RESEARCH ARTICLE

Megaregion Enlargement and the Geography of Gains: Evidence from the Yangtze River Delta

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ABSTRACT
How does enlarging a megaregion reshape the geography of gains? Leveraging the Yangtze River Delta’ s stepwise integration in 2013, we build city-specific synthetic controls for 99 prefectures (2004 – 2017) and implement event-study designs with spillover-robust inference. Relative to synthetic counterfactuals, GDP per capita growth increased by ≈1.6 pp/yr for incumbents and ≈0.5 pp/yr for 2013 entrants, but declined by ≈0.4 pp/yr for proximate non-members. Within the boundary, capital misallocation falls and industrial upgrading strengthens; labor misallocation declines only for incumbents. Gains concentrate in core, capital-rich cities and along logistics and producer-services corridors, with limited positive spillovers across the boundary. We rationalize these heterogeneous incidences with an economic-geography model in which market access interacts with factor-absorption frictions (mobility, housing, skills), yielding a “Winner-Takes-More” pattern inside the enlarged megaregion. Enlargement is not simply “More-Is-Better”: absent complementary policies, integration can reallocate activity inward while leaving the near-periphery behind. Accordingly, we highlight a policy bundle—place-sensitive connectivity and labor-market tools that relax mobility, housing, and skills constraints at the periphery—to broaden diffusion. The relevance extends beyond China. China is a hard test—*hukou* constraints, relatively slimmer intergovernmental redistribution, and segmented factor markets impede diffusion beyond incumbent cores. If spillovers are limited here, they are at least as limited where redistributive capacity is similar or weaker; where labor mobility and cohesion instruments are stronger (*e.g.*, parts of the EU), broader diffusion should be more likely. Because the mechanism is general, the predictions and diagnostics travel to EU growth corridors, U.S. megaregions, and other governance-led integrations.

KEYWORDS

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economic geography, megaregion integration, market access, spillovers, spatial inequality, misallocation, industrial upgrading, Yangtze River Delta (China)

1. Introduction

Urban agglomerations are more than dense clusters; they are ordered systems with hierarchy, functional specialization, and connective infrastructure (Fang, 2015; Fang and Yu, 2017). Related notions—megalopolis, city-regions, mega-city regions, and polycentric mega-city regions—foreground networks and interdependence (Hirschman, 1958; Krugman, 1996; Myrdal, 1957; Parr, 2002). We use megaregion to denote the multi-city, polycentric YRD governance-and-network system (boundary, integration, coordination), and reserve *agglomeration* for the new economic geography (NEG) mechanisms (agglomeration economies, sorting, market access). This article quantifies *who gains where* when a megaregion enlarges. Do policies that expand an existing system raise regional development—and for whom? Governments increasingly pursue city-region integration to reduce trade, mobility, and coordination frictions. Yet theory is ambiguous: deeper connectivity may lift productivity via market access and knowledge spillovers, but it can also concentrate gains in incumbent cores through firm sorting and factor reallocation —an old concern in the literature on spatial polarization (Friedmann, 1967; Myrdal, 1957).

China is an analytically useful setting with global relevance. First, Chinese megaregions are formal governance objects with dated boundary changes (e.g., the 2013 YRD expansion), yielding a sharp policy discontinuity and clear treated/neighboring units at metropolitan scale. Second, unusually rich city-level data and long pre-trends permit city-specific synthetic controls and spillover-aware event-time designs. Third, because labor mobility and equalization transfers are relatively constrained, owing to the *hukou* system and modest intergovernmental redistribution, China provides a "hard test": if diffusion beyond incumbent cores is limited here, it is at least as likely in places with similar or weaker redistributive capacity; conversely, where labor is mobile and fiscal instruments are stronger, broader diffusion should be more likely. The underlying mechanism—market access interacting with factor-absorption frictions—is not China-specific and maps to enlargements in EU corridors, US megaregions, and other governance-led integrations.

Our analysis is grounded in the NEG: increasing returns and transport costs can generate self-reinforcing core-periphery patterns (Fujita, Krugman, and Venables, 1999; Krugman, 1991). Micro-foundations emphasize sharing, matching, and learning (Duranton and Puga, 2004), while identification and selection/sorting are central to agglomeration empirics (Combes, Duranton, and Gobillon, 2011). Recent quantitative spatial models connect these mechanisms to general-equilibrium counterfactuals and heterogeneous incidence (Redding and Rossi-Hansberg, 2017). A complementary quasi-experimental literature exploits plausibly exogenous transport or governance shocks to identify market-access and spatial-integration effects—border shocks (German division/reunification), historical railroads, and modern highways primarily assess the creation of new links or national-scale integration (Baum-Snow et al., 2017; Donaldson, 2018; Donaldson and Hornbeck, 2016; Faber, 2014; Ghani, Goswami, and Kerr, 2015; Redding and Sturm, 2008). Work on regional/local integration—*e.g.*, Jing-Jin-Ji, the Greater Bay Area, EU enlargements—and on municipal consolidation/inter-municipal cooperation (IMC) evaluates governance expansion and coordination *per se* (Badinger, 2005; Campos, Coricelli, and Moretti, 2019; Cowell, 2010; Henrekson, Torstensson, and

Torstensson, 1997; Miyazaki, 2018; Warner, 2006). Classic and contemporary debates in institutional and regional economics similarly link integration to growth through trade, innovation, migration, and finance, with mixed evidence on aggregate gains (Baas and Brücker, 2010; Bonfiglioli, 2008; Cuaresma, Havettová, and Lábaj, 2013; Cuaresma, Ritzberger-Grünwald, and Silgoner, 2008; Landau, 1995; Martin and Ottaviano, 2001; Ottaviano, Tabuchi, and Thisse, 2002; Razin and Yuen, 1996; Rivera-Batiz and Romer, 1991; Tumwebaze and Ijjo, 2015; Walz, 1997). Beyond markets, governance-led projects seek to harness connectivity for development—*e.g.*, in St. Petersburg, Sydney, and Brazilian cities (Jr, 2002; Tokunova, 2018; Wiesel, Liu, and Buckle, 2018).

