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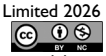

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The value-capture paradox of metro accessibility and gated communities in China

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Abstract

This paper highlights a critical challenge in China: although metro projects are justified by their potential to improve accessibility—a core public good—these benefits are often captured by private developers through the construction of gated communities around metro stations. We argue that local government's reliance on land finance to cover the high costs of the infrastructure has distorted planning priorities, relegating the creation of permeable, well-integrated station areas—a core principle of transit-oriented development—to secondary importance or irrelevance. Using a natural experiment that leverages national approval timing and local planning knowledge, we identify the causal effect of metro expansion on gated community development in Nanchang, a medium-sized Chinese city that experienced rapid growth in both metro networks and gated blocks over the past decade. Difference-in-differences estimates with multiple time periods show that, relative to control areas, each new metro station induces an average of 3.5 additional gated communities, with cumulative area increasing by 0.15–0.23 km^2 depending on the treatment year. These metro-induced effects remained statistically significant for up to six years after construction began. Our findings suggest that land-based metro financing may constrain the long-term public benefits of costly infrastructure investments, reflecting an enduring planning failure. We characterise this outcome as a "value-capture paradox," in which the public good of accessibility used to justify metro construction is displaced by short-term financing imperatives. The study offers broader insights for international debates on land finance and infrastructure-led growth in developing contexts.

Keywords

gated community, infrastructure planning, land finance, transit-oriented development

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摘要

本文揭示了中国面临的关键挑战：尽管地铁项目因其改善可达性（一项核心公共利益）的潜力而具备合理性，但其带来的好处往往被私人开发商通过在地铁站周边建造封闭式社区而攫取。我们认为，地方政府依赖土地财政来弥补基础设施高昂成本的行为，偏离了规划的优先目标，将创建开放贯通、有机整合的车站区域（这是以公共交通为导向的开发的核心原则）置于次要或无关紧要的地位。本文借助基于国家批复时序与地方规划信息的自然实验，识别了地铁扩张对南昌市封闭式社区发展的因果效应。南昌是中国一座中等规模城市，在过去十年中，其地铁网络与封闭式街区均实现了快速增长。多期双重差分估计结果表明，相较于对照组区域，每座新的地铁站平均会新增 3.5 个封闭式社区，累计面积相应增加 0.15–0.23 平方千米，具体幅度因处理年份不同而异。这些由地铁建设引发的效应保持统计显著性的时间在开工后可长达六年。我们的研究结果表明，以土地为基础的地铁融资模式，可能会制约高成本基础设施投资的长期公共收益，这反映出长期存在的规划失灵。我们将这一结果界定为“价值捕获悖论”，其中用于论证地铁建设合理性的“可达性”这一公共利益，被短期融资需求所挤占。本文为发展中国家土地融资与基础设施驱动型增长相关的国际讨论提供了更广泛的见解。

关键词

封闭式社区、基础设施规划、土地财政、以公共交通为导向的开发

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Introduction

The unprecedented scale and rapid pace of metro system development in Chinese cities have captured global attention, sparking debates about infrastructure-led urban and economic growth (Pouille, 2025; Sun et al., 2020; Szabó and Jelinek, 2023). Despite high construction costs—around 1 billion RMB (approximately $138 million USD) per kilometre—local governments have continued to invest substantially in metro systems over the past two decades. In the early 2000s, only four major Chinese cities had metro systems, with seven lines totalling 146 km. By 2015, this had expanded dramatically to 26 cities and 116 lines spanning 3618 km. As of 2022, 53 cities operate metro networks totalling 9584 km (Securities Times, 2023). For example, Chengdu, a less prosperous city in western China, has constructed a metro network spanning 634 km in just 15 years since 2010. As a comparison, the London Underground, with its 402 km network, took 150 years to reach its current length.

China's urban infrastructure faces a distinct challenge due to heavy reliance on land financing, in contrast to the tax-based systems prevalent in Europe and North America (Yang et al., 2016). The land finance system enables local governments to convert land-use rights through land acquisition, sell them to real-estate developers and other users, and capture profits from the gap between sale revenues and acquisition costs. This land financing model is central to financing major infrastructure projects like metro systems, offering important lessons for other developing contexts (Suzuki et al., 2015). Countries such as India, Ethiopia, and Vietnam have adopted similar approaches (Nguyen et al., 2018), and while their institutional and socioeconomic contexts differ, many challenges closely align with China's experiences. China's model depends on rapid growth and a rocketing housing market, both of which are now slowing. The massive metro investments have imposed even more significant financial burdens (Li et al., 2024). For example, the Shenzhen Metro reported a loss of 33.46

billion RMB in 2024, exacerbating existing local government debt (Pouille, 2025).

Despite substantial financial commitments to expand metro systems, metro projects have often fallen short of planning ideals. Instead, many new metro stations were built on farmland, routes bypassed densely populated neighbourhoods, and pedestrian access was blocked by gated communities (Sun et al., 2020). These puzzling outcomes might be linked to the reliance on land financing. Recent studies discussed distortions associated with land finance, including housing market imbalances, impacts on rural development, and unintended effects on urban form (Gyourko et al., 2022). Among these distortions, the proliferation of gated communities near metro stations, which encroach on the public good of accessibility that should underpin costly metro investment, constitutes a significant but under-studied paradox that this paper will examine.

