Effect of intercity electric multiple unit projects on regional economic development: evidence from a natural experiment in Zhongshan city, China

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ABSTRACT

This paper analyzes the impact of the opening of an Intercity EUM (Electric Multiple Units) line, Guangzhou-Zhuhai Intercity Mass Rapid Transit, on GDP and population. By constructing the difference-in-difference (DID) model for whole 24 counties in Zhongshan of China, we found that with the opening of Intercity EMU, GDP growth and population inflow of the counties with Intercity EMU stations are significantly higher than those of without stations. Based on the Sharp Regression Discontinuity (SRD) Approach, we found that with the opening of Intercity EMU, the ratio of Guangzhou’s GDP to that of other regions has obviously expanded, thus the opening of Intercity EMU has obviously widened the disparity of regional economic scale.

1. Introduction

The Chinese mainland launched its first high-speed rail line in December 26, 2009. By the end of 2016, the operating mileage of Chinese mainland high-speed railway reached 23,600 km, accounting for 65% of the world. Guangdong Province, as the most populous province in mainland China, has the highest economic total, and its high-speed railway construction is in the forefront of the country. As of the end of 2016, Guangdong Province high-speed railway density has reached 0.83 kilometers of each hundred square kilometers.

With the popularization of high-speed railway and the improvement of related construction technology, the construction of EMU is also speeding up. There are three EMU lines has been built or completed in Guangdong Province: the Guangzhou-Shenzhen city rail transit, the Guangzhou-Zhuhai city rail transit and the Guangzhou-Foshan-Zhaoqing city rail transit. In addition, there are 2 more lines, the Guangzhou-Qingyuan city rail transit and the Guangzhou-Dongguan-Shenzhen city rail transit, will be opened in 2019.

According to the "Implementation Plan for Structural Reform of Infrastructure Provinces in Guangdong Province" issued on June 28, 2017, Guangdong Province will invest about 18.95 billion dollars from 2017 to 2020 to finish 22 EMU projects of the Pearl River Delta, to start the eastern Guangdong inter-city railway planning and construction. Basically formed EMU city rail transit network that centered in Guangzhou and its the operation mileage of intercity railway about 650 kilometers.

The importance of EMU lines in Guangdong is increasing. Because of its relatively low cost and convenient use, it can promote the flow of people along the route and economic exchanges, which may have a significant impact on regional economic development.

In terms of literature, Bester et al. (1996), Christiaans (2002), Huck et al. (2002), Dreze et al. (2002) show that the location game possesses an infinity of mixed strategy Nash equilibrium. Cournot game in a two-stage non-cooperative with location choice is derived by Dorta-Gonzalez et al. (2004). Meagher and Zauner (2005), Benassi and Chirco (2008), Bárzena-Ruiz and Casado-Izaga (2008) investigate Hotelling's duopoly game of location. Pires (2009), Barr and Tassier (2010), Carbo Valverde and Fortes Escalona (2010), Garcia et al. (2011), Loertscher and Muehlheusser (2011), Bárzena-Ruiz and Casado-Izaga (2012), and Sun (2012) explore the location game models.

The Guangzhou-Zhuhai inter-city rail transit, starts from the Guangzhou, through the Shunde and Zhongshan, arrived in Zhuhai and Jiangmen. It was opened in January 3, 2011, and after 18 mouthes, the number of passengers trafficked by this EMU lines has reached 27 million. greatly promoted the Interregional exchanges of these cities. It is the second EMU line in Guangdong Province, and the first new construction of the opening of the train line since 2005 (Guang-Shen intercity motor vehicle line is based on the old line from the transformation). It is very important to investigate the actual effect of the operation of Guangzhou-Zhuhai intercity rail transit in the past five years, and will help us to

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nc-nd/4.0/).
understand the influence of other EMU lines in Guangdong and even the whole country.

