rapid expansion of HSR started. After then, the MP cities with HSR have significantly larger GRP growth rate than those without HSR. This indicates that HSR may have additional positive effect on cities already treated with MP policy.

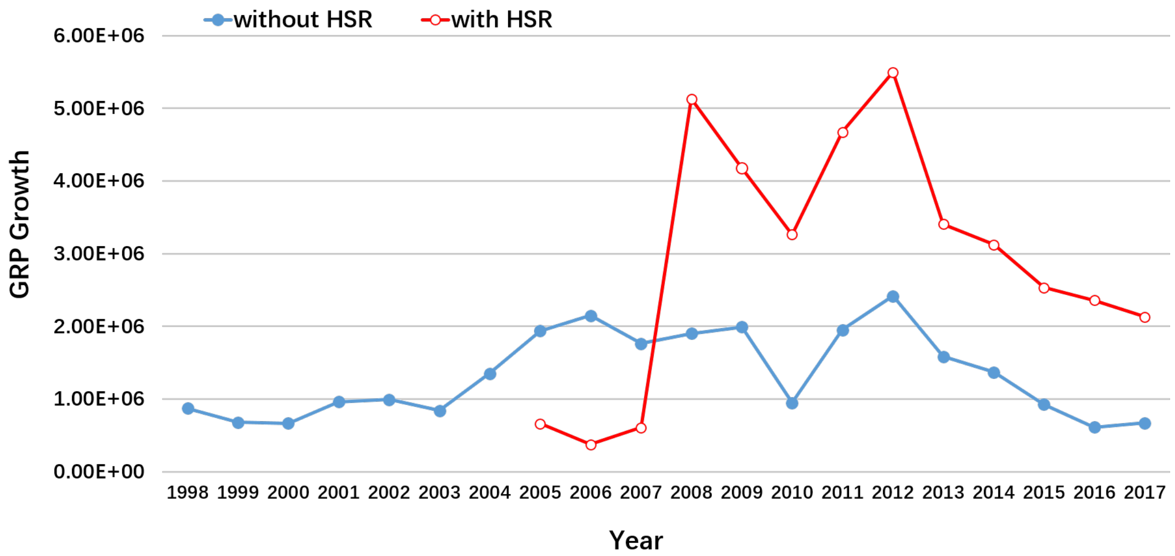

Figure 4. The average GRP Growth of MP cities with/without HSR

4. Econometric analysis: HSR, megalopolis, and joint impact

This section presents the analysis on the impact of MP, HSR and the joint intervention using econometric method. As introduced, we consider three groups of prefecture-level cities in China, i.e., the 'Full sample' including all the sampled cities in China, the 'All-MP sample' incorporating the sampled cities that have formed MP by 2017, and 'individual MP samples' for all each individual MP formed in or before 2017 consisting of cities included in the specific MP. The overall estimation results based on Full and All-MP samples are presented in Section 4.1, followed by individual MP analysis in Section 4.2.

4.1. Overall estimation

It is shown in Section 3 that cities treated with MP policy tend to have a larger extent of GRP growth, among which those served by HSR developed more rapidly from 2008 when the first HSR line has functioned for several years and HSR infrastructure started booming. This section further investigates whether MP formation and HSR service have additive effects on the economy. To this end, we examine the effects of formation of megalopolis, HSR inauguration, and the joint interventions among the Full and All-MP samples, respectively. The DID method is adopted to quantify the effects. For each analysis, the sample is divided into two groups, i.e., the treated and control group, where the treated group includes cities intervened by a specific policy, and the control group consists of cities not affected by the policy throughout the study period (1996-2017). The difference of outputs before and after treatment in the treated group and control group should be estimated to evaluate the impacts, and the difference of differences reflects the effect of a particular policy intervention (Wooldridge, 2010).