Against this backdrop, our setting parallels the European Union's enlargements, where deeper market access and regulatory coordination raised average performance but produced uneven spatial incidence. Studies from the 1990s-2010s document pro-growth effects from integration and institutional harmonization, yet also highlight heterogeneity shaped by absorptive capacity, factor mobility, and redistributive instruments such as Cohesion Policy (Baas and Brücker, 2010; Badinger, 2005; Baldwin, Francois, and Portes, 2014; Camagni et al., 2020; Campos, Coricelli, and Moretti, 2019; Niebuhr, 2008; Rodríguez-Pose, Dijkstra, and Poelman, 2024). Read through this lens, our YRD evidence generalizes beyond China as a *mechanism-conditional* prediction: when enlargement relaxes within-bloc frictions faster than labor frictions and where fiscal transfers are limited, gains concentrate in incumbent cores and large labor markets (a "winner-takes-more" pattern) with weak or localized spillovers; where labor is highly mobile and redistributive capacity is strong, diffusion to entrants and the periphery becomes more likely. The contrast between the EU, which features freedom of movement and substantive cohesion instruments, and China, which operates under *hukou* constraints and slimmer intergovernmental transfers, helps explain the concentrated gains inside the boundary and the limited spillovers while still mapping to a common market-access and factor-absorption logic that can travel across megaregion enlargements.

What remains relatively underexplored is the *enlargement of an already institutionally integrated agglomeration* and—crucially—the incidence of gains across incumbents, new entrants, and adjacent non-members. In mature systems, policy shocks may generate sizable within-boundary reallocation without broad regional benefits (Greenstone, Hornbeck, and Moretti, 2010). Theory predicts heterogeneous incidence: core regions often capture larger gains; entrants benefit where absorptive capacity and connectivity are strong; nearby non-members may experience diversion rather than diffusion. The EU offers a natural analogy—enlargements in 2004, 2007, and 2013 deepened access and coordination within the boundary (Baldwin, Francois, and Portes, 2014; Camagni et al., 2020; Niebuhr, 2008; Rodríguez-Pose, Dijkstra, and Poelman, 2024)— the *Yangtze River Delta* (YRD) differs in two salient respects: fiscal transfers are limited relative to EU cohesion instruments, and labor mobility is more constrained by *hukou*, suggesting faster adjustment on capital and composition than on labor.

We focus on two mechanisms that enlargement plausibly shifts. *Resource allocation:* moving factors toward higher marginal products raises aggregate total factor productivity (TFP) (Hsieh and Klenow, 2009; Restuccia and Rogerson, 2017). In China, policy-credit distortions and state-non-state gaps shape capital allocation (Brandt, Tombe, and Zhu, 2013), and adjustment costs make dispersion persistent (Asker, Collard-Wexler, and De Loecker, 2014). If enlargement eases coordination and finance frictions, capital misallocation should fall inside the boundary, with weaker changes elsewhere. *Industrial structure:* multi-sector and export-complexity frameworks link access/openness to reweighting toward knowledge-intensive activities (Bustos, 2011; Hausmann, Hwang, and Rodrik, 2007; Herrendorf, Rogerson, and Ákos Valentinyi, 2014; Hidalgo and Hausmann, 2009; McMillan, Rodrik, and Íñigo Verduzco-Gallo, 2014). In a mature agglomeration, unified procedures and deeper producer-service markets should facilitate upgrading along logistics corridors inside the boundary; in China, *hukou*, housing, and skills/training frictions imply that capital and composition adjust faster than labor.

In China, agglomerations are a policy priority and a recurring scholarly theme (Fang, 2015; Hu et al., 2019; Li and Wu, 2012) reflected in national plans (NDRC, 2016; CPC Central Committee & State Council, 2019; Government of China, 2019). We study the 2013 enlargement of the YRD—a discrete expansion of one of China's most integrated urban economies—to identify the causal effects of agglomeration enlargement on city outcomes. We assemble a panel of 99 prefecture-level cities (2004-2017) covering the YRD and its surroundings, and estimate impacts using city-specific Synthetic Control Method (SCM) (Abadie, Diamond, and Hainmueller, 2010, 2015; Abadie and Gardeazabal, 2003), with transparent pre-fit diagnostics, permutation inference, and event-time dynamics. Crucially, we estimate effects separately for three cohorts—*incumbents* (admitted before 2013), *2013 entrants* (admitted in 2013), and *proximate non-members* (adjacent prefectures that never joined)—to quantify incidence within the policy boundary and spillovers just outside it.

The article makes three contributions. First, we provide a comprehensive quantification of the *geography of gains* from enlargement across incumbents, entrants, and neighbors. Related EU-focused scholarship often treats these issues piecemeal rather than delivering an overarching assessment of distributional consequences (Baldwin, Francois, and Portes, 2014; Camagni et al., 2020; Niebuhr, 2008; Rodríguez-Pose, Dijkstra, and Poelman, 2024). Second, we open the mechanism box using city-level indices of capital and labor misallocation and a geometric industrial-advancement index, linking outcomes to reallocation and structural change. Third, we deliver policy-relevant guidance for jurisdictions weighing whether and how to enlarge existing agglomerations—on entry rules and phasing, and on complementary measures (easing labor-market frictions; strengthening peripheral connectivity) that can broaden gains beyond the core.

Previewing our findings, relative to city-specific synthetic counterfactuals (2013-2017), GDP per-capita growth increased by about 1.6 pp/yr for incumbents and about 0.5 pp/yr for 2013 entrants, while proximate non-members declined by about 0.4 pp/yr. Capital misallocation declined for both member cohorts and industrial-structure advancement rose within the YRD. Labor misallocation declined for incumbents but was small and statistically imprecise for 2013 entrants, consistent with frictions that slow re-sorting. Spillovers just outside the boundary were limited. Gains concentrated in core, larger, and capital-rich markets—a "winner-takes-more" pattern consistent with center-periphery reinforcement.

The remainder of the paper proceeds as follows. Section 2 sets out the two mechanisms (misallocation and structural upgrading) and states five testable predictions mapped to our city-specific SCM design. Appendix A formalizes these intuitions in a compact new-economic-geography–quantitative-spatial (NEG-QSM) framework of spatial equilibrium. Section 3 describes the institutional setting, data, and identification strategy. Section 4 reports baseline SCM effects and cohort-specific event-time dynamics, and examines heterogeneity. Section 5 investigates the reallocation and upgrading mechanisms. Section 6 discusses policy implications and concludes. Appendices B-H provide formal details, derivations, data construction, diagnostics, donor weights, robustness checks, and additional results.

2. Economic Mechanisms and Testable Predictions

This section introduces the two mechanisms that motivate our empirical analysis. We then embed them in a standard spatial-equilibrium framework that combines NEG and QSM (Allen and Arkolakis, 2014; Eaton and Kortum, 2002). Full details are consolidated in Appendix A.

