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Rail transit development in lagging regions: A development-oriented investment and financing approach

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Abstract: Transportation infrastructure investment can play a significant role in promoting urban development. How can governments finance expensive rail transit investments and promote urban development in lagging regions? This paper reviews a case in Chongqing, China, a municipality that proactively invested in rail transit development through a mechanism of land value capture and guided rapid urbanization. We use path analysis to test the assumption that the rail transit system investment, which is directly linked to the amount of available government reserve land, was an important determinant in promoting urban development. We found that the availability of government reserve land alone cannot promote urban development. However, building transportation infrastructure on government reserve land serves as the catalyst to foster urban development. We see this development-oriented investment and financing approach as promising for raising funds for rail transit investment in other lagging regions in the world.

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1 Introduction

Transportation infrastructure, as a special type of physical asset, serves economic, social, and political purposes. By 2030, one billion more people will live on this planet, and most of them will live in Asian and African cities (United Nations, 2015a). In the history of urbanization, social problems always emerge when infrastructure cannot sufficiently accommodate the needs of urban growth. Researchers recommend compact settlement adjacent to urban areas as a way to accommodate the increased population in a way that minimizes the ecological footprint (Forman & Wu, 2016). Although public transit has been recognized as a sustainable transportation mode (Burgess, 2000; Cervero & Day, 2008), the high costs associated with transit development make it difficult to implement, especially in lagging regions with low per capita incomes and weak tax bases.

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In this paper, we discuss an innovative system adopted by the Chongqing municipal government in China as a means to finance rail transit infrastructure investment and to promote urban development. Through a land banking system, the Chongqing municipal government acquired rural lands with great potential for future development in areas adjacent to existing urban areas. A monorail system was then built to connect the central city to these government reserve lands. The appreciated value of the government reserve lands was then liquefied to pay back the construction costs of the transit system. This study aims to empirically test whether and how the above mechanism can promote urban development. A path analysis was used to study the relationships among population density, per capita income, the amount of government reserve land, the transportation infrastructure investment, and the speed of urban expansion in the nine districts of the Chongqing municipality.

The rest of the paper is organized as follows. Section 2 reviews the literature on the impacts of rail transit infrastructure on urban development and the mechanisms of financing public transit infrastructure investment. Section 3 presents a new model of development-oriented financing using the case study of Chongqing. Section 4 discusses the research methodology. Section 5 presents the results, followed by discussions and conclusions in Section 6.

2 Literature review

In this section, we first discuss the impacts of rail transit infrastructure on urban development, particularly the difference between advanced regions and lagging regions, and then review the approaches to finance the costly public transportation infrastructure investments.

2.1 Impacts of rail transit infrastructure on urban development

Transportation cost is a critical factor to consider in classical urban geography and urban economic theories to explain the spatial distribution of productions and consumptions, such as agricultural land uses (Alonso, 1964; Mills, 1967; Muth, 1969), industrial locations (Hoover, 1948; Isard, 1956; Moses, 1958), and markets (Christaller & Baskin, 1966; Losch, 1954). Theories suggest that people and firms trade off between land rent and commuting costs. They are willing to bear the higher costs of commute in exchange for cheaper rents as one moves farther away from the city center. Despite the simplification of such models, empirical observations have found evidence that transportation infrastructure shapes cities by altering accessibility and land value. For instance, the construction of interstate highways starting from the late 1950s has often been cited as one of the main forces that caused massive suburbanization in the United States (Baum-Snow, 2007; Wheaton, 1977).

More specifically, rail transit, as one form of transportation infrastructure, was assumed to affect urban development. In the early 20th century, public transit systems were built as a response to the traffic problems wrought by economic and population growth in western cities such as Stockholm, London, and New York (Barker & Robbins, 1963; Hood, 2004; King, 2011; Sidenbladh, 1965). Similar to rapid transit systems in developing countries today, those rapid transit systems catalyzed the spatial expansion of the cities due to their high speed. However, the public transit systems have much less impact on cities' life and their spatial forms nowadays than before. Studies show that several urban transit corridors failed to induce significant development as expected in the United States in recent years (Cervero & Landis, 1997; Li, Rosenheim, Dong, Boarnet, & Zhong, 2017; Loukaitou-Sideris & Banerjee, 2000; Zhong & Li, 2016) as well as the recent transit lines of first-tier cities in developing countries (Jiang & Levinson, 2017). The inconsistency was mainly attributed to the different levels of existing transportation infrastructure stock and the availability of developable land. The dispersed development pattern established by highways was so profound in the United States that the public transportation failed to stimulate development and revitalization to a significant extent because the accessibility that public transportation adds to the existing transportation network is marginal (Hanson & Giuliano, 2004). In contrast, in lagging areas in developing countries that have a low supply of transportation infrastructure, the magnitude of impact from new development is expected to be high. According to many authors, the transport network growth has been one of the major engines of China's economic growth (Fan, Bai, & Pan, 2004; Lou, 2003; Zhang, 2009). Zou, Zhang, Zhuang, and Song (2008) found that public investment in road construction in poor areas is crucial for regional economic growth and poverty alleviation. Rail transit corridors have high potential to induce development and accommodate the growing population in a sustainable urban form.

Many factors affect rail transit infrastructure investment. Such factors include local land-use policy, regional economic conditions, transportation cost, land price, availability of developable land, and public support (Cao & Porter-Nelson, 2016; Knight & Trygg, 1977; Wheaton, 1977). For developed countries, land availability has been one of the main obstacles for developing public transit infrastructure because of the high cost of urban land for infill development (Luscher, 1995), difficulties in land acquisition due to fragmented land ownership (Cervero, Bernick, & Gilbert, 1994), and, fundamentally, the public sentiment against high-density development (Pendall, 1999). In China, the state ownership of urban land and government-dominated approach in urban planning and development made it relatively easier to implement rail transit infrastructure projects.