2. Theory

With the improvement of transport infrastructure, economic output and population migration along the way will be impacted. There are n motor vehicle routes in each area along the way, and the migration of population is more frequent. If these are included in the model, it will cause the nonlinear polynomial problem similar to the traveler (TSP). Whether the population will migrate to a regional development is generally determined by the willingness to pay in a given region. Assuming that the individual is limited in rationality, the individual will not migrate to the settlement of the region if it does not have a enough marginal willingness to pay for the individual of the act. To simplify the model, consider the existence of two regions, the development of these two areas of homogeneity, the two regions (A and B) each have a large leading manufacturers, and the production of products with substitutes, the behavior of individuals in the two regions move the mid-point. For this behavior individual, the choice of area A or area B, there is a marginal willingness to pay $\theta \in [0,1]$, its density function satisfies $\int_0^1 \rho(\theta) = 1$, and actually get marginal utility. This marginal utility is given by the product of region A and B, which satisfies the binomial distribution (0.1). The utility function of the individual in the period $i$ is

$$U_i = aQ_i - \gamma Q_i \theta - \frac{\gamma}{2} \alpha P_i Q_i - \tau |d_{iA} - d_{iB}|$$

(1)

Among them, the parameter $\alpha > 0$, which is the market size. $P_i$ and $Q_i$ represent the price and output of the product respectively. $\gamma > 0$ represent the marginal negative utility factor. $d_{iA}$ and $d_{iB}$ represent the individual vehicle traffic time costs for the individual area A and area B, respectively. $\tau$ indicate the difference between these two time costs compared to the ratio of utility bundles.

If the behavior of the individuals to the area A and area B motor vehicle traffic time costs are different, with the passage of time, the improvement of the transport infrastructure, $|d_{iA} - d_{iB}|$ converges to the range of (0,1); If the behavior individual to region A obtains the actual marginal utility of 0 (meaning that the product of area A is unfacilitated or very small in contrast to the location of the behavioral individual), then the actual marginal utility of area B is 1 (meaning that the product of area B is different from the location of the behavioral individual). The utility function of the behavior individual to region A and region B can be obtained from Eq. (1):

$$U_{Ai} = aQ_{Ai} - \gamma Q_{Ai} \theta - 1/2 \gamma Q_i^2 - P_{Ai}Q_{Ai} - \tau |d_{iA} - d_{iB}|$$

(2)

$$U_{Bi} = aQ_{Bi} - \gamma Q_{Bi} \theta - 1/2 \gamma Q_i^2 - P_{Bi}Q_{Bi} - \tau Q_{Bi}$$

(3)

In the model, the price of the product of the area A and B is given, which is observed by the behavior individual. And the yield of the products of the regions A and B is not given, according to the behavior of individual unit effect of the firm's observation, if the individual behavior preference region A is strictly stronger than the region B, then satisfying:

$$\alpha - \gamma \theta - P_{Ai} - \tau |d_{iA} - d_{iB}| \geq \alpha - \gamma (1 - \theta) - P_{Bi} - \tau |d_{iA} - d_{iB}|$$

(4)

$$\theta \leq \frac{P_{Bi} - P_{Ai}}{2\gamma} + \frac{1}{2}$$

(5)

Similarly, if the behavior of individual preference area B is stronger than area A, then there is:

$$\theta \geq \frac{P_{Bi} - P_{Ai}}{2\gamma} + \frac{1}{2}$$

(6)

Regions A and B are determined by the unit utility function of the individual behavior, and the revenue function of region A and region B is:

$$\pi_A = P_A \left( \frac{1}{2} + \frac{P_{Bi} - P_{Ai}}{2\gamma} \right) - \frac{P_{Ai} + P_{Bi} - P_{Ai}}{2\gamma}$$

(7)

$$\pi_B = P_B \left( \frac{1}{2} + \frac{P_{Bi} - P_{Ai}}{2\gamma} \right) - \frac{P_{Ai} + P_{Bi} - P_{Bi}}{2\gamma}$$

(8)

With the passage of time and frequent regional transactions, $P_A = P_B = P'$ and $Q_A = Q_B = Q$. Take the two order derivative of $P_A$ of formula (7). Derivative of $P_A$ first order and then $\alpha$ and derivative of $P_A$ first order and then $t$ get

$$\frac{\partial^2 \pi_A}{\partial (P_A)} = \frac{2a - 3P't - 2\gamma + \gamma}{2\gamma}$$

(9)

$$\frac{\partial^2 \pi_A}{\partial P_A \partial \alpha} = \frac{\gamma - P'}{2\gamma}$$

(10)

$$\frac{\partial^2 \pi_A}{\partial P_A \partial t} = \frac{-\gamma - P'}{2\gamma}$$

(11)

If $\gamma > P'$, it means that $\nu_B - \nu_A > P'/t$, indicating that the economies of the two economies are heterogeneous. By formula (9) we can know that $\pi_A$ is strict concave, there are $\partial P'/\partial \alpha = -\left( \frac{\partial^2 \pi_A}{\partial P_A \partial \alpha} \right) / \left( \frac{\partial^2 \pi_A}{\partial P_A^2} \right) > 0$ and $\partial P'/\partial t < 0$. With $\partial P_A/\partial \alpha > 0$ and $\partial P_A/\partial t < 0$, if $\gamma < P'$, it means that $\nu_B - \nu_A < P'/t$, indicating that the economic situation of two regional economies is homogeneous, getting that $\partial \pi_A / \partial \alpha > 0$ and $\partial \pi_A / \partial t > 0$.