2.1. Economic mechanisms

2.1.1. Misallocation and reallocation

By "misallocation" we mean cross-city (and cross-sector) dispersion in the marginal products of capital and labor conditional on technology, which depresses aggregate TFP because a given aggregate (K, L) produces less output when factors are not in their highest-return uses (Hsieh and Klenow, 2009; Restuccia and Rogerson, 2017). In China, policy-credit distortions, state-non-state differentials, local protection, and informational/contracting frictions are well-documented sources of wedges—especially in capital markets—so that the marginal revenue product of capital (MRPK) differs systematically across locations and ownership types (Brandt, Tombe, and Zhu, 2013). Adjustment costs further slow the equalization of marginal products, making dispersion persistent in the data (Asker, Collard-Wexler, and De Loecker, 2014).

A discrete enlargement within an already integrated agglomeration can relax several of these wedges inside the boundary. First, unified rules and procedures (*e.g.*, clearance/invoicing standards, procurement, licensing) reduce contracting and compliance costs. Second, denser buyer-supplier networks and shared information sets lower search/screening frictions and idiosyncratic risk. Third, deeper regional banking and fintech penetration improves collateralization and the allocation of credit toward higher-MRPK projects. Fourth, thicker markets raise contestability, disciplining low-productivity uses of capital. These mechanisms predict a decline in capital misallocation for incumbents and 2013-entrants, with weaker or no change outside the policy boundary. Given that labor mobility is additionally constrained through *hukou*, housing, and skills/training frictions, labor misallocation should adjust more slowly, with clearer short-run declines for incumbents than for new entrants.

Operationally, we track these channels using city-level relative-distortion indices for capital (τ_K) and labor (τ_L): $\tau = 0$ indicates efficient allocation, $\tau > 0$ underuse, and $\tau < 0$ overuse relative to efficient shares (Section 3.3). The mechanism tests, therefore, imply (i) $\Delta\tau_K < 0$ for incumbents and new entrants, (ii) smaller/insignificant $\Delta\tau_K$ for neighboring non-members, and (iii) $\Delta\tau_L < 0$ concentrated in incumbents in the short run, consistent with the sequencing we find in Section 4.5.

2.1.2. Structural upgrading.

We use "structural upgrading" to denote a reweighing of activity toward higher-knowledge intensity—advanced manufacturing, producer services, and IT-related services—consistent with multi-sector growth and export-complexity frameworks (Bustos, 2011; Hausmann, Hwang, and Rodrik, 2007; Herrendorf, Rogerson, and Ákos Valentinyi, 2014; Hidalgo and Hausmann, 2009; McMillan, Rodrik, and Íñigo Verduzco-Gallo, 2014). In those frameworks, access and openness raise the relative profitability of complex varieties and knowledge-intensive tasks by (i) expanding market size and demand for differentiated inputs, (ii) thickening buyer-supplier networks that transmit know-how, (iii) lowering fixed costs of quality/standards compliance, and (iv) improving complementary intangible inputs (logistics, finance, data, IP services). In a mature agglomeration, a discrete enlargement can activate these channels inside the policy boundary: unified procedures and interoperable platforms reduce coordination costs; common standards and data flows facilitate vertical specialization; and deeper business-service markets support product upgrading and service expansion. Together these forces predict a rise in the share and sophistication of tertiary and high-tech secondary activities within the enlarged system.

The temporal sequencing differs across factors. Capital and composition can adjust relatively quickly via new investment, product mix changes, and the expansion of producer services. In contrast, labor re-sorting is slower in China because *hukou* constraints, housing costs, and skills/training cycles impede rapid mobility and retooling (Au and Henderson, 2006; Chan, 2010; Poncet, 2005). Hence, we expect the composition margin (upgrading) to turn earlier and more visibly than the labor margin, especially for 2013-entrants.

Operationally, we track upgrading with the cosine-angle advancement index (Section 3.3.2), which increases as activity moves along the canonical path (primary $\rightarrow$ secondary $\rightarrow$ tertiary) and toward knowledge-intensive mixes. The mechanism yields three testable implications that align with our results in Section 4.5: (i) ΔAdvancement > 0 for incumbents and 2013-entrants, with gains internalized—neighboring non-members show limited or no change; (ii) the upgrading response precedes or exceeds the short-run labor reallocation among new entrants; and (iii) heterogeneity is systematic—gains are larger for cities with greater baseline capital scale/centrality, but attenuated where pre-2013 advancement is already high (less headroom), consistent with our moderation evidence.

2.2. Testable predictions (H1-H5)

To make the conceptual framework empirically falsifiable, we translate its mechanisms—capital (re)allocation, labor mobility frictions, and composition/upgrading—into cohort-specific, boundary-sensitive predictions. The YRD enlargement is an institutional change that plausibly internalizes gains within the policy boundary while leaving adjacent prefectures largely unaffected; China-specific frictions (*hukou*, housing, skills) imply a sequencing in which capital and composition adjust faster than labor. Our identification (city-specific SCM with long pre-trends) allows us to test these predictions along three margins: average incidence (by cohort), post-2013 dynamics (event time), and moderated responses (by baseline capital scale/advancement).

Let "incumbents" denote YRD members admitted before 2013, "2013-entrants" denote cities admitted in 2013, and "neighboring non-members" denote adjacent prefectures that never joined. The framework yields the following hypotheses—later mirrored by our cohort estimates, event-time paths, and moderation results:

- (H1) **Incidence and spatial distribution.** Average gains are positive for incumbents and weak or nil, possibly negative for neighboring non-members. Within members, incumbents benefit more than 2013-entrants ("Winner-Takes-More").
- (H2) **Capital reallocation (internal to the boundary).** Capital misallocation declines for incumbents and 2013-entrants as coordination/finance frictions ease within the enlarged system; changes for neighboring non-members are weak or absent.
- (H3) **Labor reallocation is slower and asymmetric.** Labor misallocation falls for

incumbents; for 2013-entrants the short-run response is smaller and may be statistically imprecise (*hukou*, housing, training frictions). No improvement in labor misallocation is expected for neighboring non-members.

(H4) **Structural upgrading is internalized.** Industrial-structure advancement rises among incumbents and 2013-entrants, with limited or no change for neighboring non-members.

(H5) **Heterogeneity in gains.** Treatment effects on economic growth increase with baseline capital scale/centrality (a convex capital gradient) and attenuate where pre-2013 industrial advancement is already high (less headroom for further upgrading).

These hypotheses map directly to the cohort-specific gaps, event-time profiles, and moderation evidence reported below.

2.2.1. Empirical mapping

(*H1*) is supported by evidence from cohort-specific SCM levels and event-time paths; (*H2–H3*) from city-level misallocation indices; (*H4*) from the advancement index; (*H5*) from moderation of SCM effects by baseline size/capital/centrality.