2.2 Ways of financing public transit infrastructure

Building public transportation infrastructure requires significant investment. A century ago, cities relied mostly on property taxes and later on expanded their revenue sources to include user fees and charges, sale taxes, and intergovernmental transfers (Pagano & Perry, 2008). In the recent decades, cities in developed countries largely depend on borrowing from the capital market, including loans, bonds, and stock markets, to finance transportation infrastructure investments (Wu, 2010). In China, the budgetary allocation from central to local governments was the main revenue source before its fiscal decentralization in 1980 (Wu, 2010). Since 1980, the main sources of local government revenue have been broadening through non-state channels, such as borrowing from domestic and foreign sources, using self-raised funds, and leasing lands (Wu, 2010).

Historically, public capital has rarely met the needs for public infrastructure investment (Kirwan, 1989); therefore, the private sector has stepped in through public–private partnerships (PPPs). Public–private partnerships are loosely defined as "cooperative institutional arrangements between public and private sector actors" (Hodge & Greve, 2007, p. 545). Public–private partnerships have various forms, such as built–operate–transfer (BOT), build–lease–transfer (BLT), and design–build–finance–operate (DBFO). Those forms are all variants of the build–own–operate–transfer (BOOT) (Walker & Smith, 1995). Using BOOT, a private firm builds the facility and then owns and operates it for a period of time to make some profits before transferring it to the government at the end of the operation time period. Theoretically, PPPs are win–win solutions because they reduce pressure on government budgets and generate profits for private parties. Although PPPs have gained popularity, their legitimacies have been challenged by the unequal access to information (Siemiatycki, 2013) and a conflict of interest between the public and private parties (Sclar, 2001). Regarding the financing of rail transit, self-sufficiency is a desirable goal, but very few rail systems can achieve that (Phang, 2007).

One other finance mechanism is called land value capture (LVC). Economic theories have long established a positive relationship between accessibility and land rent (Alonso, 1964; Muth, 1969; von Thünen & Hall, 1966). Land value capture is the appropriation of land value gains stemming from improvements, which in this case are potential increases in accessibility and mobility due to the construction of public transit infrastructure. The basic expectation is that the revenue generated by capturing the increments in land value will be used to recover the capital costs of the public transit investment.

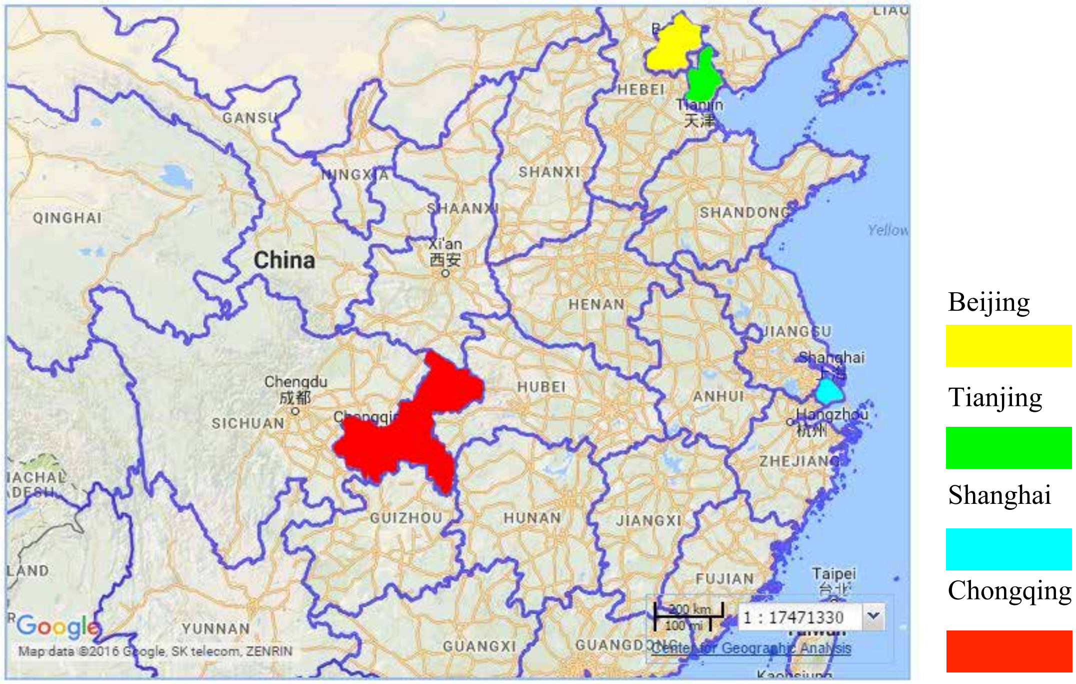
The mechanism of LVC is flexible and can be implemented in various forms, such as a betterment tax, accessibility increment contribution, and joint development (Medda, 2012). For example, tax increment financing (TIF) is a typical way to pay for development projects in U.S. cities, predominately through increased property tax revenues generated by investments (Junge & Levinson, 2012; Zhao & Block-Schachter, 2016; Zhao, Das, & Larson, 2010). In Asia, Hong Kong and Tokyo have successfully practiced joint development (Suzuki, Murakami, Hong, &Tamayose, 2015; Zhao, Das, & Larson, 2012). Instead of capturing the land value increments from landowners or developers, the joint development creates and shares incremental value among the governments, transit agencies, developers, businesses, and residents in and around transit stations (Suzuki et al., 2015). Without property taxes as a policy instrument, land sales or land leases are the main revenue sources of Chinese cities (Wang, Zhang, Zhang, & Zhao, 2011). Local governments first acquire low-cost agricultural land on the edge of urban areas. The land is then sold to developers at a much higher price by changing its land use from agricultural to urban. It should be noted that although land sales generate additional revenues, it is not a sustainable source of funding because land is a limited resource (Zhao & Block-Schachter, 2016).

As in the studies above, empirical evidence has well documented the capitalization effects of transportation investment so that the "practical applications of value capture" are indeed possible (Smith & Gihring, 2006, p. 754). To date, scant research has studied LVC in developing countries (Ferbrache & Knowles, 2016). This study presents an innovative application of LVC, which proactively uses the government-owned land to finance infrastructure investment and drive urban development in Chongqing, China.