Gated communities—privatised residential areas with restricted access and exclusive amenities—are widely criticised for reinforcing social and spatial segregation. Large gated blocks impede pedestrian routes to metro stations, reducing accessibility and, in turn, metro ridership (Sun et al., 2020). Despite this, they remain prevalent in China's middle- and high-end housing markets. Their persistence is linked to housing financialisation, in which homeownership functions as an investment vehicle (Wu et al., 2020), and to the land finance system. The sustainability of land finance relies on maintaining large gaps between land-sale revenues and acquisition costs, supplemented by recoverable real estate taxes. From 2007 to 2020, land-sale revenues exceeded RMB 55 trillion. Acquisition costs accounted for about 65% of revenues, while real estate taxes recouped roughly 75% of land-sale profits, highlighting their scale and importance in China's land finance system (Gyourko et al., 2022). To maximise returns, land leasing favours higher land prices to generate greater land-sale profits and tax revenues. Such prices are typically—and often only—offered by developers of gated communities with high-end housing projects, which remain profitable after accounting for land costs. Much of the revenue from these land-based financing activities is then used to fund infrastructure projects.

This creates a complex interplay between land finance and value-capture incentives in metro projects and station-area gated communities, where the accessibility objectives of new infrastructure may conflict with the financial priority of maximising land-sale profits. The issue of impermeable metro station catchments has been discussed in various ways in the transit-oriented development (TOD) literature, which emphasises integrating public transit and land use to enhance accessibility and connections between stations and neighbourhoods (Ibraeva et al., 2020). Most previous research focuses on pedestrian access to metro stations, as poor walking connections between stations and surrounding areas can reduce metro usage (Jiao et al., 2017). While new metro lines are often justified as improving public transport capacity, if this function is not prioritised and is undermined by gated communities, the resulting paradox raises questions about the true motivations behind such large local government investments.

At a deeper level, research on land value capture shows that metro projects in China are often used as speculative tools to stimulate development potential and raise property values, reflecting their complex interaction with land finance (Shen and Wu, 2020). Financial pressures have pushed local governments to urge metro companies to adopt self-financing models to reduce reliance on subsidies. Regardless of funding source, metro investments rely heavily on land-leasing revenue and on using land as collateral for borrowing. Local governments, controlling land acquisition and the sale of land-use rights, exploit monopoly rents (He

et al., 2025), and both institutional and market factors reinforce the profitability of land finance. Under this logic, TOD principles, such as optimising station accessibility, can become secondary or even irrelevant.

We characterise the outcomes of metro-induced gated communities as a "value-capture paradox," in which the public good of accessibility used to justify metro investments is displaced by short-term financing imperatives. Empirically, this paper tests whether the concentration of gated communities near metro stations is random or whether metro construction has systematically attracted them. We employ a natural experiment, drawing on planning knowledge of national approval and local decision-making processes to structure treatment and control groups (He et al., 2024). Using Nanchang—a medium-sized Chinese city with extensive gated development along four metro lines—we map the evolving spatial relationship between metro expansion and gated communities and estimate the causal effects. By doing so, the study also critiques the current phase of metro-led urban development in China, where gated communities restrict access and suppress ridership, pointing to a significant planning failure.

Related work

Impermeable gated morphology around metro stations

Gated communities in China vary widely in housing prices, urban design, services, and management. The origins trace back to the post-1949 socialist urban form, characterised by Soviet-inspired wide streets, large blocks, and "danwei" (work-unit) compounds, micro territories, mostly gated and managed by work units for their employees. In the late 1990s, US-style urban arterials and driveways reconfigured this urban form, alongside a boom in gated commodity housing developments designed as impermeable superblocks (Sun et al., 2018). This marked a shift from state-provided housing to market-driven residential developments, following property rights and housing reforms in the late 1990s that resulted in a combination of private (leased) homeownership with privatised community services replacing those previously provided by work units. Today's gated communities include renovated "danwei" estates and newer market-driven developments (Chiu-Shee et al., 2023). A common feature is spatial segregation via gates and walls, limiting permeability and connectivity (Sun et al., 2018).

While gated communities provide private benefits to residents, their segregation significantly shapes urban morphology. Their presence near metro stations raises critical questions about accessibility, urban equity, and efficiency. Studies using centrality and behavioural approaches have shown that gated communities reduce permeability for metro users (Sun et al., 2018, 2020). Residents of middle- and high-end gated communities near stations are often more car-dependent than metro-reliant (Li and Zhao, 2017), while lower-income groups, reliant on metro access, are pushed to peripheral areas by rising housing costs (He et al., 2024; Kuang Deng et al., 2025). Large-block gated developments near stations exacerbate socio-spatial segregation, limit street-level vitality, and discourage walking and cycling. Streets inside gated compounds are cut off from city networks, and exterior walls often present "dead frontage" with minimal retail or public amenities, reducing street activity (Sun et al., 2017). In contrast, a permeable station area, which facilitates ease of movement and connectivity, is widely regarded as a hallmark of good urban design in TOD. Gated communities around stations undermine this principle by restricting access, contrary to the planning ideal.

Land-based financing and its impacts on metro development

The financial situation of Chinese metro systems remains a serious concern. Recent reports indicate that 28 metro companies

carry a combined debt of 4.3 trillion RMB, alarming both the economic press and local observers (Pouille, 2025). Local governments share responsibilities for financing and funding existing and new metro projects. Their strong incentives to maximise profitability in land finance for infrastructure investments have heightened economic and social risks (Gyourko et al., 2022). Land has become both a windfall resource and a source of financial leverage, a dynamic reinforced by centralised political structures, the land management system, and state-controlled banks (Tsui, 2011).