Beyond this intuition, we develop a NEG − QSM economic-geography model that formalizes these mechanisms and delivers testable comparative statics. Formal primitives and results are organized in Appendix A: preferences and price indices (A.1); technology and wedges (A.2); the producer-services externality (A.3); pricing and gravity (A.4); mobility and policy (A.5); equilibrium and hat algebra (A.6); links to empirical outcomes (A.7); comparative-statics propositions (A.8); and the short-run hat-algebra system used in the computations (A.9).

3. Data and empirical strategy

3.1. Setting: the Yangtze River Delta

The YRD is one of China's core urban economies. It produces roughly one quarter of national output and about one third of patents, R&D expenditure, and inward foreign direct investment (FDI). In 2013 the region's population was 115 million, and by 2018 its GDP was approximately USD 2.2 trillion-comparable to Italy (Zhang, 2020). The YRD is also among the most integrated urban systems in China, reflecting long-running programs of physical and regulatory coordination (Hu et al., 2019). Transport investments have been extensive—a high-speed rail line serving Shanghai, Suzhou (苏州) and Nantong; an interconnected expressway network centered on Shanghai—while complementary network infrastructure has expanded in parallel, including a natural-gas pipeline from Rudong to Chongming (Hu et al., 2019). Regulatory alignment has proceeded in parallel, including convergence in medical insurance and ecological-environmental standards (Hu et al., 2019; Li and Wu, 2012).

Against this backdrop of deepening transport connectivity and regulatory harmonization, the region's economic functions have sorted into a clear multi-center pattern. Producer and other high-end services concentrate in Shanghai, Nanjing, and Hangzhou, yielding a tri-polar configuration in which these cities act as regional command hubs (Zhang and Tong, 2018). Larger cores score higher on management-to-production specialization, while manufacturing-oriented cities, such as Suzhou (苏州), exhibit lower functional specialization[1]. A north-south gradient is evident: scientific research and applied engineering/technical services concentrate more in northern YRD cities, whereas information, software, and IT services coalesce around southern locations—especially the Hangzhou area (Hu et al., 2019). Finance remains anchored in Shanghai, the region's financial center, although spatial "hot spot" tests are sensitive to intra-Shanghai delineations and neighboring-city effects (Hu et al., 2019). In parallel, manufacturing has increasingly shifted from the cores toward peripheral cities-amounting to partial deindustrialization in some hubs—so that services dominate at the center while production disperses to the periphery (Hu et al., 2019; Zhang and Tong, 2018). Taken together, these patterns align with the view of agglomerations as hierarchical, yet networked, systems in which accessibility and intra-regional linkages shape functional specialization across space (Fang and Yu, 2017).

Institutionally, the YRD's integration has deep roots in China's reform era. The State Council established the Shanghai Economic Zone in 1982 as an administrative platform directly under the State Council to catalyze horizontal, city-to-city cooperation; it was not a full government tier with party/state staffing but a facilitative mechanism for spontaneous collaboration (Li and Wu, 2012). Tensions between top-down direction and local initiatives led to a more bottom-up architecture in 1992: the Yangtze River Delta Economic Association, created by the Economic and Trade Bureaus of 14 cities (Shanghai, Nanjing, Hangzhou, Wuxi, Suzhou (苏州), Yangzhou, Nantong, Changzhou, Zhenjiang, Ningbo, Zhoushan, Shaoxing, Huzhou, Jiaxing), operating as a member-based partnership (Luo and Shen, 2009). Because bureau-level meetings yielded limited tangible coordination, the "mayors' joint session" replaced this arrangement in 1997, under the YRD Economic Coordination Committee, bringing political leadership directly into regional decision-making (Luo and Shen, 2009). Subsequent meetings set out a series of substantive initiatives—including scientific and technological cooperation; SOE reforms; coordination on trade and tourism (1995); integrated employment services and standardized processes for graduate immigration (2006); and regarding port operations, environmental protection, and a regional development strategy (2007). Subsequent collaborations spanned research centers, medical insurance, exhibitions (2009), off-site elderly care, parks and industrial logistics (2010), cutting-edge technology, and port development and traffic management (2011). Recent developments have incorporated pilot free trade zones, cross-border e-commerce, and green industrial development (2020-2021) (CPC Central Committee & State Council, 2019; Government of China, 2019).

These regional initiatives have been embedded in national policy. The *YRD Regional Plan* (NDRC, 2016) sought a unified regional strategy, industrial coordination, and the easing of administrative barriers to factor flows. The agenda was renewed in 2019 with the *Master Plan for Integrated Regional Development of the YRD* (CPC Central Committee & State Council, 2019), which established objectives for integrating urban and rural areas and developing high-tech industries, infrastructure, public services, and ecological protection by 2025. There was an overarching goal of creating a unified internal market with freer movement of resources (Zhang, 2020). National leadership has repeatedly emphasized that local governments should "break administrative barriers, enhance policy coordination, and enable the easier flow of production factors" (Government of China, 2019). The YRD offers, therefore, a setting with mature physical connectivity, active institutional coordination, and clear policy intent to use agglomeration as a

[1] We use pinyin for city names. When different cities share the same pinyin, we add the Chinese characters to disambiguate—*e.g.*, Suzhou in Jiangsu (苏州) versus Suzhou in Anhui (宿州).

growth strategy (Fang, 2015; Hu et al., 2019; Li and Wu, 2012).