3 Infrastructure financing in Chongqing — the "Chongqing Model"

3.1 Basic information about Chongqing and its transit development

Chongqing, the youngest municipality directly under the regulation of the Chinese Central Government since 1997, serves as a regional center of economic, political, and industrial activities in Southwest China. It is located in the inland southwest of China (see Figure 1). The other three municipalities directly under the regulation of the Central Government are Beijing, Shanghai, and Tianjin. The municipalities directly under the regulation of the Central Government were established for their comparatively high level of economic growth. The municipalities directly under the regulation of the Central Government have comparatively strong decision-making rights and the responsibility to lead regional development (He & Wu, 2005). Compared with the other three municipalities, Chongqing is far less urbanized and its infrastructure is inadequately provided (see Table 1). The urban population in Chongqing accounts for only 60% of the total population, whereas the percentages are above 80% in the three other municipalities. Also, the per capita GDP, real estate investment, the length of the rail transit system, and the rail transit ridership of Chongqing are far behind those of the other three municipalities. The length of rail transit system per 10,000 people in Chongqing accounts for only less than half that of the other municipalities.



Map source: ChinaMap, Center for Geographic Analysis, Harvard University.

Note: Highlighted colors are rendered by authors.

Figure 1: Chongqing and its relative location to Beijing, Shanghai, and Tianjing

Except for Chongqing, the other three cities are historically wealthy places due to their geographical locations and political functions. Although Chongqing has lagged behind the other three municipalities in urbanization and per capita economic measures, Chongqing has achieved high economic growth in recent years. In 2015, Chongqing ranked first by posting an 11% GDP growth, which was 4.1 percentage points higher than the national average. The city has huge developmental potential due to its central location in the southwest region and the urbanization trend of underdeveloped areas. At the beginning of the 2000s, the Chinese government launched the Western China Development Program, which is intended to close the income gaps between the western inland provinces and coastal regions. The program's strategy has centered on infrastructure construction, along with a series of fiscal initiatives and institutional innovations. Building a monorail system in Chongqing was the top of the ten key projects (Long, Wu, Wang, & Dong, 2008).

Table 1: Economic indicators of four municipalities

Municipality	Population (10,000)	Urbanization Rate	GDP per Capita (US$)	Real Estate Investment per Capita (US$)	Total Length of Rail Transit System (km/10,000)	Rail Transit Ridership per Capita
Beijing	1333.40	0.86	24611.29	4286.71	0.40	254
Shanghai	1438.69	0.90	25202.09	3428.81	0.40	235
Tianjin	1016.66	0.82	23798.81	16717.98	0.57	333
Chongqing	3375.20	0.60	6501.10	1654.72	0.17	100

Source: National Bureau of Statistics o China, 2014
Note: the monentary value is converted from RMB using 6.5 as the exchange rate.

The Chongqing government has ambitious plans for rail transit development. The Chongqing Metro expects that by 2050, 18 monorail transit lines of 820 km will be built, 780 km of which would cover the main urban areas and the density of monorail transit will be 0.69 km/km^2; the mode share of the rail transit is projected to be 45%, which accounts for 60% of the public transportation mode share. By October 2013, Phase 1 was completed. Rail transit lines 1, 2, 3, and 6 have been built and are in operation, connecting eight main districts, 13 urban clusters, five commercial zones, airports, rail stations, and long-distance bus stations. The whole system has 213 km of rail lines and ranked first in western China by December 2016 (CQMetro, 2017). In Phase 2, by 2020, the length of the rail system will be increased to more than 400 km. Sixty percent of the population is expected to live within a ten-minute walking distance from rail transit stations. Residents can get from downtown to suburban centers within a half-hour commute.

Figure 2: Monorail stations under construction in Chongqing (Left: Line 1, Laijiaqiao Station; Right: Line 6, Longfengxi Station)

3.2 The "Chongqing Model" of financing transit development

What is counterintuitive is that a considerable number of monorail system lines run through rural areas without established ridership (see Figure 2). This is due to the government's LVC principle in financing of its monorail system. When the Chongqing municipal government was deciding where to locate the monorail system, it considered both the existing ridership (i.e., population density) and the availability of government reserve land.

Figure 3 demonstrates the infrastructure investment finance mechanism of the Chongqing Municipal government. Three major parties are involved: private parties, the government, and banks. First, the government provides land and injects a small amount of initial capital into a government-owned investment platform. Then, a project investment company is formed under the investment platform and uses land as collateral to obtain loans from the banks. With those funds, the government can build the infrastructure either by itself or through PPPs.

In Chongqing, five major investment platforms undertook investment in different fields (such as transportation, public rental housing, industrial zones, schools, and hospitals). Among these platforms, the Chongqing City Transportation Development & Investment Group Co., Ltd. (CCTDIG), is responsible for rail transit investment. The CCTDIG was established in April 2009, when the municipal government of Chongqing consolidated the original open investment company, bus group, and station yards group together as a new company. Currently, it is a municipality-owned key enterprise that combines public welfare and service that is in charge of investment and financing construction as well as the operation and management of transportation infrastructure including city buses, railways, station yards, and airports in Chongqing. As the only platform in China that organizes a variety of transportation modes as a whole, the CCTDIG has a long-term partnership with many state-owned banks that provide investment loans. Currently, the bank cooperating with the CCTDIG in the field of rail transit construction is the China Development Bank (CDB), which was founded in 1994 as a policy financial institution under the direct leadership of the Chinese State Council. The CDB provides medium- to long-term financing facilities that serve China's major long-term economic and social development strategies. The CDB can provide up to 80% of the funds required for rail transit construction. The other funds are from the initial capital provided by the government and phase advance funds provided by construction companies. Typically, the CDB provides long-term loans over five years with an interest rate lower than those of commercial banks.

The project investment company is the Chongqing Rail Industry Investment Company (CRIIC), which, in practice, is held by CTDIG. Its main function is to implement the construction of rail transit projects. The CRIIC is usually responsible for the construction of rail infrastructure as well as supporting facilities around rail stations (such as parking and ancillary commercial facilities, etc.). These facilities were transferred to the Chongqing Rail Transit Corporation (CRT) to operate after completion (expenses of vehicle purchase are paid by the CRT).

After the completion of rail lines and their surrounding facilities, the government sells the remaining reserve land around the rail lines to private real estate companies at favorable prices. The land transfer expenses can repay the loans once the lands are sold, and the government will capture the increased value from the infrastructure investment to pay debts and invest in new infrastructure through this mechanism again.