Land leasing, a form of "equity financing" that sells land-use rights to generate revenues (Gyourko et al., 2022), operates through two main mechanisms in China, each with distinct pricing dynamics. The first involves industrial land, often allocated at discounted rates to attract investment, foster job creation, and drive economic growth (Zhou et al., 2019). Typically converted from farmland into development zones, these parcels aim to generate long-term tax revenue rather than upfront income. The second mechanism involves residential land, which, until recently, has commanded premium prices due to booming real estate markets. Auctioned to the highest bidder, residential land accounts for a small share of leased land but generates the majority of land-sale revenue (Tao, 2023). During China's real estate boom, governments leased increasingly larger plots to finance expanding infrastructure, including metro lines, with developers building gated communities on these large tracts, achieving economies of scale and premium designs.

A broader view of land-related profits underscores the greater importance of equity financing. Beyond land-sale revenues, local governments derive substantial income from real estate transactions, including taxes on property stocks and developer contributions, reinforcing the role of equity financing (Gyourko et al., 2022). Despite current property market volatility and rising local government debt, officials are reluctant to disrupt this vital revenue stream. As a result, large land parcels continue to be leased for gated communities, despite the clear need for station-area permeability in line with TOD planning principles.

In addition to land leasing, local governments create financing vehicles—entities that implement government investment projects and use land as collateral for loans—legally permitted to engage in "debt financing" to fund major urban development (Feng et al., 2022). New metro lines often play a central role in the land-infrastructure-leverage strategy, which addresses fiscal pressures and circumvents strict central government regulations on borrowing and land quotas (Shen and Wu, 2020; Tsui, 2011). Local governments favour more flexible, informal arrangements that use future land-sale revenues as an implicit guarantee for debt financing. Rather than pledging land-use rights directly, repayment relies on expected land-sale revenues and profits, tightly linking "equity financing" with "debt financing" and making infrastructure investments contingent on land-finance profitability (Liu and Xiong, 2018). Consolidating public assets, including infrastructure, into these vehicles strengthens their financial position and access to external funds. Metro systems, seen as vital fixed assets, raise land values and premiums, which are leveraged for further investments. While metro lines aim to improve accessibility, if financial pressures from construction and operations paradoxically undermine that accessibility, their contribution to debt financing would become unachievable.

Conceptual Framework

The value-capture paradox in land-based metro financing

Our conceptual framework is illustrated in Figure 1, which we refer to as a value-capture paradox in Chinese cities. It highlights how land-based strategies for metro

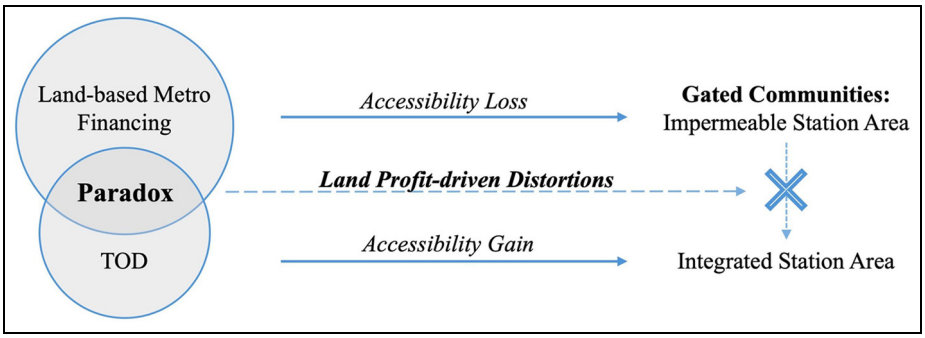

Figure 1. The capture value paradox in China's metro projects.
Source: The authors.

financing result in gated communities capturing metro accessibility. Here, we elaborate on this proposition in relation to specific institutional arrangements.

Current land finance strategies prioritise short-term financial returns through leasing to high-end housing development over long-term, integrated station areas, creating three distinct scenarios in which financial imperatives undermine metro accessibility. The first is the *land-sale pooling model*, whereby governments lease land unrelated to metro accessibility and pool the proceeds for metro construction and other public expenditures (Wang et al., 2019). This practice reveals a fundamental disconnect between metro and land-use planning: land around planned or future stations may already have been leased, leaving little scope for integrated design. As a result, value-capture opportunities are foregone, and metro stations remain poorly integrated with surrounding neighbourhoods. The second scenario involves property development by metro companies, inspired by the Hong Kong *rail-plus-property model*, which grants them use rights to land above metro depots (Aveline-Dubach and Blandeau, 2019). While conceptually aligned with TOD principles, implementation often prioritises capturing windfall profits through one-off land transactions with other state-owned developers in China (He et al., 2025). This typically occurs without substantive engagement in land development, overlooking long-term revenue streams from well-integrated design in favour of short-term gains from land-use-right transfers (Sun and Webster, 2024). The third scenario is *development-oriented routeing*, in which metro lines are deliberately rerouted through undeveloped areas to enhance land asset leverage in new districts (He et al., 2025; Shen and Wu, 2020; Yang et al., 2016). For example, lines may bypass established core neighbourhoods in favour of greenfield sites, or stations may be located in suburban and remote areas, where state-led speculative investment frequently results in oversupply and under-occupied "ghost towns" when real estate development outpaces actual demand (e.g. Chenggong in Kunming and Binhai in Tianjin).