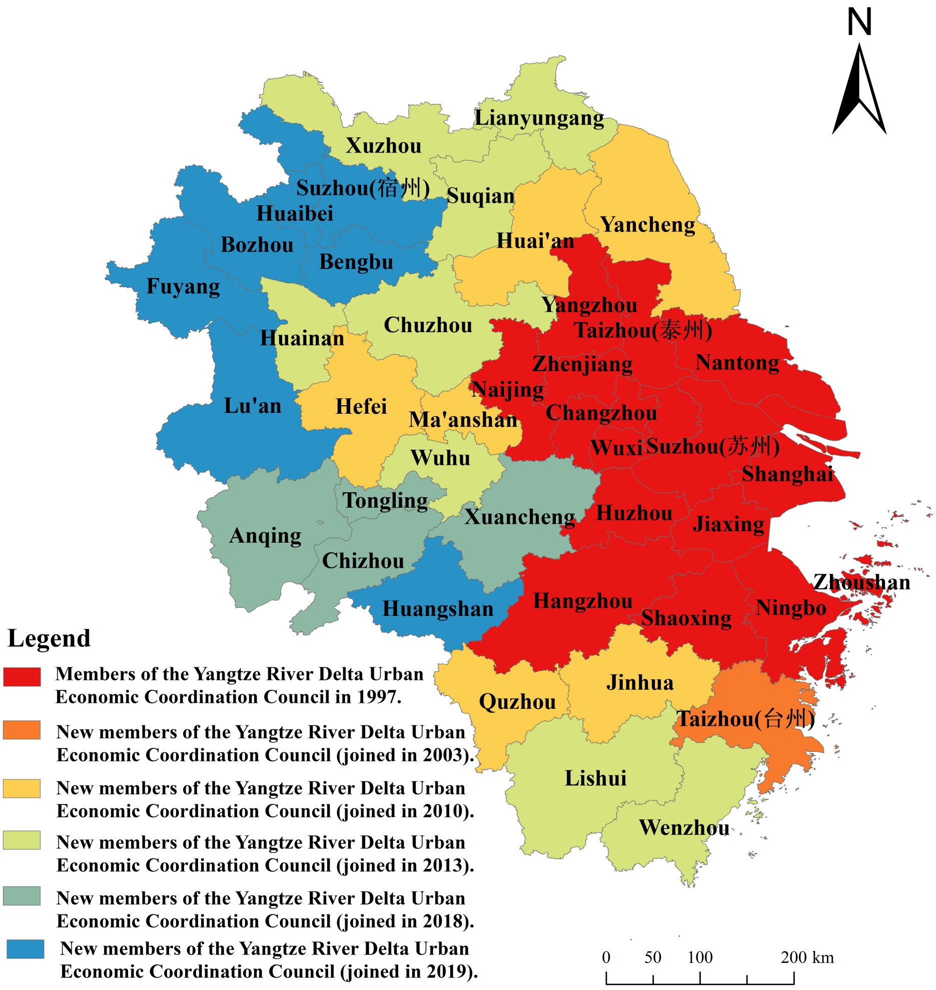


Figure 1. The expansion of the YRD

We exploit the 2013 enlargement as a policy shock to study how the formal expansion of an existing agglomeration affects city-level development. Our empirical design treats three exposure cohorts: (i) incumbents (pre-2013), (ii) 2013-entrants (added in 2013), and (iii) neighboring non-members just outside the boundary. This tri-partition lets us estimate average effects for the region as a whole and trace their incidence—how gains are distributed between incumbent cores and new members—and whether benefits spill over to adjacent non-members. These dimensions speak directly to the agglomeration literature and to policy debates on promoting core growth while safeguarding peripheral equity. As detailed below, we implement a SCM (Abadie, Diamond, and Hainmueller, 2010, 2015; Abadie and Gardeazabal, 2003) with long pre-treatment trends to construct city-specific counterfactuals and to separate effects for each cohort.

The 2013 timing is also dictated by data requirements. Earlier adjustments in 2003 leave too short a pre-period. We do not use 2010 as the cut-off because its effects are confounded by the 2013 expansion. We take 2013 as the policy cut-off because it marks a discrete intensification and widening of YRD integration along three fronts. First, the YRD City Economic Coordination Council expanded in April 2013, admitting a new cohort of prefecture-level cities, which provides a clear "entry" date for 2013-entrants and leaves earlier members as the incumbents (China Daily, 2013). Second, the China (Shanghai) Pilot Free Trade Zone—launched on 29 September 2013—triggered region-wide trade and customs facilitation (*e.g.*, "regional customs clearance integration") across the YRD (State Council, 2013; Shanghai Municipal Finance Bureau, 2013; GACC, 2014). Third, 2013 also coincides with salient connectivity milestones (*e.g.*, the first cross-provincial metro link between Shanghai and Kunshan) (People's Daily Online, 2013; International Railway Journal, 2013).

By contrast, subsequent national documents—most notably the 2016 Development Plan for the YRD Urban Agglomeration—primarily codified and consolidated the post-2013 configuration rather than initiating a new shift (NDRC & MOHURD, 2016). The plan formalizes geographic scope and membership, sets coordination mechanisms, and outlines corridor layouts and policy priorities, but does not itself generate a fresh integration shock. Taken together, these steps make 2013 a natural breakpoint for distinguishing pre- and post-integration dynamics and for separating incumbents from entrants. In estimation, we hold the donor pool (control group) fixed across specifications and exclude all cities admitted in 2010 to ensure a clean comparison.

Our sample spans 2004-2017, the 2017 end date reflects identification and measurement reasons. Extending the time-frame would conflate the 2013 shocks with the successive rounds in 2018 and 2019, creating overlapping/staggered exposure and spillovers that violate the single-shock setting required by our city-specific SCM. Moreover, post-2019 outcomes are heavily affected by COVID-19: large, heterogeneous demand and supply shocks, prolonged quarantines and mobility restrictions, and repeated, localized lockdowns introduce common shocks unrelated to YRD integration, making attribution problematic. The YRD's policy trajectory—regional planning in 2010, the 2013 enlargement, and subsequent national reinforcement in 2019—ensures that the 2013 event is both policy-salient and empirically tractable within our data window (Hu et al., 2019; Li and Wu, 2012; NDRC, 2016; CPC Central Committee & State Council, 2019; Zhang, 2020; Government of China, 2019).

3.2. Identification, data, and implementation

3.2.1. Design and estimator

We use the SCM to estimate city-specific effects of the 2013 YRD enlargement. The unit of analysis is the city-year with policy date $T_0 = 2013$. For each treated city, we construct a synthetic counterfactual from a donor pool of never-exposed prefectures—units that were neither YRD members nor immediate neighbors at any time during 2004-2017-restricted to geographically proximate provinces to preserve comparability while limiting contamination. SCM chooses non-negative donor weights to minimise pre-2013 discrepancies in outcomes and predictors (Abadie, Diamond, and Hainmueller, 2010, 2015). Post-2013 effects are the gaps between observed and synthetic outcomes, summarised by cohort (levels, growth, and event-time paths). Pre-fit is assessed by RMSPE; units with poor pre-fit are reported but excluded from causal interpretation. We implement permutation tests, report pre-RMSPE, visualise unit paths, and probe donor-composition robustness (random donor draws). Relative to two-way fixed effects (TWFE) difference-in-differences (DID), SCM relaxes parallel trends and preserves unit heterogeneity—crucial with discrete timing, few treated units, and plausible spillovers

(Callaway and Sant’Anna, 2021; Sun and Abraham, 2021). The formal setup, estimator, diagnostics, and donor-exclusion rule are detailed in Appendix B; a DID-SCM pre-fit comparison appears in Appendix B.4 (Figure B1). Sensitivity analysis is reported in Appendix E, with permutation (placebo) tests in Appendix E.2.