Proposition 1. If the two regional economies are heterogeneous and the traffic time cost is shortened, it is advantageous to optimize the regional resource allocation, enhance the development scale of the economy and benefit the economic growth. If the two regional economies are homogeneous and the cost of transit time is shortened, the competition between economies is aggravated, and if the appropriate market size is maintained, resources are not skewed, which will be beneficial to economic growth.

In fact, the regional development is generally unbalanced because of the different resources endowments and the inclination of government policies in China, that is $y_A < P'$. Considering the behavior of the individual to the same traffic time as the region A and region B, the utility function of behavior individual to region A and region B can be obtained by formula (1):

$$\tilde{U}_{Ai} = aQ_{Ai} - \gamma Q_{Ai} \theta - 1/2 \gamma Q_i^2 - P_{Ai}Q_{Ai}$$

(12)

$$\tilde{U}_{Bi} = aQ_{Bi} - \gamma Q_{Bi} \theta - 1/2 \gamma Q_i^2 - P_{Bi}Q_{Bi}$$

(13)

The process of deriving the model is exactly the same as described above, and is not repeated here. Because of the different regional development, general $\gamma > P$, can get the revenue function of the regional A manufacturers $\tilde{\pi}_A$ about market scale $\alpha$'s first order condition is greater than 0($\partial \pi_A / \partial \alpha > 0$), the region A product price about market scale's first order condition is also greater than 0($\partial \bar{P}_A / \partial \alpha > 0$), so we can get the following proposition:

Proposition 2. The opening of the train line, greatly shorten the transportation time, converge to the transportation time cost is consistent, the price of the product rises with the market scale enlargement, the local economy gross also will rise with the increase.

No matter the time cost of transportation is very different or the same,
the balanced output of the region and the profit of the manufacturers are different. Combining formula (2), formula (3), formula (12) and formula (13), a comparison of the two is obtained:

\[
Q_a = Q_b = Q^* = \frac{1}{2} (a - P^*) - \frac{\gamma}{8} \leq \hat{Q}_a = \hat{Q}_b = \hat{Q}^* = \frac{1}{2} (a - P^*) - \frac{\gamma}{n}
\]  

(14)

\[
\hat{\pi}^* = \hat{\pi} - \frac{1}{2} P^* \hat{\pi} < \hat{\pi}^*
\]  

(15)

Proposition 3. The equilibrium yield of the same area of transportation time cost and the equilibrium income of the manufacturer are more than that of the different transportation time cost.

Proposition 4. At the beginning of the opening of the train line, the regional economy and market scale will be enlarged, and with the regional division of labor and the optimization of the train line, the transportation time cost is shortened, the regional transaction is more and more frequent, and the regional product output and GDP will rise.

3. Methodology

3.1. Econometric methodology

This section of the analysis using the DID(Differences in Differences) model. As the influence of intercity train line is mainly through the docking site, and this effect decreases with increasing distance. Because of its high construction cost, the general planning and construction of the Intercity railway line is coordinated by the national or provincial government, and its route and site setting must take into account economic development. Therefore, it is possible to view the construction of the Guangzhou-Zhuhai intercity rail and its site as “quasi-experiment” of an external impact on economic growth along the route.

The DID model groups samples according to whether they are impacted, and introduces grouping and staging of two dummy variables. By analyzing the grouped dummy variables, the staged dummy variables and the intersection of two dummy variables in the regression model, the actual impact magnitude of the impact on the impacted sample can be obtained after the second order difference, which can solve the problem of internal and external validity during the implementation of “quasi-experiment”. Therefore, this article sets up the area with the stations in the experimental group, in the control group. Study on the impact of setting up a site on the regional GDP and migration trend of the Guangzhou-Zhuhai intercity rail. The overall structure of the DID model is as follows:

\[
Y_0 = \gamma + \beta_1 G_i + \beta_2 T_j + \beta_3 G_iT_j + \sum_{k=1}^{n} a_k x_k + \epsilon_i
\]  