Equation (1) presents the regression model based on the DID method. The treatment variable for individual i, denoted by $TREATED_i$, is binary and $TREATED_i \in \{0,1\}$, where one means that individual i belongs to the treated group and zero otherwise. $Policy_{it}$ also takes the value of either zero or one. Only in post-treatment period of treatment group, it equals one. This study examines three types of policy interventions using DID method, i.e., the formation of MP, the HSR inauguration, and the coexistence of both policies, where the $Policy$ variables are represented by MP, HSR and $MP \times HSR$, respectively. Since $Policy_{it}$ represents the policy intervention, the coefficient β estimates the impact of being treated with the particular policy on economic growth and is the result of interest. $Y_{D,T=t}$ is the output variable related to output of treatment or control regions before or after the treatment. In this paper, we measure the dependent variable, Y_{it}, by GRP per capita of the prefecture-level city, represented by GRP_PC_{it}.

Based on Wooldridge (2010), covariates X_{it} related to the change in output without treatment should be included in the regression model as control variables. Apart from external policy interventions, the dependent variables (GRP per capita) can be driven by a large variety of internal characteristics, such as the population size, structure of industries, and availability of investment. Given this, the explanatory variables X_{it} include the population (POP), proportions of secondary and tertiary industries in GRP (GRP_2ND, GRP_3RD), investment in fixed assets (FA), the number of projects for contracted foreign direct investment (FC_PRO), the amount of foreign capital utilized (FC_CAP), and the investment in real estate development (RE). During the period $t \in \{1, 2, \dots, T\}$, year dummies $YEAR_t$ take the value of one only in year t when the data were observed. μ_{it} represents unobserved error, β_0 is the intercept, and α, β, δ_t, and γ are coefficients of corresponding variables. Amongst, the coefficient α represents the difference between treated group and control group during the pre-treatment time. The coefficient δ_t represents the difference in output variable between the base year and year t without considering treatment. The coefficient for the policy variable β estimates the effect of the policy in concern, i.e., the difference of differences.

$$Y_{it} = \beta_0 + \alpha \cdot TREATED_i + \beta \cdot Policy_{it} + \sum_{t=1}^{T} \delta_t \cdot YEAR_t + \sum_{n=1}^{N} \gamma_n X_{it} + u_{it}, \quad (1)$$

It is noteworthy that there is a premise to use DID method that if there is no treatment imposed on the treated group, outcomes of treated group should have a parallel trend to that of the control group. If this assumption is violated, pretreatment difference rather than treatment will give rise to the difference in difference result. Following Wan et al. (2016) and Zhang et al. (2018), we examine the premise by assessing the yearly fixed effects of treatment and control groups using pretreatment period data where policy variables are removed, as shown in Appendix B. The yearly fixed effect plots start from 1997 regarding year 1996 as the baseline. As shown, the yearly effects of treatment and control groups are generally parallel with all model specifications, meaning that the DID method is suitable for the analysis and the results can be meaningfully interpreted without being contaminated by the potential reversed endogeneity. Moreover, according to the Hausman test, time fixed effect model is chosen over the spatial or double fixed effect models. The potential heteroscedasticity and autocorrelation are identified by Breusch-Pagan Test and Durbin-Watson Test based on the panel data. Thus, the generalized least square method instead of ordinary least square is adopted to estimate the model.

Table 3. Effects of MP formation, HSR entry, and their interaction

	Full sample (1)-(3)			All-MP sample (4)-(5)	
	(1)	(2)	(3)	(4)	(5)
	Meg	HSR	Meg×HSR	HSR	Meg×HSR
POP	-30.43***	-29.33***	-28.10***	-33.91***	-32.69***
	(1.250)	(1.242)	(1.246)	(1.692)	(1.693)
GRP_2ND	620.3***	709.5***	697.4***	704.1***	703.0***
	(36.19)	(35.60)	(35.89)	(60.82)	(60.51)
GRP_3RD	755.1***	803.3***	775.1***	837.1***	807.9***
	(44.86)	(45.34)	(45.01)	(75.54)	(75.31)
FC_PRO	18.98***	20.42***	20.17***	22.65***	22.63***
	(1.136)	(1.144)	(1.134)	(1.463)	(1.453)
FC_CAP	0.04924***	0.04952***	0.04950***	0.03107***	0.03063***
	(0.004464)	(0.004504)	(0.004456)	(0.006244)	(0.006213)
FA	4.502e-04***	4.432e-04***	3.952e-04***	4.974e-04***	4.729e-04***
	(7.992e-05)	(8.079e-05)	(7.986e-05)	(1.058e-04)	(1.053e-04)
RE	1.134e-03***	1.126e-03***	8.959e-04***	0.001504***	0.00427***
	(2.379e-04)	(2.406e-04)	(2.389e-04)	(3.114e-04)	(3.099e-04)
MP	6662***				
	(963.0)				
HSR		5868***		8114***	
		(1181)		(1742)	
MP×HSR			15,390***		13,400***