3.2.2. Donor pool and treatment effect

The donor pool comprises prefecture-level cities that were neither YRD members nor immediate neighbors at any point in 2004-2017 but are economically comparable due to geographic proximity. This balances two concerns: avoiding policy exposure and maintaining plausibly similar fundamentals. For each treated city i, with outcome Y_{it} (log real GDP per capita) and intervention year T_0, the treatment effect is the post-2013 gap between the realized outcome and its synthetic analogue,

$$\mathrm{TE}_{it} = Y_{it} - \sum_{j \in D} w_j Y_{jt}, \quad t > T_0,$$

where D denotes the donor pool and the weights satisfy $w_j \geq 0$, $\sum_{j \in D} w_j = 1$. We choose w to minimize pre-2013 discrepancies in the outcome and a set of predictors; see Appendix D.1 for donor selection and predictors, Table C1 for variable definitions, Appendix D.2 for the pre-RMSPE table, and Appendix D.3 for city-by-city SCM paths.

3.2.3. Data

We assembled a 2004-2017 city-year panel for the YRD and the surrounding area. The working sample contains 106 prefecture-level cities; the balanced panel used in robustness checks comprises 99 cities. For incumbents, we exclude Hefei and Ma’anshan; for 2013-entrants, we omit Wuhu and Huainan; for the neighboring-cities (spillover) analysis, we exclude Lu’an, Tongling, and Anqing. In addition, Heze, Bozhou, and Fuyang are dropped because their SCM solutions collapse to a single donor (100% weight) and/or exhibit high pre-treatment RMSPE. The outcome is the log of real GDP per capita; predictors include sectoral structure, demographics, investment and openness, innovation, labor-force participation, market activity, fiscal spending, and transport infrastructure. Variable definitions, sources, and descriptive statistics are provided in Appendix C; see Table C1. Comparative evidence on donor/treatment pre-trends is given in Figure D1; the donor list is supplied in Table D2. Diagnostics, inference and sensitivity analysis follow SCM convention (Appendix B.3, Eq. (B6); Appendices D.2-D.3; Appendix E).

3.3. Mechanisms: indices, specification, and moderation

This subsection defines the mechanism indices (capital/labor misallocation, industrial-structure advancement) and outlines the cohort-specific two-way FE and moderation designs used to test their response to enlargement.

3.3.1. Resource (mis)allocation

We follow Hsieh and Klenow (2009) and Aoki (2012). For city i in year t, aggregate production is Cobb-Douglas with Hicks-neutral technology and constant returns to scale

(CRS):

$$Y_{it} \;=\; A_{it}\, K_{it}^{\alpha_i}\, L_{it}^{1-\alpha_i}, \quad \alpha_i \in (0,1).$$

For compactness, the derivations below suppress the time subscript t; all objects are implicitly time-specific.

Let capital and labor face city-specific wedges $\tau_{K,i}$ and $\tau_{L,i}$, interpreted as *ad valorem* distortions on factor prices. Let the (nominal) output share be

$$\delta_i \;\equiv\; \frac{P_i Y_i}{\sum_\ell P_\ell Y_\ell}, \quad \text{so that } \sum_i \delta_i = 1,$$

where P_i is the output price index (GDP deflator). Let the aggregate (output-weighted) capital elasticity be $\alpha \;\equiv\; \sum_i \delta_i \alpha_i$.

Under common factor prices P_K, P_L across cities, profit maximization with wedges $\tau_{K,i}, \tau_{L,i}$—which scale effective factor prices to $(1+\tau_{K,i})P_K$ and $(1+\tau_{L,i})P_L$—implies the factor-allocation shares

$$K_i \;=\; \frac{\delta_i\, \alpha_i\, \rho_{K,i}}{\sum_j \delta_j \alpha_j \rho_{K,j}}\, K, \quad L_i \;=\; \frac{\delta_i\, (1-\alpha_i)\, \rho_{L,i}}{\sum_j \delta_j (1-\alpha_j) \rho_{L,j}}\, L,$$

where the "efficiency factors"

$$\rho_{K,i} \;\equiv\; (1+\tau_{K,i})^{-1}, \quad \rho_{L,i} \;\equiv\; (1+\tau_{L,i})^{-1}$$

equal 1 when there is no wedge.

Define relative distortions as the ratio of the actual factor share to the efficient share (the latter obtained when $\tau_{K,i} = \tau_{L,i} = 0$ and hence $\rho_{K,i} = \rho_{L,i} = 1$):

$$\bar{\rho}_{K,i} \;\equiv\; \frac{K_i/K}{(\delta_i \alpha_i)/\alpha}, \quad \bar{\rho}_{L,i} \;\equiv\; \frac{L_i/L}{\delta_i(1-\alpha_i)/(1-\alpha)}.$$

Under efficient allocation, $\bar{\rho}_{K,i} = \bar{\rho}_{L,i} = 1$ for all i.

We then define mismatch indices by inverting and centering at zero:

$$\tau_{K,i} \;\equiv\; \bar{\rho}_{K,i}^{-1} - 1, \quad \tau_{L,i} \;\equiv\; \bar{\rho}_{L,i}^{-1} - 1.$$

By construction, $\tau = 0$ indicates efficient allocation; $\tau > 0$ indicates underuse (actual share below the efficient share); and $\tau < 0$ indicates overuse. These indices are unit-free and comparable across cities and factors.

Data construction (including the PIM and depreciation) and elasticity-estimation details are provided in Appendices F.1 and F.2.

3.3.2. Industrial structure advancement

Following Fu (2010), let $\boldsymbol{x} = (x_1, x_2, x_3)$ be the (non-negative) output shares of primary, secondary, and tertiary industry. Define

$$\theta_j = \arccos\left(\frac{x_j}{\sqrt{x_1^2 + x_2^2 + x_3^2}}\right), \quad j \in \{1,2,3\},$$

and compute

$$\text{Advancement} = \sum_{k=1}^{3} \sum_{j=1}^{k} \theta_j \;=\; 3\theta_1 + 2\theta_2 + \theta_3,$$

so that higher values indicate a more advanced (tertiary-intensive) structure.

3.3.2.1. Rationale. We adopt Fu (2010) because it is directional along the canonical path (primary → secondary → tertiary), geometric and scale-invariant (angles summarize the full three-sector composition without arbitrary weights and remain well defined at the corners), and parsimonious: a single smooth statistic captures upgrading more transparently than a tertiary share, ratios, or entropy measures. It is also practical with city-year accounts, avoiding the data demands of product-sophistication/complexity indices.

3.3.2.2. Implementation. We compute the index annually using reported sectoral shares: if given as percentages, divide by 100; enforce non-negativity (truncate tiny rounding negatives to 0); note the formula is well defined when a share equals 0 or 1; and, as a robustness check, we winsorize shares to $[0, 1]$ and verify $\theta_1+\theta_2+\theta_3$ against the reporting total. Summary time paths appear in Appendix G.