(16)

Since the construction of intercity train line needs to consider the economic benefits, this grouping is not completely random from the perspective of economic development and needs to be adjusted by adding other covariates. In addition, the introduction of covariates can reduce the variance of disturbance items and make the estimation more accurate. \(x_i\) in the above equation is the covariate. When the sample is in the experimental group, \(i = 1\); when the sample is in the tracking period, \(j = 1\); \(G_i\) is a group dummy variable, and \(T_j\) is a staged dummy variable, and the specific values are as follows:

\[
G_i = \begin{cases} 
1 & \text{if } i = 1 \\
0 & \text{else}
\end{cases}
\]  

(17)

\[
T_j = \begin{cases} 
1 & \text{if } j = 1 \\
0 & \text{else}
\end{cases}
\]  

(18)

According to the analysis, by a first order difference performed for each group, the variation of the dependent variables in the two period for each group can be obtained, which can eliminate the impact caused by the change of the internal factors such as industrial structure change in the period of two. Then, to eliminate the influence of individual factors among groups by a second order difference, and the actual impact of impact on the impacted samples is obtained. Make \(D = (Y_{i1} - Y_{i0}) - (Y_{01} - Y_{00})\), obviously, there is:

\[
D = (Y_{i1} - Y_{i0}) - (Y_{01} - Y_{00}) = \beta_1 + \epsilon_{i1} - \epsilon_{i0} - \beta_1 + \epsilon_{01} - \epsilon_{00} = \beta_1 + \Delta \epsilon
\]  

(19)

Among them, \(\Delta \epsilon\) is the result of second order difference of random perturbation term, the expectation is 0. In this way, the coefficient \(\beta_1\) of the intersection of two dummy variables can be used to evaluate the significance of the policy effect.

The construction of the intercity rail line improves the traffic conditions along the line. On the one hand, it can reduce the cost of interregional division of labor, so that the hold market is enlarged and can provide more jobs for residents along the route. On the other hand, more convenient traffic makes life easier for residents along the routes and eventually improve the region’s appeal to residents. These changes will ultimately affect the economic and social development. In order to investigate the direct influence of the construction of Guang-Zhu City rail on the areas along the line, this section will analyze the GDP and the population transfer number respectively.

3.2. Data description

In view of the small scope of the research object, only four municipal and one district administrative units are involved. If the DID model is analyzed directly using municipal data, the sample size is too small to affect the measurement results, so the data of the municipal administrative units is not used in this section.

In addition, the current statistical yearbook in mainland China is generally published only to the relevant data of the next level of administrative units in the statistical units, so the public statistics are generally up to the county (district) level. As the only pilot of Guangdong province covering county, Shunde district has a considerable degree of financial autonomy. However, due to its establishment still belongs to Foshan, the specific data below the district level is not disclosed in the yearbook. Zhuhai and Jiangmen as Municipal city, its county (district) level data can be found in the yearbook, but because Zhuhai only three districts, and Jiangmen district only three districts and four counties, its sample size is still less, will affect the accuracy of the model. In addition, Guangzhou as the capital of Guangdong province and South China’s transportation hub center, from Guang-Zhu City rail opened till now, there are other intercity rail lines, such as the Guang-Fo subway, which have different impacts on different districts. If you use the data below the Guangzhou city level, it may cause some interference. Therefore, the relevant data of the above three cities and one distinct are not used.

Zhongshan city is one of the only two cities in mainland China to implement the municipal-town two-level administrative system (another is Dongguan city). Unlike other districts that implement the municipal-county-town three-level administrative system, the data of 24 township-level administrative units of Zhongshan city all have detailed records in the Statistical Yearbook. On the one hand, the size of the sample is relatively sufficient; On the other hand, the regional division of the township administrative units is finer, which makes the relevant data of the district administrative units more detailed and deeper, and can reflect the facts more objectively. In addition, the Guangzhou-Zhuhai intercity rail transit runs through the whole territory of Zhongshan.
4. Results

4.1. DID experiment

GDP is one of the most important indicators to measure economic development. In view of the fact that GDP is also affected by the size of the population and the size of the investment, this section adds covariance to these two aspects.