			(1355)		(1783)
TREATED	3773***	-420.8	35.43	-5412***	-5891***
	(767.1)	(782.2)	(723.6)	(1309)	(1273)
Constant	-42,020***	-45,510***	-44,730***	-41,390***	-40,420
	(3229)	(3230)	(3198)	(5380)	(5352)
Observations	5648	5648	5648	3487	3487
Sample size	280	280	280	167	167
Treated group size	167	196	131	131	131
Control group size	113	84	149	36	36
R^2	0.5965	0.5893	0.5980	0.5798	0.5840
Adjusted R^2	0.5943	0.5871	0.5958	0.5762	0.5804

Significant codes: ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘#’ 0.1

Table 3 presents the regression results of DID estimation based on the Full sample and All-MP sample, respectively, where the values in brackets are standard errors. Using the Full sample, we examine the national average effects of MP, HSR, and their interaction MP×HSR on prefecture-level city GRP per capita, shown in columns (1)-(3) in Table 3. Since the All-MP sample excludes those not treated by MP (all cities belong to the MP treated group), the effects of HSR and MP×HSR are examined, which are shown in columns (4)-(5). Most explanatory variables are associated with positive coefficients implying the positive correlations between them and the economic output, except POP since a larger population is associated with less GRP per capita. The following analysis will focus on the results related to the policy variables, MP, HSR, and MP×HSR.

The results of Full sample regressions indicate that both MP inauguration and HSR induction are associated with positive economic growth. Specifically, the MP inauguration is associated with an average increase of 6662 CNY (Currency: Chinese Yuan) in annual GRP per capita of a prefecture-level city in China, and the introduction of HSR is associated with an average increase of 5868 CNY in annual GRP per capita. However, the simultaneous impact of MP×HSR is associated with the largest GRP growth (15,390 CNY), more than the sum of the former two. The results indicate that MP and HSR entry both may have stimulating effects on regional economic growth. When influenced by the joint intervention of both MP and HSR at the same time, the strategical and transport policies have reinforcement effects on one another and the combined impact is more than the sum of individual interventions in terms of national average.

For the All-MP sample where only MP cities are included, the HSR and MP×HSR are observed to have positive correlations with the GRP per capita, respectively, while the effect of the joint policy intervention is less than twice that of HSR inauguration. When compared with the results of the Full sample, it is found that the positive influence of HSR on GRP_PC on MP cites is larger than the national average (comparing column (4) with (2)). This may be because that the MP cities are often geographically adjacent and share the integrated policy concerning infrastructure construction due to the inauguration of MP. Thus, MP cites are more likely to be connected by the same HSR lines with more frequent services to facilitate the development of MP urban clusters. Therefore, they are prone to benefit from HSR more than the average at the national level.

The effect of joint policy MP×HSR on MP cities is less than the national average (comparing column (5) with (3)). This phenomenon indicates that the intervention of MP has dominating effect on regional economic growth over HSR. This can be explained by that the treated groups affected by the joint policy are identical for the Full and All-MP samples, whereas the control groups (comparison baseline of DID estimation) are different. The control group for the Full sample analysis includes all prefecture-level cities in China, but that for the All-MP sample only includes those classified in MP but not connected HSR (treated by MP but not HSR). This implies that the reference point for the All-MP sample is higher than the Full sample, and thus the additional effect of HSR on top of MP is lessened.