3.3.3. Mechanism specifications and moderation design

We relate the policy to mechanisms using cohort-specific TWFE models with the full control set. For each cohort c, we estimate:

$$\text{Mismatch}_{it}^{(f)} = \beta_{0f} + \beta_{1f}\,\text{Exp}_{it}^{(c)} + X_{it}^{\top}\gamma_f + \delta_i + \delta_t + \varepsilon_{it}^{(f)}, \quad f \in \{K, L\}, \tag{3.1}$$

$$\text{Advancement}_{it} = \beta_{0a} + \beta_{1a}\,\text{Exp}_{it}^{(c)} + X_{it}^{\top}\gamma_a + \delta_i + \delta_t + \varepsilon_{it}^{(a)}. \tag{3.2}$$

Here, $\text{Mismatch}_{it}^{(K)}$ and $\text{Mismatch}_{it}^{(L)}$ are the absolute values of the capital- and labor-misallocation indices. By construction, $\tau_K = 0$ and $\tau_L = 0$ denote efficient allocation; deviations from zero capture the magnitude of misallocation (the sign in the underlying indices distinguishes under- vs. over-utilization). Advancement_{it} is the industrial-structure advancement index. We define $\text{Exp}_{it}^{(c)} \equiv \mathbf{1}\{t \geq 2013,\ i \in c\}$; X_{it} is the control set in Table C1; and δ_i, δ_t are city and year fixed effects. Index construction is described in Appendix F and Section 3.3.2. Standard errors are clustered at the city level.

Moreover, to examine heterogeneous responses, we interact exposure with city characteristics $M_i \in \{\,|\tau_K|, |\tau_L|, \text{Advancement}\,\}$. For each cohort c, we estimate the following moderation specification—where the outcome Z_{it} is, in turn, $|\tau_K|$, $|\tau_L|$, or industrial-structure advancement; M_i and Z_{it} are not the same variable; β captures the average post-2013 effect; and θ captures how that effect varies with the moderator:

$$Z_{it} = \alpha + \beta\,\text{Exp}_{it}^{(c)} + \delta\,M_i + \theta\Big(\text{Exp}_{it}^{(c)} \times M_i\Big) + X_{it}^{\top}\gamma + \delta_i + \delta_t + \varepsilon_{it}, \tag{3.3}$$

with X_{it} denoting controls and δ_i, δ_t city and year FEs. Full estimates are reported in Appendix H, Table H1.

4. Results: baseline effects and dynamics

4.1. SCM results by cohort: incumbents, 2013-entrants, and neighboring non-members

Using the SCM implementation in Section 3.2 and Appendix B, we estimate city-level effects and summarise them by cohort. Pre-treatment fit is tight (median pre-RMSPE: 0.010 for incumbents, 0.008 for 2013 entrants, 0.011 for neighbors); cities with weak pre-fit or major boundary changes (*e.g.*, Wuhu, Huainan) are reported for transparency but excluded from causal interpretation (Table D3). Figure sets D5-D7 show a clear spatial pattern anchored on Shanghai-Suzhou-Hangzhou-Nanjing: incumbents diverge positively from their synthetic controls after 2013, 2013 entrants exhibit modest or short-lived gains, and neighboring non-members show small, statistically weak responses—consistent with (*H1*) and a "Winner-Takes-More" dynamic within the enlarged megaregion. Cohort growth-rate effects (pp/yr) and level gaps (log points) are reported in Table D4.[2]

4.2. SCM gaps for treated cities (pre-fit and post-treatment effects)

We examine the distribution of SCM-based treatment effects to assess whether integration into the YRD improved urban economic efficiency (proxied by GDP per capita). For each treated city i and year t, we compute $\mathrm{TE}_{it} = Y_{it} - Y_{it}^{\mathrm{SCM}}$ and align observations around the entry year for comparability by cohort (incumbents vs. 2013-entrants; full cohort assignments in Table D1). Values near zero indicate no discernible deviation from the synthetic counterfactual; positive (negative) values indicate higher (lower) outcomes than the synthetic control in that period.

We compare the distributions of TE_{it} before and after entry separately for incumbents (admitted before 2013) and 2013-entrants. Figure 2 shows pre-treatment gaps tightly centred at zero, confirming good pre-fit. Post-treatment, the distributions widen and become fat-tailed: incumbents shift to an approximately normal distribution with a positive mean, whereas 2013-entrants display a skewed and more heterogeneous pattern. This divergence underscores timing-dependent heterogeneity in the gains from integration.

This distributional evidence highlights that cooperation does not imply uniform gains: with strategic complementarities and competition in producer services, short-run incidence can be non-uniform across cities within the same megaregion. Pooling all treated cities can, therefore, be misleading. What might initially resemble a zero-sum allocation at entry can evolve into positive-sum collaboration as institutional alignment and regional coordination deepen. Consequently, we next estimate an event study to compare treatment effects across cohorts and study dynamics. Viewed through (*H1*), the widening post-2013 dispersion in Figure 2 is exactly what we would expect when enlargement reinforces incumbents' centrality more than it benefits later entrants or neighbors.

[2]Unless noted, SCM treatment effects are reported in log points; growth differentials are percentage points per year (pp/yr). Standard errors are heteroskedasticity-robust and clustered at the city level.

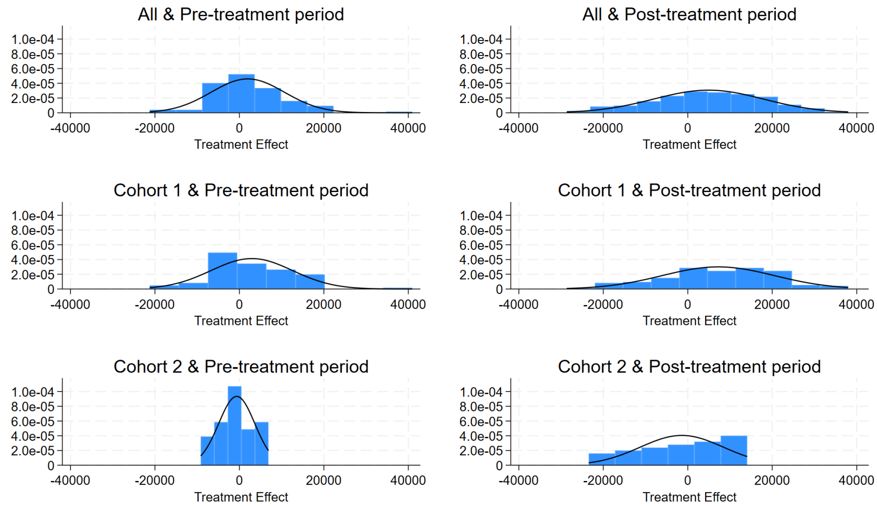


Figure 2. Treatment effects across different periods and cohorts

Notes: Each panel indicates a cohort specification. "All" pools all treated observations; "Cohort 1" denotes the incumbents; "Cohort 2" denotes the 2013-entrants. The pre-treatment window spans up to four years before entry; the post-treatment window includes the event year and the next three years to ensure comparability across timing.