In view of the population size, on the one hand, because Guangdong Province is the largest imported labor force in mainland China, permanent population of non-native population accounts for a large proportion. Zhongshan city is located in the Pearl River Delta region, from 2010 to 2015, its registered population in the permanent population accounted for less than 50%. On the other hand, due to the impact of the current household registration system, the household registration population is different from the immigrant population in terms of real estate investment and education, and there are many differences in their labor quality. In view of this, the household population scale, denoted by \( re \), and the resident population, denoted by \( in \), are introduced to measure the size of the population.

For the scale of investment, investment in fixed assets is the most important aspect. first of all, the total investment in fixed assets, denoted by \( fai \), is introduced. In addition, Zhongshan is located in the Pearl River Delta, which is the earliest opening area in mainland China, the impact of foreign investment is also an important factor in this region. The total amount of foreign capital actually utilized, denoted by \( fiu \), is introduced here as another measure of investment size. To simplify the model, we use a linear production function, according to Eq. (1), getting:

\[
GDP_i = \gamma + \beta_1 G_i + \beta_2 T_i + \beta_3 G_i T_i + \alpha_1 in_{ij} + \alpha_2 re_{ij} + \alpha_3 fai_{ij} + \alpha_4 fiu_{ij} + \epsilon_{ij}
\]  

(20)

Measurement results are shown in Table 2.

Among them, the \( I_{\text{diff}} \) is the \( \beta_3 \) of formula 1 and formula 2, and the coefficients of the orthogonal item of the group dummy variable and the staged dummy variable. From the measurement results, the orthogonal item is significantly positive at the level of 5%, P value is 0.047, indicating that the setting of the intercity EMU station could significantly increase the GDP of the site-setting area. In addition, the four covariance

## Table 1

| Variable          | Sample | Average | SD    | Minimum | Maximum | Skewness | Kurtosis | Remake         |
|-------------------|--------|---------|-------|---------|---------|----------|----------|----------------|
| gdp               | 12     | 1660031 | 112388| 671642  | 4433056 | 1.387104 | 4.149126 | GDP            |
| first             | 12     | 18167.17| 22706.71| 1128    | 64162   | 0.950768 | 2.295248 | Output of the first industry |
| second            | 12     | 10259.29949514.6 | 272101 | 3525964 | 1.713809 | 5.028032 | Output of the second industry |
| third             | 12     | 61939.35381490.9 | 200496 | 1322560 | 0.6830774 | 2.166397 | Output of the third industry |
| registered        | 12     | 95454.83581490.9 | 108041 | 324590  | 0.5963652 | 1.98156   | Number of resident population |
| Fai               | 12     | 50922.68382877.5 | 114046 | 1528849 | 1.691639 | 5.285004 | Registered population |
| FiU               | 12     | 5115.417398166. | 465   | 21303   | 1.67418  | 4.01109  | Foreign capital investment |
| m1_mop            | 12     | 971.251679.016 | 56    | 5971    | 2.458449 | 7.85212  | Number of people moving from other parts of the province |
| m2_mop            | 12     | 576.8335385867 | 134   | 1615    | 0.8381531 | 2.073153 | Number of people moving from other parts of the province |
| m3_mop            | 12     | 398.758460068. | 28    | 3051    | 2.883977 | 9.566961 | Number of people moving to other provinces |
| m4_mop            | 12     | 307.252975079. | 65    | 955     | 1.164902 | 3.042542 | Number of people moving to other provinces |

## Table 2

GDP in the area along the line affected by EMU.

| Variable | Std. Err. | t     | P > t | [95% Conf.Interval] |
|----------|-----------|-------|-------|---------------------|
| \( \Delta G_i \) | 226532.8 | 84115.23 | 2.69 | 0.010 | 56529.56 | 396536 |
| \( \Delta T_i \) | -823.3254 | 116540.2 | -0.01 | 0.994 | -236539.8 | 234713.2 |
| \( \Delta \text{diff}_i \) | 302011.5 | 147460.3 | 2.05 | 0.047 | 3983.123 | 600039.9 |
| \( \text{in} \) | 4.336874 | 0.9144192 | 4.74 | 0.000 | 2.488764 | 6.184984 |
| \( \text{re} \) | 0.4077585 | 1.494011 | 0.54 | 0.592 | -2.211751 | 3.827268 |
| \( \text{fai} \) | 1.12199 | 0.232563 | 4.82 | 0.000 | 0.651292 | 1.59272 |
| \( \text{fiu} \) | 44.28472 | 13.42997 | 3.3 | 0.002 | 17.15181 | 71.41764 |
| \( \text{cons} \) | -291385.9 | 80897.07 | -3.6 | 0.001 | -454885 | -127886.8 |
By estimating the sum of the number of miop, since, and the difference between the number of the total migration population, denoted by welfare guarantee is not specially introduced here. Therefore, the covariance of social variables. In addition, social welfare security is an important factor along the area, and the more convenient traffic, we separately measured to certain extent. And this change will eventually play a role in the change in the trend of population migration, we separately measured to a certain extent. And this change will eventually play a role in the household register.