The first two scenarios rely on land-sale revenues for equity financing, while the third focuses on debt financing through land-related borrowing. The role of land finance via land-sale revenues or borrowing has been, and can only be assessed through qualitative studies and document analysis, as Chinese local governments do not disclose the exact amounts of land transferred, which parcels were sold and for what purposes, or how much revenue was directed to metro projects (He et al., 2025; Sun and Webster, 2024; Yang et al., 2020). Regardless of the scenario, developers who acquire the land typically

build gated communities to maximise profitability. This reflects a land finance system that relies on high sales prices and real estate taxes, reinforcing the value-capture paradox. When metro accessibility primarily serves these gated blocks, investments shift from public benefit to private gain, perpetuating a cycle of infrastructure-led growth driven by land finance and short-term housing speculation, rather than the long-term benefits envisioned by TOD planning.

Land-based metro financing may have driven the development of gated communities that capture metro accessibility. Empirically testing the relationship between new metro and station-area gated communities is essential and policy-relevant. Such analysis can show how financially driven infrastructure practices undermine public utilities, compromise urban equity, and shape the spatial and social structures of cities for decades to come. The remainder of the paper presents empirical evidence of the value-capture paradox between metro accessibility and gated communities.

Methodology

Natural experimental design

We selected Nanchang, a city with ambitious metro planning and extensive gated communities, as the case study for our natural experiment. Despite its relatively recent metro history, Nanchang has constructed four metro lines with 103 stations, and a total of 128.6 km of rail. As the capital of Jiangxi Province, Nanchang had an urban population of 2.4 million in 2017, projected to reach 5 million by 2023 due to the annexation of rural counties in the census. During the planning phase, the municipal government submitted a metro network plan to the National Development and Reform Commission (NDRC) for approval. The plan, consisting of five metro lines, adhered to the NDRC's criteria, including ridership projections, population density, alignment with the city's master plan, and land development potential. All five metro lines were submitted as a single package (the city's network plan) and publicly announced in 2009. The approved metro plan (NDRC's construction plan) represented a five-year phase, during which the approved lines were intended to be completed. Over time, Lines 1–4 and their extensions were gradually approved, while Line 5, included in proposals submitted in 2009, 2013, 2022, and 2024, has not yet been approved as of 2025.

The variation in approval time introduces an "as-if randomness," allowing us to establish two types of control groups for robust comparison: (1) "never treated" (Line 5) and (2) "not-yet-treated" lines (Lines 2–4, depending on approval timing). To ensure comparability with the approved and built lines (treatment groups), we conducted document analysis and verified planning rationales with local government and metro company officials. Importantly, we established that the unapproved metro lines were not based on planning rationales or outcomes related to gated communities but on factors such as municipal debt levels, national policy priorities, housing market conditions, and lobbying efforts by local governments (Sun and Webster, 2024). For example, national controls on metro approvals were relatively relaxed between 2009 and 2016 but tightened after 2018 as part of the central government's efforts to kerb local government debt and financial risks. Despite these restrictions, local governments have remained enthusiastic about applying for additional metro lines, and the national level constraint resulting in delays of line approval can be taken to constitute a natural experiment.

Comparability across groups and the as-if randomness in the approval process enable us to isolate the causal effects of metro construction on gated community development while obviating confounding factors (He et al., 2024). To ensure the observed treatment effects, we conducted a parallel trend test, measuring gated community changes with five years of data before the

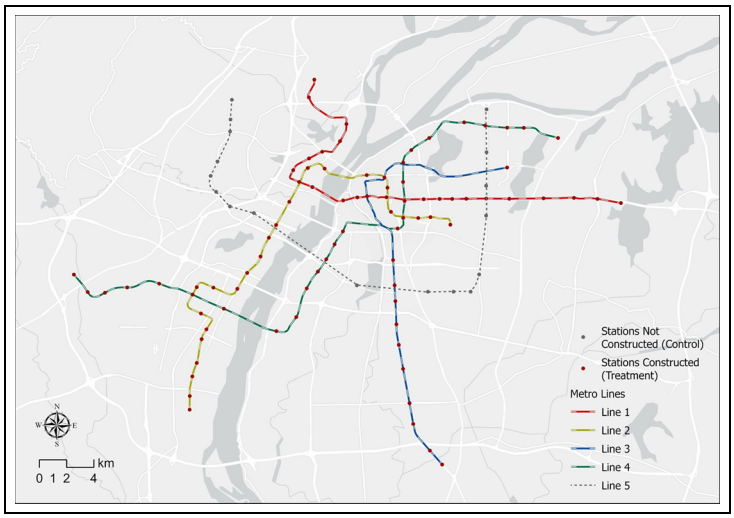

Figure 2. Treatment and control group assignment around metro stations and lines in Nanchang.
Note: We have two types of control groups for robust comparison: (1) "never treated" unit (Line 5) and (2) "not-yet-treated" unites (Lines 2–4, depending on approval timing).
Source: The authors.

announcement of the line construction plan. We employed a difference-in-differences (DID) approach, using the initiation of construction of the treatment metro line as the intervention (Figure 2). Longitudinal data on gated communities within a buffer area of operating metro stations (treatment groups) were compared with similar buffer areas around control groups: the "never-treated" (Line 5) and the "not-yet-treated" groups (Lines 2–4). We defined three pre- and post-treatment points—2009 (when Line 1 was approved and construction began), 2013 (when Lines 2 and 3 were announced and construction started), and 2017 (when Line 4 began construction)—to assess the metro's impact on gated community development.

Measuring gated community outcomes

We collected data on the presence of gated communities from two online sources in 2023: Baidu and Beike. Baidu is a map provider that includes entities like real estate, while Beike operates an online platform for housing sales and rentals (KE Holdings Inc.). To avoid omitted gated communities, we used both sources to ensure high geographical coverage. We identified gated communities using a validated method (Sun et al., 2018). This involved manual identification through historical Baidu street views, remote sensing imagery, and other online textual information. A key part of this process was to verify the presence of restricted barriers for pedestrians at the entrances of residential communities. In addition, gated communities are typically recognised by gates and walls visible in street views and often have western-style names featuring modern terms. In aerial imagery, they are distinguishable by high-rise geometries and physical layouts. Moreover, we converted it into panel data reflecting the annual distribution of gated communities during the study period, based on the year of construction and housing types, and processed them in a GIS geodatabase for longitudinal data analysis.