4.2. Individual megalopolis analysis

To analyze the relative effect of MP and HSR on each MP, we introduce the following simple regression model involving MP and MP×HSR, representing MP inauguration and the joint policy, respectively. The other explanatory variables X_{it} are the same as those in Equation (1), including the population (POP), proportions of secondary and tertiary industries in GRP (GRP_2ND, GRP_3RD), investment in fixed assets (FA), the number of projects for contracted foreign direct investment (FC_PRO), the amount of foreign capital utilized (FC_CAP), and the investment in real estate development (RE).

$$Y_{it} = \beta_0 + \beta_1 \cdot (T_t \cdot MP_i) + \beta_2 \cdot (T_t \cdot MP \times HSR_i) + \sum_{t=1}^{T} \delta_t \cdot YEAR_t + \sum_{n=1}^{N} \gamma_n X_{it} + u_{it} \quad (2)$$

Table 4 summarizes the effects of MP and the joint intervention of MP and HSR based on each individual MP sample. Note that only the policy variables are presented while the coefficients of other explanatory variables are omitted to save space (the coefficients are in similar magnitudes to those in Table 3). The MPs are presented in the descending order of 2017 GRP per capita. The coefficients of MP are larger and more significant than those of MP×HSR, indicating that, again, the MP intervention has dominating effect on regional economic growth over HSR.

To visualize the relationship between the effect of policy intervention and development condition of the MP, we depict the scatter diagram of the regression estimation coefficient and the GRP per capita (in 2017) of each MP in Figure 5. The x-axis represents the 2017 GRP per capita and the y-axis represents the corresponding regression coefficient associated with the MP, where results in low significance ($p > 0.05$) are excluded. Figure 5 indicates that the treatment effect of MP policy is neutral to the intrinsic development condition of the region; hence, there is no obvious relationship between the coefficients of MP and GRP per capita. However, the relationship between the coefficients of MP×HSR and GRP per capita tends to be linear, implying that the joint treatment of MP and HSR is likely to benefit more the wealthier regions with larger GRP per capita than the under-developed regions. Relative to the effect of MP, the additional effect of MP×HSR may facilitate economic resources being siphoned from under-developed regions to more developed regions and thus contribute to the escalation of inter-regional disparity. The implication is consistent with the observations of Cheng et al. (2015) and Qin (2017).

Table 4. Effects of MP policy and the doubly policy of MP and HSR on each MP

Megalopolis	GRP per capita	MP	MP×HSR
HBO	207442.4	76,130***	-
		(18690)	
PRD	203715.9	51,190*	49,230***
		(23,490)	(13,960)
YRD	111098.2	3413*	5458*
		(1731)	(2423)
CZT	98648.56	32,630***	-
		(3236)	
SDP	95943.46	-	-
TSNS	91752.86	-	-
JZ	79881.2	-	-
WH	77878.41	37,190***	-
		(5790)	
JJJ	67568.55	12,420***	-
		(3711)	
HC	59381.28	20,420*	20,420*
		(8359)	(8359)
CLN	58381.71	26,300***	4959*
		(4741)	(2248)
WTS	51910.16	-	8725***
			(2056)
JH	50278.68	11,690***	-3740#
		(2098)	(1890)
PYL	43860.34	35,380***	-7820***
		(4213)	(1866)

CY	40143.69	24,650*** (1737)	-
BBG	37032.34	35,050*** (2767)	-
DZ	35482.63	35,050*** (9640)	-
CP	34888.26	-	-2491# (1268)
MQ	29974.31	9352** (2400)	-6683** (2165)