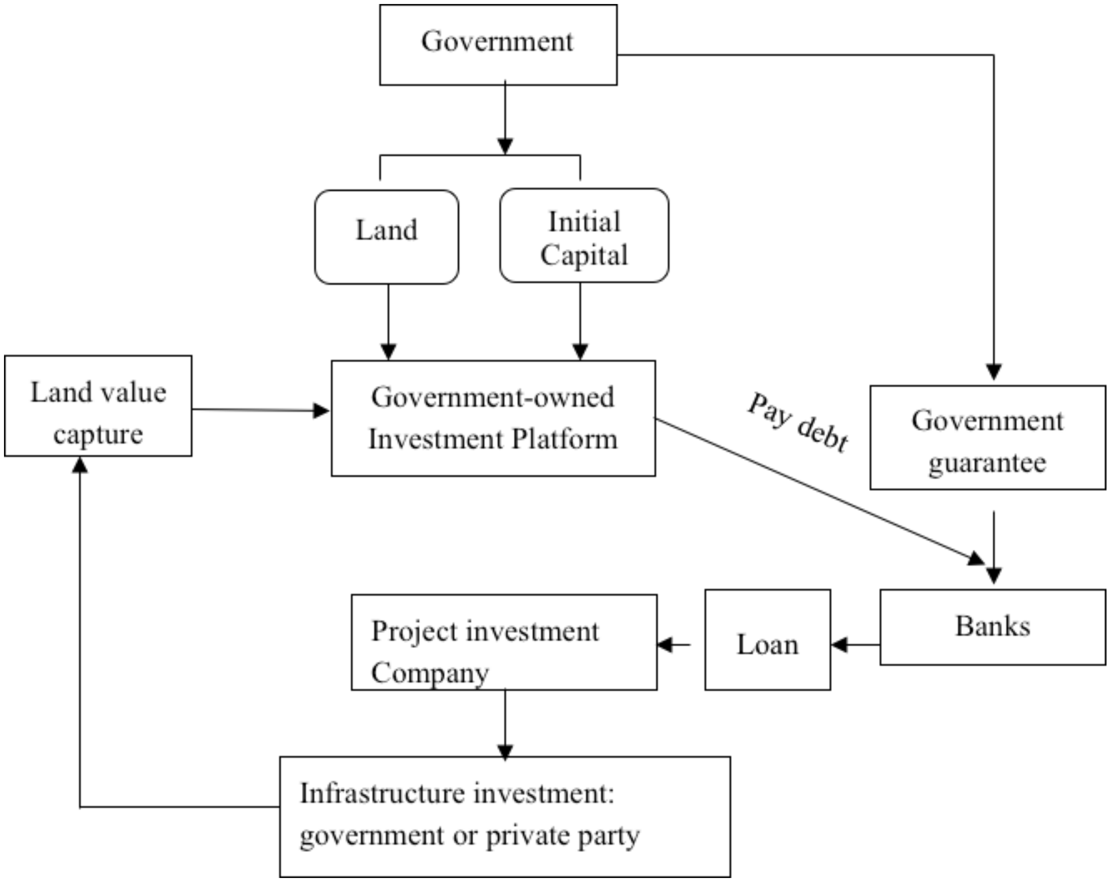


Figure 3: The Chongqing model–infrastructure investment finance mechanism of Chongqing municipal government

3.3 What is special about the "Chongqing Model"?

The demand for urban public transport has soared in recent years as a result of rapid urbanization in China. Rail transit with the advantages of accommodating a large traffic volume, high speed, punctuality, safety, and comfortable travel conditions has become the primary choice for urban public transport construction to solve the urban traffic congestion problem in China (Shen, Xiao, & Wang, 2016). However, rail transit construction requires significant investments and long construction periods; therefore, relying on one investment entity or financing channel is prone to difficulties.

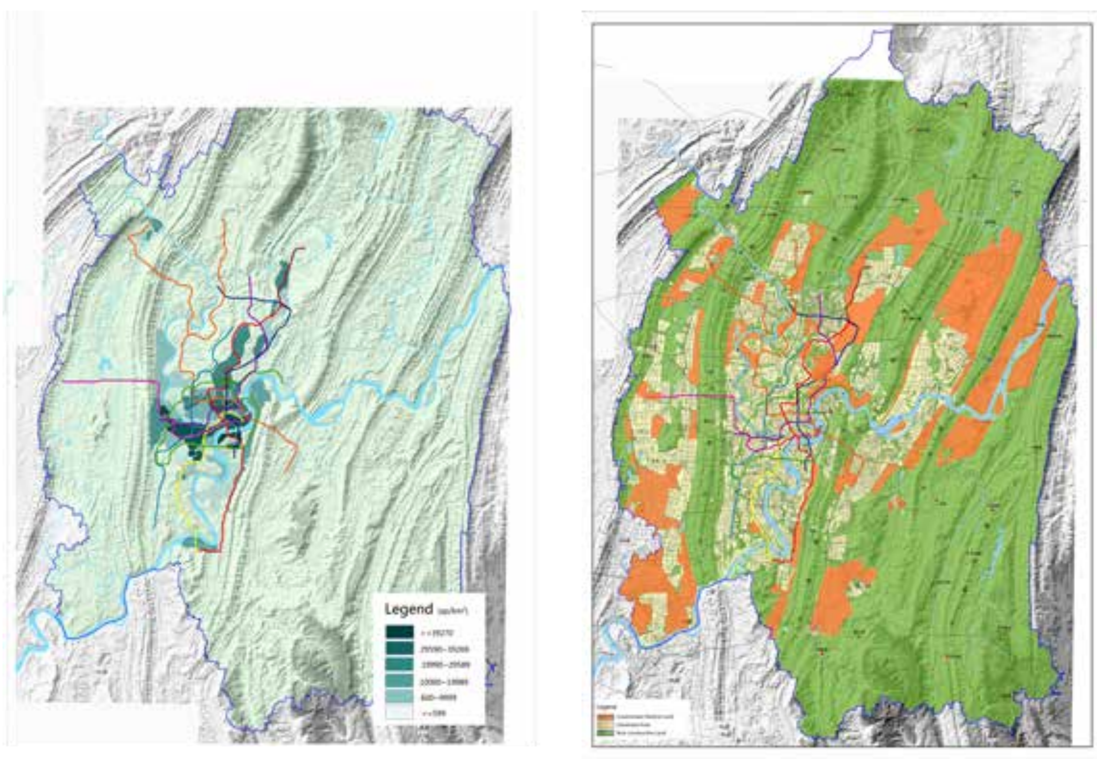
As discussed in Section 2, there are a few ways to finance urban transit development, many of which have been adopted by Chinese cities to build their urban rail systems, and details are shown in Table 2. Some cities where the local government has high financial strength, such as Beijing, Shanghai, and Guangzhou, use fiscal revenue or credit loans as part of the financing resources to invest in rail transit construction. Besides high financing efficiency, this mode also has an advantage of simple operation due to a single participant and less financing links but also places higher pressure on government finance (Wang, Wu, Hu, Liang, & Wang, 2015). Other cities with weak fiscal support have to seek private capital to solve the problem of insufficient funds. Public–private partnerships, BOTs, and build–transfers (BTs) are usually taken as multivariate financing modes, such as for the Qingdao Metro Line 1 to Line 4 and Hangzhou Metro Line 1 (Lv, 2012). With the expansion of infrastructure construction scales, cities such as Beijing, which previously relied mainly on financial investment, also adopted the PPP mode for some metro lines (Xin, 2015).