We used two buffer sizes around stations—800 and 1600 m—as the areal units

of analysis for measuring the emergence of gated communities. The two buffer dimensions are based on typical walking and cycling distances to metro stations in China (Sun et al., 2016). Additionally, recent housing studies commonly use these two thresholds to ensure the robustness of the treatment effects of metro intervention (Zhu and Diao, 2024).

Within our buffers, we calculated both the number and geographic footprint of gated communities. Specifically, we determined whether the centroid of any gated community identified fell within the buffer. If it did, the gated community was included in the analysis for that buffer zone. This approach enabled us to systematically examine the spatial distribution of gated communities in relation to metro stations. The panel data on gated communities cover the five years preceding the construction of a station for treatment lines and extend to 2023. For the "never-treated" group (Line 5), we extracted equivalent buffers around the proposed stations. Our sample buffers include all stations that do not overlap with the buffers of other previously built stations. A station at the intersection of two lines was considered part of the line built first and, therefore, excluded from the control set. This non-overlap criterion addresses potential spatial spillovers that would otherwise violate the stable unit treatment value assumption, minimising interference between units, preventing contamination of the control group, and strengthening the estimation of treatment effects.

Difference-in-differences modelling

We first examined summary statistics regarding treatment and control groups. We conducted a *t*-test to compare the differences in mean numbers and areas of gated communities before and after the intervention, following the announcement of the construction. We then estimated the average treatment effect (ATT) by using two-way fixed effects (TWFE) DID and Callaway and Sant'Anna's CSDID model. Because the metro lines in Nanchang were built at different times, our DID framework has multiple treatment groups and multiple treatment years, unlike the canonical DID method with one treatment group and two time periods. Previous studies have noted that, in cases like this, the coefficients from standard two-way fixed effects (TWFE) DID models may not accurately reflect the true average treatment effect, because estimates from TWFE include those from forbidden comparisons in which early-treated units serve as control groups. To address this potential issue, our CSDID model (Callaway and Sant'Anna, 2021) estimates "group-specific average treatment effects," enabling us to estimate ATTs by metro lines and by fixed points in time (e.g. the ATTs of the stations in 2015).

In the TWFE and CSDID regressions, we have two dependent variables: (i) the number of gated communities; (ii) the geographic footprint (m^2) of gated communities in the 800 and 1600 m distance buffer around each metro station. Our DID framework with two-way fixed effects is estimated by:

$$Y_{i,t} = \alpha_i + \alpha_t + \beta D_{i,t} + \varepsilon_{i,t} \qquad (1)$$

where $Y_{i,t}$ indicates the number or footprint of gated communities in the buffer around station i in year t. $D_{i,t}$ is a dummy variable recording whether unit i experienced metro construction in period t or before. The α_i and α_t are station and year-fixed effects, respectively. The parameter of interest β is interpreted as the average treatment effect (ATT). The error term $\varepsilon_{i,t}$ is clustered at the station level to adjust station-level correlations.

Our CSDID model estimated longitudinal changes occurring during the metro

construction with two types of control groups ("never treated" and "not-yet-treated"), to enhance model robustness and sensitivity. The group-specific ATT can be estimated from the ATT(g,t) in period t for group g by aggregating them according to certain criteria (e.g. by metro line). The ATT can be expressed as

$$ATT(g,t) = E\left[GC_t - GC_{g-1} | G_g = 1\right] - E\left[GC_t - GC_{g-1} | C = 1\right] \quad (2)$$

where $C = 1$ indicates the control group, including "never treated" or the "not-yet-treated" stations.

Finally, we estimated dynamic treatment effects ATT(g,t), aggregated by time since treatment. For each period before and after treatment, we calculated the average treatment effect. This approach allows us to estimate the impact of metro construction on gated community development in the years surrounding the intervention. Results were presented in graphs with confidence bands reflecting robust standard errors. Our inference procedures utilised clustered bootstrapped standard errors at the station level, which are robust to arbitrary spatial and serial autocorrelation within clusters and ensure valid, conservative inference.

Results

Summary statistics

Figure 3 shows the distribution of gated communities in 1600 m buffer areas surrounding metro stations, from pre-metro construction (2009, 140 gated communities) to the completion of the four metro lines in Nanchang (2023, 821 gated communities). We observe a significant increase in gated communities along with the new metro lines.

The average number of gated communities in the 1600 m buffers from our stations in the treatment group (Line 1, 2, 3, 4) was 14.08 after the metro construction years; 5.96 in the "not-yet-treated" groups (– six to – one year from the treatment year); 6.96 in the "never-treated" group (Line 5) for the

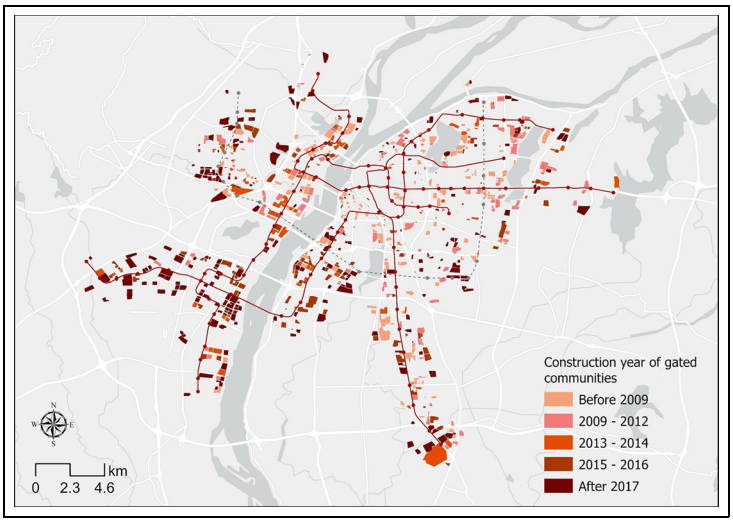

Figure 3. Spatial patterns between metro expansion and gated community development.
Source: The authors.