Significant codes: '***' 0.001 '**' 0.01 '*' 0.05 '#' 0.1

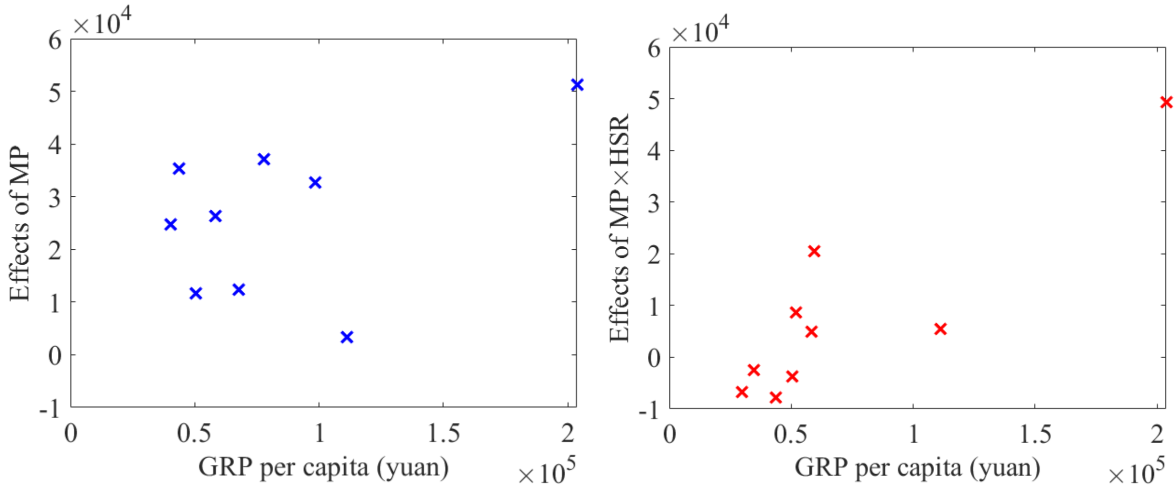

Figure 5. The relationship between the effect of policy intervention and the 2017 GRP per capita of each MP

5. Conclusions

With the developments of megalopolis (MP) and High-speed rail (HSR) in China, there is increasingly more economic interactions among urban agglomerations, which is expected to enhance regional economic development. The interventions of MP and HSR are often interactive. On one hand, MP cities tend to share common policies such as infrastructure planning and thus are more likely to be connected with same HSR lines. On the other hand, better connectivity through HSR network can facilitate production factors and resources exchange and thus blur the boundaries among cities within an MP. The inaugurations of MP and HSR both can contribute to economic prosperity by bringing more frequent economic interaction among cities. However, the previous study on the effects of MP are primarily qualitative and rarely draw attention to the combined effect of MP and HSR inaugurations. This study provides a systematic investigation into the regional economic impacts of MP formation, HSR development, and the joint intervention of MP and HSR.

To compare the effects at different scales (national and regional), this paper examines three groups of prefectural cities in China, i.e., the 'Full sample' including all the sampled cities in China, the 'All-MP sample' incorporating the sampled cities that have formed MP by 2017, and 'individual MP samples' for all each individual MP formed in or before 2017 consisting of cities included in the specific MP. The estimation using Full sample and All-MP sample are based on the difference-in-differences (DID) method and individual MP samples are analyzed using simple linear regression method.

Main findings of this paper include: 1) While both MP and HSR have stimulating effects on the regional economic growth, the effect of MP is dominating; 2) The simultaneous and joint impact of the joint policy has the most significant effect, more than the sum of the effects of individual policies; 3) MP cities are found to benefit more from HSR inauguration than those not classified in MPs; 4) The joint intervention of MP and HSR is likely to benefit more the wealthier regions with larger GRP per capita than the under-developed regions, which may escalate inter-regional disparity.

Several policy implications for urban development can be obtained from the results. Firstly, the positive effects of MP and HSR, in particular the joint intervention, on regional economic growth provides important empirical evidence to support the joint planning of urban agglomeration and transportation infrastructure developments. However, it is also identified that the joint intervention of MP and HSR may escalate the cross-regional divergence of economic development. The implications are twofold. For the central government, the observation highlights the importance of equity-enhancing policies as part of the planning of MP with HSR infrastructure, especially for disadvantaged regions, in order to balance cross-regional resource allocation. When treated with joint intervention of MP and HSR, the local government is advocated to incentivize investment in cross-regional and/or transportation-dependent sectors to exploit the advantage of HSR connection, which may in turn benefit the local economy by securing frequent and efficient HSR services in a virtuous cycle.