Table 2: Main rail transit investment finance modes in China

Financing mode	Definition	Advantage	Disadvantages	Cases
Government financial investment mode (operated by state-owned enterprises)	The design, construction and operation of rail transit are entirely funded by the government	Low financing costs, high service level	High occupation of financial resources, lack of effective supervision, low operating rate	Beijing Metro Line 1, 2
Debt financing mode from financial support (operated by state-owned private enterprises)	Funds are made up of the government financial investment, bank loans and loans from foreign institutions	Low financial pressure, easy and fast to financing	High financing costs, the government assumes high risk, low local capital market utilization	Beijing Metro Line 13, Beijing Metro Batong Line, Shanghai Metro Line 1, 2, Guangzhou Metro Line 1-5
Public-Private Partnership mode	The government and private enterprises jointly fund the establishment of the MTRC, responsible for rail transit investment, construction and operation	Share investment income, risk and responsibility, low operating rate, separate government functions from enterprise management	High financing risk and cost, difficult in management coordination	Beijing Metro Line 4, Beijing Metro Daxing Line, Hangzhou Metro Line 1, Shenzhen Metro Line 6, Qingdao Metro Line 1-4, 8, 11, Chengdu Metro Line 18
Build-Operate-Transfer mode	The project company has the franchise to finance the construction and operation of a specific public infrastructure for a limited period of time and, at the expiration of the concession period, transfers the infrastructure to the government	Deepen the marketization and reduce the financial burden, easy in management coordination and cost control	The government loses control of the project during the concession period, high bidding price	Shenzhen Metro Line 4, Harbin Metro Line 2, 3, Nanjing Metro Line 2
Build-Transfer mode	The project company invests, finances and builds the project, commits it as agreed after completion and recoup the investment from the government's payment	Relieve government financial pressure, low investment risk for the government, available for poorly profitable infrastructure	Not perfect in legal contract, high demand for financing ability and management capacity of investors, lack of effective supervision	Shenzhen Metro Line 5, Nanjing Metro Line 6, Wuhan Metro Line 8, 11, Chengdu Metro Line 3, 7

Source: *2016 Urban Rail Transit Statistics and Analysis Report* released by China Urban Rail Transit Association

How is the "Chongqing Model" different from other cases? What makes the "Chongqing Model" different is the amount of government reserve land and the rail line location choices. The innovative point here is that the rail line route selection is driven by the availability of government land rather than purely the demand for travel, which is usually the one of the key factors for transit network design (Cipriani, Gori, &, Petrelli, 2012; Fan & Machemehl, 2006). From Figure 4, we can tell that the monorail system stretches out to areas with low population density. Conventionally, an urban rail system is a rapid and high-capacity mode of commuting to meet travel demands. As a result, it is usually located in places with high population density, which ensures ridership. However, the distribution of the rail system in Chongqing is different from this principle. Due to a lack of infrastructure, undeveloped land in suburban areas has a low value. When suburban areas are connected by rail systems, the land value in suburban areas substantially increases and can be captured by the local government to finance new development. Although urban areas have higher population density, limited land availability, high demolition, and high resettlement expenses diminish the benefits of land value capture. Also, construction costs will be higher in urban areas compared with suburban areas. In Figure 4, we can see that the distribution of the rail system in Chongqing overlays the available government reserve land. Only a small portion of the rail system serves areas with high population density, whereas the rest of the rail system is located in areas with lower population density and where more government reserve land is available.



(a) (b)

Figure 4: (a) Rail system distribution and population density; (b) rail system distribution and government reserve land (parcels in orange)

4 Research approach, methodology, and data

In this study, we model the mechanism of LVC in Chongqing, China, using a path analysis. Path analysis is a special case of structural equation modeling that deals with only measured variables. It was invented by Sewall Wright, one of the most influential evolutionary biologists in the 20th century (Wright, 1920, 1921), and has been widely recognized as a powerful approach for modeling causal relationships in sociology (Alwin & Hauser, 1975; Blalock, 1964, 1969; Duncan, 1966). By using path analysis, we can model and assess the cascading relationships among the variables and test causal hypotheses. For a robustness check, we compared results from path analysis (structural form model) with results from panel models (reduced and flattened form). Results from panel models are presented in the Appendix.

4.1 Research question and conceptual model

The research question we ask is, how does development-oriented transportation infrastructure investment affect urban development in regions with low transportation infrastructure stock? To answer the research question, we constructed a conceptual model of an infrastructure–land–development coupled system (see Figure 5).