Table 1. Summary statistics.

(Within a 1600 m Buffer)	Num. of GCs		Area. of GCs	
	Mean	Std.	Mean	Std.
Total (all sample buffer areas in −6 years up to + 10 years from intervention)	11.44	9.10	586,065.86	517,475.01
Never-treated (for all times of control group (Line 5), 2003–2023)	6.96	6.79	546,297.43	434,731.32
Not-yet treated (buffers in Line 1, 2, 3, 4 of the pre-intervention time)	5.96	6.22	236,734.88	253,253.69
Treated (buffers in Line 1, 2, 3, 4 stations of the post-intervention time)	14.08	9.09	754,801.87	528,016.67

Table 2. Mean-difference test results (*t*-test).

	(1) Before (T–1)		(2) After (*T* + 4)		Diff. (2) – (1)	*t*	*p*-value
	Mean	S.E.	Mean	S.E.			
Num. of GCs	9.06	0.80	17.42	0.89	8.35	6.95	0.000
Area of GCs	352,221.2	33,167.29	851,917.7	53,462.04	499,696.5	7.94	0.000

Note: This *t*-test compares the changes in the 1600 mbuffer in five years: one and + four years from the intervention year (T).

whole period 2003–2023 (Table 1). After the intervention, the total gated community footprints around metro stations (754,801 m^2) were significantly larger than those of the control groups (236,734 m^2 for "not-yet-treated", 546,297.43 m^2 for "never-treated"). The results with 800 m buffers consistently showed a similar pattern (Supplemental Table A-2 in Online Supplemental Materials).

Table 2 reports the mean-difference test results ($p < 0.001$), showing the increase in gated community metrics over five years by comparing year 1 to year + 4 relative to the intervention with the treatment station buffers. On average, around eight additional gated communities were built within the buffers five years after construction; the gated community footprints across the treatment group of areas increased by 499,696 m^2 compared to five years previously (Table 2). We conclude that gated communities around the stations in the treatment group have rapidly increased after the metro construction.

DID estimation results

Table 3 presents two-way fixed-effects estimates of the overall impact of the new metro lines on the development of gated communities around stations. The treatment group experienced increases in the number and geographic footprint of gated communities in station areas ($p < 0.001$). From the two-way fixed-effects model, metro station construction was found to induce an average of three more gated communities per station and an additional 167,049 m^2 of total gated community area. The results imply that metro stations have induced more gated community developments beyond the effects

Table 3. Metro construction and gated communities: Two-way fixed effect models.

	Num. of GCs in		Area of GCs in	
	Coeff.	*p*-value	Coeff.	*p*-value
ATT	3.16 (0.32)	0.000	167,049.40 (22,006.68)	0.000
Station FE	Yes		Yes	
Year FE	Yes		Yes	
Observations	1529		1529	
R-squared	0.86		0.80	

Note: Standard errors are in parentheses and clustered at the station level.

Table 4. CSDIDresults: ATTs of metro construction on gated communities (control: never treated).

	Num. of GCs			Area of GCs		
	Coeff.	S.E.	*p*-value	Coeff.	S.E.	*p*-value
ATT	3.52	1.12	0.002	186,506.39	63,959.61	0.004
ATT by Group						
Group average	3.36	1.06	0.001	182,578.59	61,525.89	0.003
G2009	4.32	1.42	0.002	144,933.22	73,687.11	0.049
G2013	3.63	1.51	0.017	227,768.44	93,572.46	0.015
G2017	1.98	0.87	0.023	147,527.25	75,379.56	0.050
Calendar average effects						
CAverage	3.35	0.96	0.001	166,886.02	54,658.93	0.002
T2009	0.86	0.31	0.005	45,558.14	17,910.93	0.011
T2010	2.77	0.52	0.000	68,697.84	33,476.35	0.040
T2011	3.37	0.76	0.000	96,596.29	41,855.69	0.021
T2012	4.27	1.00	0.000	167,316.55	50,991.07	0.001
T2013	2.74	0.71	0.000	116,576.49	34,049.67	0.001
T2014	4.24	0.85	0.000	184,299.04	50,460.39	0.000
T2015	4.29	1.29	0.001	223,490.49	64,070.20	0.000
T2016	4.84	1.55	0.002	254,844.29	83,820.24	0.002
T2017	4.28	1.34	0.001	242,863.56	72,116.01	0.001
T2018	4.05	1.45	0.005	239,254.23	82,331.65	0.004
T2019	4.33	1.45	0.003	253,385.44	81,396.11	0.002
T2020	3.37	1.58	0.033	183,659.49	103,474.70	0.076
T2021	2.55	1.49	0.088	151,227.11	107,006.14	0.158
T2022	2.15	1.47	0.143	137,760.67	106,170.74	0.194
T2023	2.15	1.47	0.143	137,760.67	106,170.74	0.194

Note: Standard errors are clustered at the station level.

attributed to area-specific and year-specific variations.