The construction of intercity rail lines improves the traffic situation along the area, and the more convenient traffic will increase the attractiveness of the area to the residents, thus affecting the trend of population change to a certain extent. And this change will eventually play a role in the economic and social development. This section will make the measurement analysis of the influence of Guangzhou-Zhuhai inter city rail transit on the household register migration of the site settings.

In view of the impact of economic development, the migration of household registration is joined by output of three major industrial, fixed assets investment and actual utilization of foreign capital as a covariant variables. In addition, social welfare security is an important factor affecting the migration intention, but because the samples used in this section are from Zhongshan, there is no difference in the social welfare policy and the concrete implementation between towns from experimental groups or control groups. Therefore, the covariance of social welfare guarantee is not specially introduced here.

In terms of dependent variables, in order to more objectively reflect the change in the trend of population migration, we separately measured the number migration in the province of Zhongshan in this year, denoted by sn, the number migrations outside the province, denoted by sw, and the total migration population, denoted by w. sn is the difference between the number of miop, emigrating from the province, and the number of miop, emigrating to the province. sw is the difference between the number of miop, migrating from outside the province, and the moop, emigrating to the outside province, in this year. z is the sum of sn and sw.

\[
s_{0} = \gamma + \beta_{1}G_{1} + \beta_{2}T_{1} + \alpha_{1}first_{ij} + \alpha_{2}second_{ij} + \alpha_{3}third_{ij} + \varepsilon_{i} \quad (21)
\]

\[
sw_{ij} = \gamma + \beta_{1}G_{1} + \beta_{2}T_{1} + \alpha_{1}first_{ij} + \alpha_{2}second_{ij} + \alpha_{3}third_{ij} + \varepsilon_{ij} \quad (22)
\]

\[
z_{ij} = \gamma + \beta_{1}G_{1} + \beta_{2}T_{1} + \alpha_{1}first_{ij} + \alpha_{2}second_{ij} + \alpha_{3}third_{ij} + \varepsilon_{ij} \quad (23)
\]

Measurement results are shown in Table 3.

The number migration in the province of Zhongshan in this year is significantly positive at 5% level. That is, the sites of EMU line setting significant increases in the attractiveness of residents from other parts of the same province of that region. The intersection of the total number of migrants was significantly positive at 10% level, at 1028, that is, the opening of Guangzhou-Zhuhai intercity rail transit allowed the site to set an additional annual increase of about 1028 citizens. On the contrary, the intersection of the number people immigrate to Zhongshan outside the province is not significant, that is, the influence of Guangzhou-Zhuhai intercity rail transit on the emigration from other provinces to Zhongshan is not significant. In addition, the effect of primary output value on three items is not significant, and the second industry output value only has a significant positive effect on the number of Zhongshan migration in the outside of the province, while the tertiary industry was significant at the level of 1% to the three items.

### 4.2 SRD experiment

This section uses the SRD(Sharp Regression Discontinuity) model for analysis. The idea of regression discontinuity design is that there is a continuous variable \(X_0\), it determines the processing variable \(D\) by a breakpoint, and this continuous variable \(X_0\) is called the assignment variable. The random distribution of samples in the small neighborhood \([\delta - \mu, \delta + \mu]\) of \(X_0\) is regarded as "quasi experiment". By estimating LATE(Local Average Treatment Effect), it is possible to reduce whether the dependent variable has a breakpoint in \(X_0 = \delta\). Among them, LATE = \[ \lim_{X_0 \to \delta^-} E(Y | D = 1) - \lim_{X_0 \to \delta^+} E(Y | D = 0) \] (24)

In this paper, the time variable is used as \(X_0\). Since its opening at the first quarter of 2011, the impact of the Guangzhou-Zhuhai intercity rail transit line is starting. So, the breakpoint at the individual treatment concept from 0 to 1 is consistent with the assumption of breakpoint regression.