As discussed in the literature review section, transportation infrastructure can encourage development, particularly in underdeveloped regions. Because development is more likely to occur where land is more available, the availability of developable land is one of the driving forces in our conceptual model. In the case of Chongqing, because its initial level of transportation infrastructure is low, we expect positive effects from the transportation infrastructure investment on urban expansion. We expect the amount of government reserve land and the transportation infrastructure investment together will stimulate urban expansion, which is measured as an increase in urban area per year. Also, the amount of government reserve land, which is small in urban areas, drives the transportation infrastructure investment. To summarize, we formulate the primary hypotheses as follows:

- H1. The greater the transportation infrastructure investment, the greater the speed of urban expansion.
- H2a. The greater the amount of government reserve land, the greater the speed of urban expansion.
- H2b. The greater the amount of government reserve land, the greater the transportation infrastructure investment.

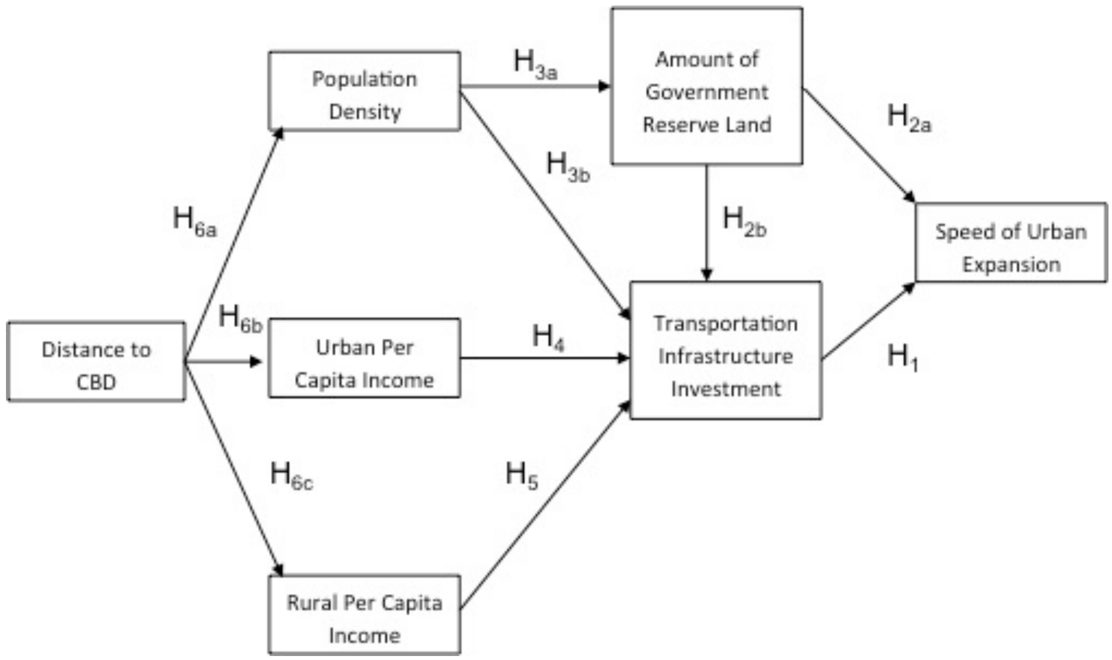


Figure 5: The conceptual model for path analysis

We also tested a few secondary hypotheses related to transportation infrastructure investment and government land reserves. Because local governments acquire land from low-density rural areas into their reserves, we expect that higher-population-density areas will have less government reserve land. Because higher-density areas are more likely to be developed, the room for value capture is limited. Therefore, we expect more investment in low-density areas to maximize the post development value increase that can be captured later. Because rural areas with higher incomes have a higher potential for development, we expect such areas to receive more transportation infrastructure investment. Development in urban areas with higher per capita income could be more costly than in the low-income areas (i.e., demolishing and population relocation may be more costly); therefore, we expect urban areas with higher per capita income to receive less money for transportation infrastructure investment.

To summarize, the secondary hypotheses are as follows:

- H3a. The greater the population density, the smaller the amount of government reserve land.
- H3b. The greater the population density, the smaller the transportation infrastructure investment.
- H4. The greater the urban per capita income, the smaller the transportation infrastructure investment.
- H5. The greater the rural per capita income, the greater the transportation infrastructure investment.
- H6a. The closer to the central business district (CBD), the greater the population density.
- H6b. The closer to the CBD, the greater the urban per capita income.
- H6c. The closer to the CBD, the greater the rural per capita income.

4.2 Data

We obtained data from nine districts in the Chongqing municipality from 1997 to 2012 from the *Chongqing Statistic Year Book*. The data set includes the amount of transportation investment in each year, urban and rural per capita income, population density, and the speed of urban expansion measured by the annual increase in the urbanized area (Table 3). The other data—the amount of government reserve land—are from the Land Resources and Housing Management Bureau of the Chongqing municipality.

Table 3: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Dependent Variable					
Speed of urban expansion (km^2 increase in urban area per year)	135	367.31	501.92	-171.4	2,590.90
Independent Variable					
Distance to CBD (km^2)	144	20.52	9.47	4.00	33.10
Transportation infrastructure investment (10,000 RMB)	135	436,291.10	424,236.90	18,418.00	2,013,852.00
Per capita income in urban areas (RMB)	135	17,224.36	7,239.31	6,039.00	35,192.00
Per capita income in rural areas (RMB)	116	4,857.72	2,658.09	2,203.00	12,437.00
Resident population density (person/m^2)	90	0.52	0.93	0.04	3.27
Government Reserve Land (10,000 m^2)	99	47.89	37.64	0	150.74

Note: Data from years 1997–2012

5 Results

The conceptual model in Figure 5 is fitted using path analysis. In Figure 6, the values on the arrows represent standardized regression coefficients from one variable to another, which are the direct effects. The indirect effects are calculated by multiplying the coefficients of one or more intermediate variables along the path.