This study can be extended along several directions. Firstly, while this paper focuses on effects of HSR on regional economy, interactions between HSR and other transport modes may affect the economic impacts, especially those between HSR and aviation services (e.g., Li et al., 2019b; Liu et al., 2019; Ma et al., 2019; Zhang et al., 2020). Secondly, the effect of HSR on economic equity needs to be examined quantitively. Chen and Haynes (2017) found that HSR service mitigated the economic disparity in China at national and regional level through bringing efficient rail transport to the peripheral or underdeveloped cities, which is disagreed by Wang et al. (2018) who suggested that the disparity of accessibility would widen among regions, provinces and cities in China. Thirdly, market structure and pricing of HSR can be considered. As Li et al. (2019a) pointed out, recent HSR development in China has little impact on the market power of the rail operator while the willingness-to pay for HSR services significantly outweighs the current pricing.

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Appendix A. Descriptive statistics of prefecture-level city GRP.

Table 5. Descriptive statistics of prefecture-level city GRP

	Megalopolises without HSR		Megalopolises with HSR		Cities not in megalopolises		Cities in megalopolises	
Year	Mean ($\times 10^6$)	Std ($\times 10^6$)	Mean ($\times 10^6$)	Std ($\times 10^6$)	Mean ($\times 10^6$)	Std ($\times 10^6$)	Mean ($\times 10^6$)	Std ($\times 10^6$)
1998	0.87	1.08			0.31	0.71	0.87	1.08
1999	0.68	0.75			0.19	0.63	0.68	0.75
2000	0.67	0.80			0.22	0.39	0.67	0.80
2001	0.92	1.22			0.27	1.01	0.96	1.22
2002	0.99	0.98			0.33	0.48	0.82	0.91
2003	0.84	0.83			0.38	0.51	1.04	1.09
2004	1.35	1.41			0.54	0.74	1.62	1.86
2005	1.94	1.83	0.66		0.74	0.81	2.08	2.04
2006	2.15	2.67	0.38		0.78	1.57	2.39	4.19
2007	1.76	1.41	0.61		0.91	1.15	2.13	2.29
2008	1.90	1.42	5.13	5.54	1.23	1.43	2.65	3.05
2009	1.99	1.56	4.18	2.35	1.35	1.34	2.89	2.97
2010	0.95	0.68	3.26	2.63	0.87	1.39	2.14	2.80
2011	1.95	0.97	4.68	3.33	1.71	1.78	3.80	3.97
2012	2.42	1.28	5.50	4.11	2.16	2.41	4.43	4.42
2013	1.59	0.92	3.41	3.06	1.57	1.82	3.03	3.30
2014	1.37	0.71	3.13	2.69	1.51	1.81	2.95	3.49
2015	0.93	0.56	2.54	2.58	1.30	1.89	2.70	3.63
2016	0.61	0.54	2.36	2.61	0.98	1.26	2.05	3.07
2017	0.67	0.61	2.13	3.59	1.29	2.35	2.67	4.73

Appendix B. Yearly fixed effects of treatment and control groups in DID models.

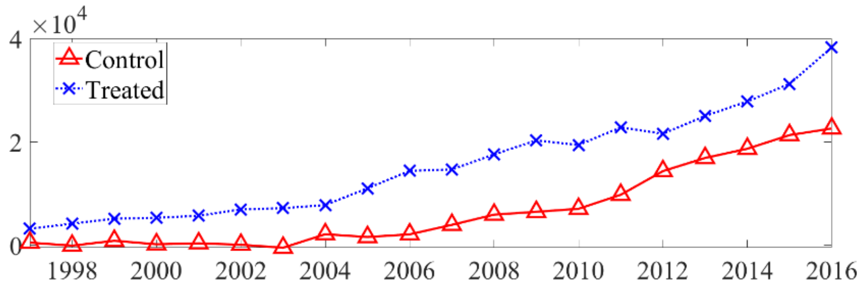

Figure 6. Yearly fixed effects of treatment and control groups affected by MP (Full sample)