As a local random experiment, the introduction of covariables does not affect consistency of the breakpoint regression estimator. However, introducing covariables that can explain the dependent variable, can effectively reduce the disturbance variance and improve the accuracy of estimation effectively. Because of the differences of industrial structure, the seasonal shocks are not the same to different cities. In order to reduce the related fluctuations, this section introduces the first production ratio, denoted by \(s\), the second production ratio, denoted by \(s\), to measure the differences in industrial structure. The ratio of total import and export volume to GDP, denoted by \(z\), was introduced as a covariate to measure the extent of foreign trade dependence. The regression equation is as follows:

\[ Y_i = \alpha + \beta X_i + \sigma D_i + \gamma D_iX_i + f_i + s_i + z_i + \varepsilon_i \] (25)

Among them, \(D_i = \begin{cases} 1 & \text{if } X_i > 2011 \\ 0 & \text{else} \end{cases} \) (26)

The original hypothesis of the test is:

\[ H_0 = \lim_{X_0 \to \delta^-} Y_i - \lim_{X_0 \to \delta^+} Y_i = 0 \] (27)

Because regression discontinuity design is a local random test, only the observed values near the breakpoint, in principle, should be used. Excessive observation periods may affect the progress of the test. In order to compress the range of observations as much as possible under the premise of guaranteeing the number of samples, this section uses quartery statistics. In view of the lack of Shunde district eight quarters of data, that is, the lack of all the data before the breakpoint, in premise of guaranteeing the number of samples, this section uses quartery statistics. In view of the lack of Shunde district eight quarters of data, that is, the lack of all the data before the breakpoint, in order to reduce the error, this section does not use the relevant data of Shunde district. The data used in this section are all from Guangdong Provincial Statistics Network. The data of the four quarters in 2009 are calculated from the actual data and growth rate in 2010. The general characteristics of the data are given in Table 1.

In the four cities and one distinct of the Guangzhou-Zhuhai inter city rail transit crossing, the Guangzhou is the most economically developed

| Variables | sn | sw | z |
|-----------|----|----|---|
| t         | -197.7 | -14.94 | -212.6 |
|           | (268.4) | (60.89) | (281.0) |
| g         | -212.6 | -43.63 | -256.3 |
|           | (361.3) | (81.96) | (378.2) |
| diff      | 1.136** | 108.5 | 1.028 |
|           | (489.7) | (111.1) | (512.7) |
| first     | -0.00395 | -0.000505 | -0.00446 |
|           | (0.00607) | (0.00138) | (0.00636) |
| second    | -0.000355 | 0.000284*** | -7.14e-05 |
|           | (0.000229) | (5.19e-05) | (0.000246) |
| third     | 0.00109*** | 0.000279*** | 0.00137*** |
|           | (0.000379) | (8.59e-05) | (0.000396) |
| Constant  | 82.21 | -78.97 | 3.241 |
|           | (263.5) | (59.79) | (275.9) |
| Observations | 48 | 48 | 48 |
| R-squared | 0.352 | 0.602 | 0.414 |

Note: Standard errors in parentheses ***p < 0.01, **p < 0.05, *p < 0.1.
variable. The ratio of each period in the city is divided by the ratio of GDP.

In order to observe the trend more intuitively, this section uses the three covariates: peak season. Here we use the annual data to estimate the size of the total volume of imports and exports to GDP, it may also cause unnecessary fluctuations due to the impact of different industries during the off-peak season. Here we use the annual data to estimate the size of the three covariates.

Because there are some differences in the economic scale of the three cities, in order to observe the trend more intuitively, this section uses the ratio of standardized municipalities to Guangzhou's GDP as the analytic variable. The ratio of each period in the city is divided by the ratio of GDP

Table 5 Change of GDP ratio of other cities and Guangzhou with covariate variables.

| g2011  | Coef. | Std. Err. | z    | P > z | [95% Conf.Interval] |
|--------|-------|-----------|------|------|---------------------|
| lwald  | -10.09926 | 4.622810 | -2.18 | 0.029 | -19.15980 -1.038722 |
| lwald50 | -1.492242 | 3.281893 | -0.45 | 0.649 | -7.924534 4.940251 |
| lwald200 | -0.133621 | 3.868907 | -0.03 | 0.972 | -7.716539 7.449297 |

Table 6 Continuity check results of covariate conditional density at breakpoint.