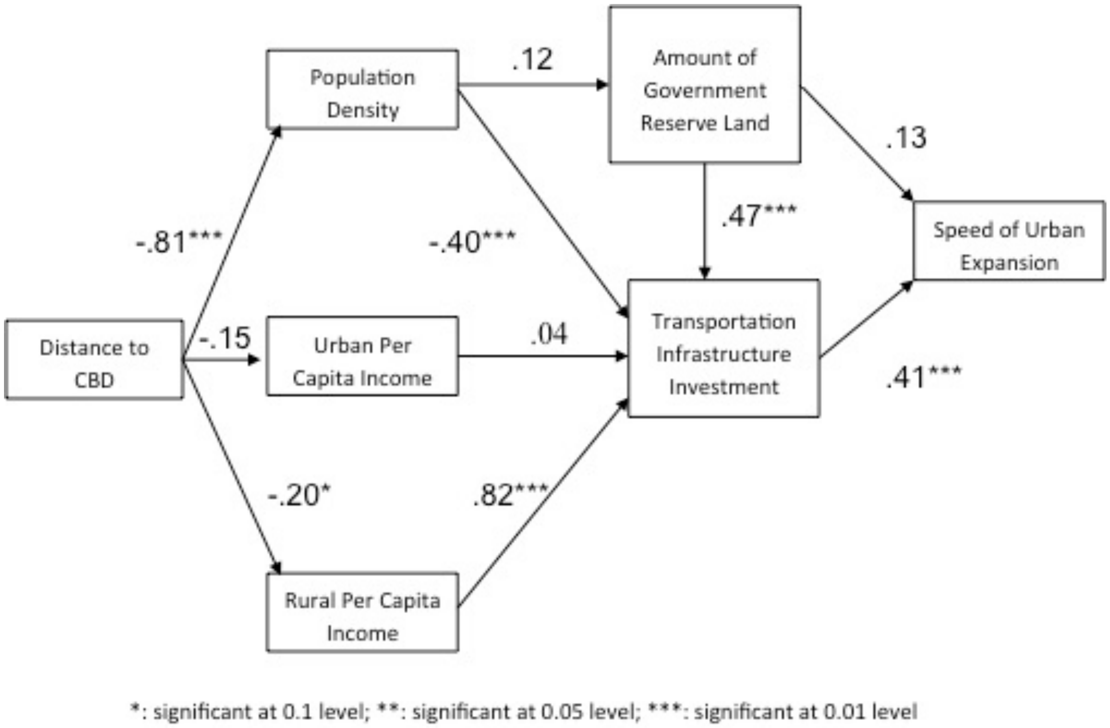


Figure 6: The results for path analysis

Table 4: Hypotheses testing results

Hypotheses	Path coefficients	Results
Primary hypotheses		
H1: Transportation infrastructure investment → urban expansion	0.41***	Supported
H2a: Amount of government reserve land → urban expansion	0.13	Indirectly supported
H2b: Amount of government reserve land → transportation infrastructure investment	0.47***	Supported
Secondary Hypotheses		
H3a: Population density → amount of government reserve land	0.12	Not supported
H3b: Population density →transportation infrastructure investment	-0.40***	Supported
H4: Urban per capita income → transportation infrastructure investment	0.04	Not supported
H5: Rural per capita income → transportation infrastructure investment	0.82***	Supported
H6a: Distance to CBD → population density	-0.81***	Supported
H6b: Distance to CBD → urban per capita income	-0.15	Not supported
H6c: Distance to CBD → rural per capita income	-0.20*	Supported

5.1 Direct effect

The results from the path analysis are shown in Figure 6 and Table 4. The coefficients identify the strength of the relationships among variables. Transportation infrastructure investment has a statistically significant direct influence on the speed of urban expansion (0.41), as postulated. However, there is no significant direct relationship between the amount of government reserve land and urban expansion. This is in line with other studies. The land availability is necessary but not sufficient for spurring urban development, although transportation infrastructure improvements can result in urban development (Cervero, 2003; Giuliano, 2004). Distance to the CBD has a statistically significant relationship with both rural per capita income and population density. As the distance to the CBD increases, rural per capita income and population decrease.

The strongest direct predictor of transportation infrastructure investment is rural per capita income (0.82) followed by the amount of government reserve land (0.47) and population density (–0.40). Urban per capita income has no statistically significant relationship with transportation infrastructure investment. These coefficients properly reflect the transportation infrastructure investment strategy. Rural areas adjacent to the urban area (higher per capita income) with more government reserve land receive more transportation infrastructure investment.

5.2 Indirect effects

The distance to the CBD indirectly affects the transportation infrastructure investment in each district through rural per capita income ($-0.2 \times 0.82 = -0.164$) and population density ($-0.81 \times -0.4 = 0.0324$). The net indirect effects of the distance to the CBD are negative, indicating areas closer to urban core receive more transportation infrastructure investment. Although the amount of government reserve land has no statistically significant effect on the speed of urban expansion, its indirect effect through the mediating variable, transportation infrastructure investment, is imputed as 0.193 (0.47×0.41). Population density, urban per capita income, and rural per capita income do not have a direct influence on the speed of urban expansion. However, the indirect influences of population density ($-0.40 \times 0.41 = -0.164$) and rural per capita income ($0.82 \times 0.41 = 0.336$) are channeled through the transportation infrastructure investment. This result squares with the finding of Cervero (2003) that transportation-induced urban development tends to gravitate to areas with higher personal income.

The results above suggest that the availability of government reserve land alone cannot promote urban development. However, investing in transportation infrastructure on government reserve land can promote urban development. This finding aligns with urban economic theories of accessibility and urban land rent reflecting the increased demand for the land (Alonso, 1964; Muth, 1969). The increased demand on the land leads to an uplift in land values, which, in return, can be used to finance the cost of transportation infrastructure.

5.3 Scenario analysis

We conducted a scenario analysis to show how the two leverages, government reserve land and transportation infrastructure investment, affect the speed of urban expansion. We calibrated parameters from the path analysis in Section 5.2. We used information from the data used in the path analysis as the baseline scenario. By altering the amount of government reserve land and transportation infrastructure investment, we revealed the differences in the speed of urban expansion, assuming the relationship holds. We simulated four scenarios to see how the speed of urban development differ when the amount of transportation infrastructure investment and government reserve land change. Table 5 shows the speed of urban development in the four scenarios defined by average/maximum transportation infrastructure investment and average/maximum government reserve land. All other variables have the average values in the four scenarios. The scenario analysis shows that the changes in government reserve land alone have only marginal effects on the speed of urban expansion. Keeping the government reserve land as average, an increase in transportation infrastructure investment still has a considerable impact. Increases in both the transportation infrastructure investment and government reserve land generate the largest impact.