CSDID model coefficients are shown in Table 4. The overall ATTs for metro construction were significant ($p < 0.001$) and resulted in an average of 3.52 additional gated communities within the 1600 m buffers of the treatment stations. The estimates show some heterogeneity, but all metro lines had a significant effect on gated community development, ranging from an average of 1.98 to 4.32 more gated communities being

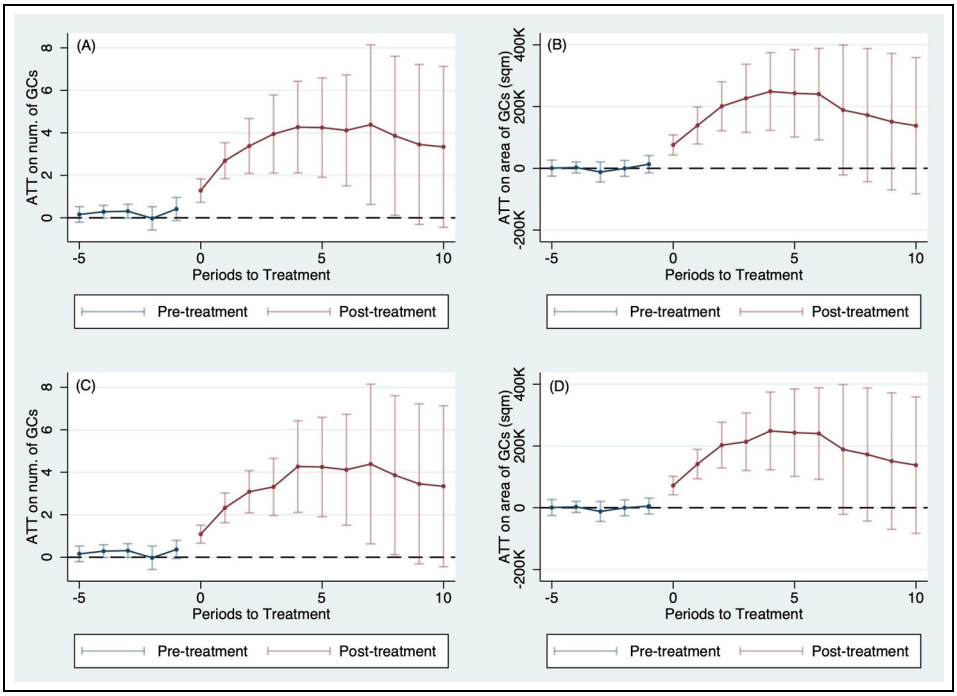

Figure 4. Dynamic average treatment effects of metro construction on gated communities' development.
Note: Panels show the average treatment effects in the treatment group by length of exposure before and after treatment, measured by(A) number and (B) area (m^2) of gated communities within 1600 m buffers. (A and B) Compare with "never-treated" controls, and (C and D) compare with "not-yet-treated" controls. The estimates are consistent with the assumption of parallel trends: the estimates for the years before intervention are all close to zero and present no pre-trends.
Source: The authors.

built. We also observe that early-developed station areas had a greater influence on their surrounding areas than later lines. For the gated area aggregated by group, the effects ranged from a buffer average of 144,933–227,768 m^2 in 1600 m buffers, depending on the treatment years.

The calendar-average effects generally increased from 2009 to 2019, showing a recurring pattern of increases and stabilisation over the years. From 2009, when the first metro line was constructed, the average effect per year increased for four years until 2012, then decreased slightly in 2013. Again, from 2014, when the second and third metro lines were under construction, the average effects showed higher values for three years. This high calendar effect remained until 2020, when the fourth line's construction was ongoing. This provides time-series evidence that metro station construction induced and accelerated gated community development.

Figure 4 shows the dynamic effect following the year of metro construction. The plots demonstrate a difference between the treatment and control groups in the years pre- and post-treatment. The average treatment effects rise and stabilise over time. From a low start at $T(0)$, ATT grows for three to five years, peaking in the 4th or 5th year, then slows but remains significant until the

6th year. The downward slope of the curves suggests that, after up to six years of strong treatment effects, the effect size decreases, probably as treatment stations' buffers reach full capacity to accommodate more development. Backing our "value-capture paradox" hypotheses, Figure 4 shows that gated communities have taken advantage of the new metro lines as a preferred location when the opportunity arises.

We also conducted a series of analyses using an 800 m buffer and the "not-yet-treated" group as a control for robustness checks. The results show consistent patterns with those from the 1600 m experiment (see Online Supplemental Materials).

Discussion and conclusion

Land finance has been instrumental in shaping urban infrastructure in China (Gyourko et al., 2022), but its profit-driven distortions on urban form outcomes remain undermeasured. We address this gap by examining the metro-induced gated communities, a value-capture paradox. Using a natural experiment, we provide the first causal evidence that gated communities have been encroaching on land near new metro stations. The locational capture occurs immediately upon the announcement of a metro project. It persists for roughly six years, with a notable increase in both the number and size of gated communities during this phase of the value-capture paradox. We conclude by discussing the broader implications of these findings.

The causal evidence of metro-induced gated communities

Our natural experiment research design is the first to causally identify the paradox of metro accessibility and station-area gated communities. Previous studies have largely applied TOD principles to examine how new metro lines change travel mode choices. However, our findings suggest that the dominance of gated communities around metro stations may underlie these challenges; we also document the scale of the problem. An impermeable, gated urban form contradicts the TOD ideal of integrating land use and transport (Ibraeva et al., 2020). Such developments increase access times and likely dampen metro ridership.