| g2011  | Coef. | Std. Err. | z    | P > z | [95% Conf.Interval] |
|--------|-------|-----------|------|------|---------------------|
| f      | -0.01115 | 0.022551 | -0.49 | 0.621 | -0.05535 0.033052 |
| s      | 0.024052 | 0.018708 | 1.29 | 0.199 | -0.01262 0.060720 |
| zp     | -0.08718 | 0.879419 | -1.09 | 0.292 | -1.81081 1.636451 |
| lwald  | -5.96095 | 6.935322 | -0.13 | 0.896 | -23.1359 4.052029 |
| f50    | -0.00673 | 0.020575 | -0.33 | 0.744 | -0.04705 0.033598 |
| s50    | -0.00724 | 0.015162 | -0.48 | 0.633 | -0.03696 0.022475 |
| zp50   | -0.08718 | 0.752950 | -1.26 | 0.207 | -1.56293 1.388577 |
| lwald50 | -6.11496 | 4.886555 | -1.26 | 0.207 | -15.6180 3.380031 |
| f200   | -0.00402 | 0.014295 | -0.28 | 0.779 | -0.03204 0.022998 |
| s200   | -0.00761 | 0.016148 | -0.47 | 0.637 | -0.03926 0.024035 |
| zp200  | -0.08140 | 0.519849 | -0.16 | 0.876 | -1.10029 0.937482 |
| lwald200 | -1.47286 | 4.576923 | -0.32 | 0.748 | -10.44346 7.497746 |

Table 7 Related data of Control Group.

| Variable | Sample | Average | SD | Minimum | Maximum | Skewness | Kurtosis | Remake |
|----------|--------|---------|----|---------|---------|----------|----------|--------|
| gdp      | 36     | 767024.4| 399779.3| 155803 | 1874955 | 0.6657001| 3.102528 | GDP    |
| first    | 36     | 26056.92| 17898.47| 908    | 73236   | 0.6083737| 2.617837 | Output of the first industry |
| second   | 36     | 367938.6| 172008.8| 92691  | 769575  | 0.4512259| 2.496653 | Output of the second industry |
| third    | 36     | 373628.4| 316906.5| 53834  | 1683521 | 2.178778 | 9.203611 | Output of the third industry |
| inhabitant| 36   | 113411.8| 49660.85| 31410  | 223460  | 0.4505494| 2.701982 | Number of resident population |
| registered| 36 | 54281.3 | 24997.33| 7804   | 103608  | 0.129985 | 2.086856 | Registered population |
| Fai      | 36     | 302141  | 175355.3| 57600  | 726140  | 1.089805 | 3.365686 | Fixed-asset investment |
| Fiu      | 36     | 1590.75 | 1791.494| 0      | 6502    | 1.143728 | 3.259765 | Foreign capital investment |
| miip     | 36     | 278222  | 4442123 | 29     | 3623    | 4.338217 | 22.99272 | Number of people moving from other parts of the province |
| miop     | 36     | 221972  | 226168  | 0      | 872     | 1.54867 | 6.454142 | Number of people moving from other parts of the province |
| moip     | 36     | 1228889 | 2210578 | 4      | 129     | 4.415258 | 23.31192 | Number of people moving to other parts of the province |
| moop     | 36     | 1150278 | 9260129 | 0      | 396     | 1.530005| 4.807416 | Number of people moving to other parts of the province |
5. Conclusion

EMU lines will be a key point for the construction of infrastructure in China for in future a long time. On the one hand, the construction of EMU line needs a large amount of funds in the early stage, and it will involve a series of issues such as land expropriation and noise in the area along the line. On the other hand, it has a significant role in promoting the development of regional economic integration and the construction of urban agglomerations. Therefore, the research on the actual influence of the construction of Intercity train line is of great significance.

Based on the results of the DID model constructed in this paper, we can know that, in terms of longitudinal impact, the opening of Intercity rail line is conducive to the migration of people from other areas to the area along the rail line, speeding up the population agglomeration along the area, and promoting the improvement of economic aggregates along the region, and increasing the absolute speed of economic growth along the region. However, through the horizontal comparison of the breakpoint regression, we find that the opening of the Intercity railway line will further expand the economic development gap between the first and the after areas along the region, making the relative speed of post-development economic growth slowed down, which may further aggravate the unbalanced development of the area along the line in turn.

Declarations

Author contribution statement

Heyuan Huang: Conceived and designed the experiments; Wrote the paper.
Weikun Zhang: Performed the experiments.
Yiming He: Analyzed and interpreted the data.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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