Table 5: The speed of urban development by different amount of transportation infrastructure investment and government reserve land

	TI Mean	TI Max
GL Mean	390.78	1163.10
GL Max	575.43	1347.74

Notes: TI denotes transportation infrastructure investment; GL denotes government reserve land. Mean denotes average value; Max denotes maximum value. The speed of urban development is square kilometer increase in urban area per year.

6 Discussions and conclusions

Instead of choosing high-density locations, the Chongqing municipal government locates its monorail transit system on the government reserve lands that are owned by the government and mostly vacant and developable. The newly built transportation infrastructure connects the land with the existing urban network, which allows the expected development to take place. Our path analysis results support the hypothesis that the development-oriented investment and financing approach is promising for raising funds for rail transit investment and promotes sustainable urban development in lagging regions. Although Hess and Lombardi (2004) criticized that constructing rail lines based solely on availability and affordability will diminish the role of public transit as an economic agent, providing mobility to adjacent rural areas and promoting sustainable urban development would be sufficient to warrant the route selection in the context of a lagging area with insufficient transportation infrastructure but high development potential such as Chongqing.

The mechanism in Chongqing is novel compared with general land value capture applications. In the United States, land value capture is usually achieved through property tax increments (Smith & Gihring, 2006). Two factors have contributed to this mechanism. First, the transportation infrastructure investment in the United States is usually a reaction to meet increasing travel demands. Therefore, the locations for investing in transportation infrastructure are selected by criteria such as travel demand and spatial coverage of destinations and origins (Cipriani et al., 2012; Fan & Machemehl, 2006; Mamun, Lownes, Osleeb, & Bertolaccini, 2013). To meet these criteria, proposed transit routes usually go through developed urban areas with high populations and employment densities. Second, the land is mostly privately owned in urban areas. The government can capture the benefits only through increased property taxes rather than land sales. However, the innovative application of land value capture, in this case, is that the government invests transportation infrastructure on government reserve land, which is rural land with nearly zero travel demands. Unlike the reactive public transit investment in developed countries, Chongqing proactively uses the monorail transit system as a tool to shape urban development, not only for paying back investments but also as a tool to promote lagging regional development.

Our descriptive case study and statistical results suggest that the development-oriented financing approach can be used to promote urban development through infrastructure investment in lagging regions where capital is scarce. We have some suggestive evidence that urban development can be faster in suburban areas with higher per capita income and more government reserve lands because of more opportunities for transportation infrastructure investment. The transportation infrastructure investment in the Chongqing municipality was in areas with low population density but a high rural per capita income and a large amount of government reserve land. The speed of urban expansion was significantly associated with transportation infrastructure investment and the availability of government reserve land.

This mechanism for promoting urban development in lagging regions, where land is abundant but capital is scarce, is promising. The United Nations (UN) projected that the world urban population will be 66.4% in 2050, rising from 53.6% in 2014 (United Nations, 2015b). The increase in urban population would certainly demand space and public infrastructure, especially in lagging regions where more potential for transit-oriented development is expected (Xu, Guthrie, Fan, & Li, 2017). With the development potential, the development-oriented financing model fits the situation in developing countries that lack capital but have a large amount of land available. In the meantime, the provision of infrastructure more significantly affects developing countries due to a lower baseline of infrastructure inventory. Other studies also show that property tax is a viable tool to pay for the public infrastructure (Zhang & Wang, 2013; Zhang & Xu, 2017). However, the property tax is per transaction rather than based on yearly revenue in China, which would be not a Big Push to rail transit development but can cover some of the operation and maintenance costs. The development-oriented financing system can relieve the financial burden of infrastructure provisions and simultaneously promote urban development.

Urban development led by public transit can develop in a more sustainable way, as Cervero and Day (2008) implied. Auto-dependency and the construction of freeways have been the main contributors of urban sprawl in developed countries, such as the United States (Squires, 2002). Many developing countries, such as countries in Africa, Asia, and Latin America, are facing huge urban population growth in the future (United Nations, 2015b). The future urban growth pattern of these areas largely determines whether these countries can develop sustainably. During the urbanization process, a certain level of transportation infrastructure expansion is necessary. The question of how those countries will expand their transportation infrastructure arises here.

The development path of the United States has been criticized as a failure, with its construction of freeways on a massive scale and dependence on the automobile, which has led to urban sprawl, pollution, and environmental degradation. Fortunately, many developing countries have the opportunity to learn from this example and are choosing public transportation to promote urban development. Policymakers may be concerned about the possible consequence of urban sprawl. However, Glaeser and Kahn (2004) claimed that people might live farther away but in the areas with high density. Developing countries, particularly China and India, have been rapidly moving toward urbanization (or suburbanization) along with motorization, which is causing the same urban problems as in developed countries (Pucher, Peng, Mittal, Zhu, & Korattyswaroopam, 2007). The pursuit of economic development and pressing urban problems make public transit one of the top choices for policymakers in China (Cervero & Day, 2008; Zhang, 2007).

Finally, one caveat: the development-oriented financing approach depends on land appreciation, which may not be feasible for countries with little government-owned land or low development potential. The presence of government ownership of land is critical in this financing mechanism. In places where government ownership of land is low, this mechanism could be restricted. One solution adopted by Stockholm, whose land was mostly government owned, was to buy the land, the whole block of the development parcel, before announcing the development (Sidenbladh, 1965). In addition, land price is low in many lagging regions. Through land purchasing and consolidation, this financing mechanism also could be effective. Low development potentials have not been a severe issue because China's urbanization rate was less than 55% and the market highly appreciates accessibility to public transit (Yang, Chen, Le, & Zhang, 2016). This partially explains why the economic development impacts of public transit are not significant in many developed countries (Mackett & Edwards, 1998; Zhong & Li, 2016), but it is still an important determinant in developing economies (Zheng & Kahn, 2008). However, the amount of developable land is not limitless. Moreover, the projected urbanization rate is not the same among all developing countries. The development-oriented financing system may work the best in mid-stage urbanization and economic development stages. Upon reaching a certain level of urbanization, countries may resort to other financing mechanisms for matured transportation infrastructure system.

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Appendix

Appendix A is available online at https://www.jtlu.org/index.php/jtlu/article/view/1235.