We further argue that the root of the problem lies in land-based infrastructure financing in China. Profit-driven land finance practices channel land to middle- and high-end developers who build large, gated communities to maximise the land-sale profits and real estate tax intake, distorting the intended TOD design and rendering it secondary or irrelevant. This strategic misalignment prioritises short-term gains from land leasing over the long-term benefits of high-quality urban design that supports metro accessibility. Our DID estimates of the induced effects of station-area gated communities, together with existing evidence that metro systems are used as development-oriented tools (Shen and Wu, 2020; Sun et al., 2020), indicate reduced land-use efficiency and weaker economic returns, contradicting the original objective of infrastructure investments.

Metro-induced gated communities may produce a parasitic outcome, driven by a land finance system in which local governments prioritise recouping metro construction costs, often at the expense of more optimal land uses in highly accessible areas created by new stations. An earlier study on the co-evolution of gated communities and local public goods found that gated communities often capture benefits intended for the public by exploiting competitive land market dynamics (Woo and Webster, 2014). These dynamics reflect the interplay between private neighbourhood spaces and public infrastructure and services. Whether this competition is commensal or parasitic is an

empirical question. In a commensal relationship, private neighbourhoods benefit from local public goods without diminishing their quality for others. Our analysis, however, points to a parasitic relationship: land-based metro financing enables gated communities to capture benefits from public goods (the accessibility) at the expense of long-term societal gains. By obstructing local access, gated communities dampen ridership growth and undermine metro investments. We examined this urban form distortion, driven by the land finance system, as measured by the presence and scale of gated blocks. Population density could provide complementary insight into ridership mechanisms; however, such data are unavailable or unreliable at the community level, partly due to speculative and vacant housing in suburban areas. Future access to reliable density data would allow a more complete assessment of ridership effects.

Planning failure and institutional void for better design

The paradox of metro accessibility being captured by gated communities is fundamentally a product of local government action and public policy design, making it more a planning failure than a market failure in infrastructure delivery. At its core is the "value-capture paradox," which reveals a conflict between the need to finance infrastructure and the optimal use of land for public benefit. While market forces—developers seeking profit and residents preferring gated communities in certain locations—play a role, the root cause lies in the state's land monopoly and its drive to maximise land-sale profits and real estate tax revenue (Gyourko et al., 2022; He et al., 2025).

Under this land finance model, local governments lease or collateralise land to fund metro projects through a land-sale pooling model, rail-plus-property development, or development-oriented routeing, as we elaborated earlier. In these arrangements, governments provide public goods but, due to the institutional design of land finance, are reluctant to prevent developers from capturing much of the resulting public benefit. Long-term public gains are sacrificed for short-term land revenue. This approach undermines the expensive investments in new metro lines. The outcome is both ironic and a critique of China's major infrastructure planning and delivery model, in which local governments partner with developers, leasing large plots to streamline transactions, reduce uncertainty, and maximise immediate financial returns.

The planning failure also exposes an institutional void: there is no integrated framework linking metro financing with TOD planning principles. State-backed metro investments typically lack incentives to negotiate with property rights holders to deliver high-quality designs that serve the public interest, while real estate developers have little motivation to incur additional costs to improve residents' access to metro stations. This institutional gap deepens the paradox: residents of gated communities near metro stations cannot benefit much from their proximity, even if they wish to. Connecting metro exits to gated communities complicates access rights (Chiu-Shee et al., 2023) and requires sophisticated, costly, and legally supported coordination among public and private stakeholders. These mechanisms are largely absent in China, perpetuating the disconnect between metro investment and optimal urban outcomes.

Policy implications

Our empirical evidence alerts local governments to the negative impacts of gated community development around new stations, which weakens value capture and results in

long-term fiscal and social losses. Local government needs to establish institutional arrangements for sustainable metro planning and financing. International experiences may prompt planners to ask why they did not intervene to advise local governments against selling large land parcels that have led to inefficient land use. The question highlights structural constraints faced by urban planners in China, where they are technical professionals without decision-making power (Wu, 2015). Major infrastructure decisions and land sales are decided by mayors, whose priorities focus on broader political goals rather than land-use efficiency. The perceived reliability of financing massive metro expansion often outweighs any planning ideals. There is a need to move away from a growth-first planning model—where infrastructure is built to fuel expansion and growth is prioritised above all else, while quality and long-term outcomes are treated as secondary.

There are, however, alternative and more rational approaches consistent with the land finance logic of infrastructure delivery. For example, Hong Kong's metro company shifted from relying on one-off land and housing sales profits to a property management model that leverages high-quality urban design to capture value from pedestrian flows generated by large metro ridership (Aveline-Dubach and Blandeau, 2019). This approach creates sustainable, long-term revenue that supports both metro infrastructure and vibrant station-area neighbourhoods. This model succeeds in Hong Kong because it unifies public goods and private property rights. By integrating costs and benefits into a single ownership structure, continued ownership by the metro company or its partners incentivises high-quality urban design and effective transit-oriented development.

In conclusion, this paper establishes a causal link between metro accessibility and the proliferation of gated communities, revealing a value-capture paradox that undermines the sustainable transport objectives of costly metro investments. Our findings show that these objectives are often compromised by the very financing systems designed to support them. Addressing this paradox demands a fundamental rethinking of land-financing practices in major infrastructure delivery. Beyond China, these insights inform international debates on land finance, infrastructure-led growth, and the infrastructure financing and delivery strategies.

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Supplemental material

Supplemental material for this article is available online.

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