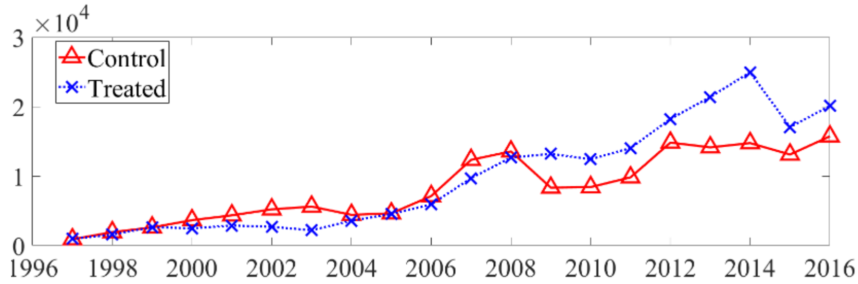

Figure 7. Yearly fixed effects of treatment and control groups affected by HSR (Full sample)

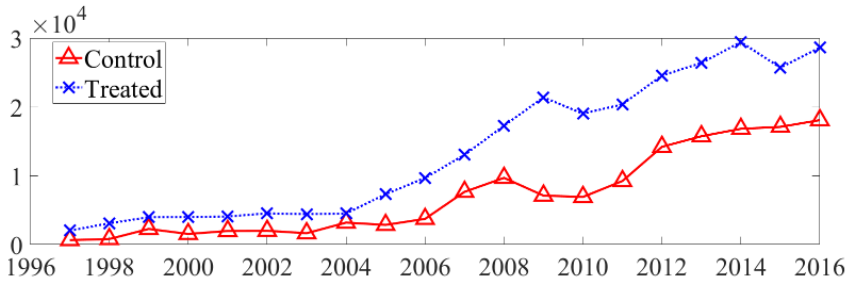

Figure 8. Yearly fixed effects of treatment and control groups affected by MP×HSR (Full sample)

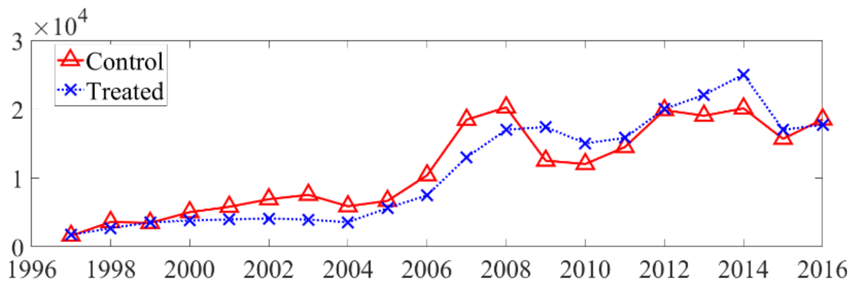

Figure 9. Yearly fixed effects of treatment and control groups affected by HSR (All-MP sample)

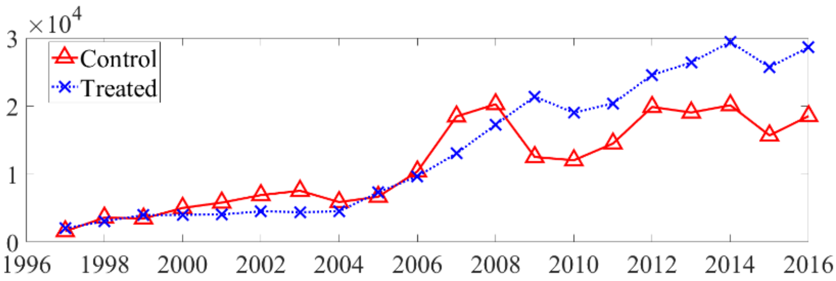

Figure 10. Yearly fixed effects of treatment and control groups affected by MP×HSR (All-MP sample)

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