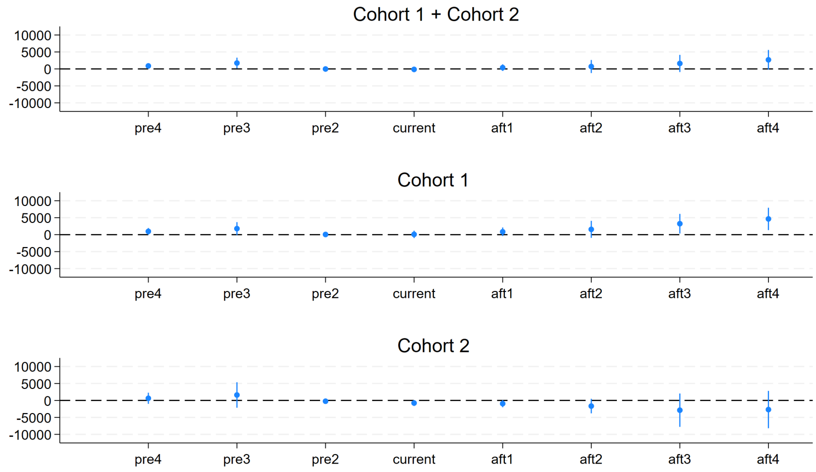
4.3. Event-time effects: incumbents, 2013-entrants, and neighboring non-members

To evaluate how the timing of entry into the YRD megaregion—before or after the 2013 expansion—affects city-level outcomes, we estimate an event study on SCM-based treatment gaps, $\mathrm{TE}_{it} \equiv Y_{it} - Y_{it}^{\mathrm{SCM}}$, for treated cities. . The estimation equation is presented in Eq. (4.1), where D_t represents a set of event-time dummies indicating periods relative to the treatment year. γ_i and γ_t are city and year FEs, respectively, and u_{it} is the error term.

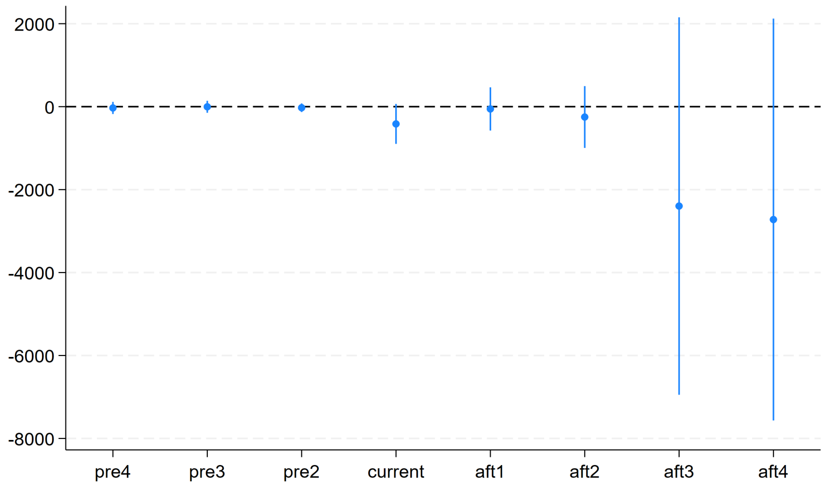
$$\mathrm{TE}_{it} = \alpha + \sum_{t=-4,-3,-2,0,1,2,3,4} \beta_t D_t + \gamma_i + \gamma_t + u_{it}. \tag{4.1}$$

To ensure temporal balance and reduce potential bias from asymmetric time windows, we define the event window to include four years before and four years after the treatment year, covering the period from 2009 to 2017. Since all observations pertain to treated cities, we omit the dummy for $t = -1$ (the year immediately prior to treatment) as the reference period to avoid perfect multicollinearity. The estimation results are illustrated in Figure 3.

The event-study estimates yield several noteworthy results. For incumbents, pre-treatment trends are flat (statistically indistinguishable from zero), and per capita GDP rises progressively after the 2013 expansion, with treatment effects at aft3 and aft4 positive and statistically significant (confidence bands lie entirely above zero). This pattern is consistent with a first-mover advantage reinforced by subsequent entry: the enlargement expanded the market served by incumbents, reduced supply-chain matching frictions, and allowed scale economies and specialization to deepen over time. For both 2013-entrants and neighboring non-members, pre-treatment trends are also flat;



(i) Treated cities (Cohorts 1–2)



(ii) Neighboring non-members (Cohort 3)

Figure 3. Event studies for treated and neighboring non-member cities

Notes: Panel (3i) presents an event study of treatment effects for cities that eventually joined the YRD Urban Agglomeration. To ensure temporal symmetry, the event window is 2009-2017, with the year immediately preceding the event (pre1) used as the reference period. Pre-treatment periods are labelled pre2-pre4, and post-treatment periods are labelled aft1-aft4; 'current" denotes 2013, the policy implementation year. Cohort 1" comprises incumbent members that joined no later than 2013; Cohort 2" includes 2013-entrants; and All cohorts" pools both groups. Panel (3ii) shows the event study for neighboring non-members (Cohort 3"). All estimates are based on robust standard errors; the central dot is the point estimate and the vertical line is its confidence interval.

however, their post-expansion effects are negative and statistically indistinguishable from zero. Overall, the dynamic response supports (*H1*): gains accrue—and strengthen over time—to incumbents, whereas 2013-entrants and neighboring non-members do not exhibit comparable post-2013 improvements.

Taken together, these patterns are suggestive of a "Winner-Takes-More" dynamic. The enlargement appears to have relaxed market-access barriers, primarily in ways that reinforced the pre-existing centrality of the original core, creating a centre-periphery structure in which incumbents—with stronger economic fundamentals and denser linkages—captured a disproportionate share of the gains, while 2013-entrants and neighboring non-members did not experience any significant improvement. We probe this mechanism below in Section 4.4.

4.4. Why did a "Winner-Takes-More" pattern emerge?

A further question is why effects differ across cities. Larger economic scale could translate into bargaining power-suggesting a "Winner-Takes-More" mechanism. Alternatively, distinctive industrial structures might face weaker head-to-head competition and stronger complementarities. Spatial externalities might also matter.

In China's policy environment, pilot-driven reforms can create a "spotlight" on early movers that is not easily scalable to followers; whether integration generates spillovers to nearby non-treated cities is, therefore, an empirical matter. If so, the YRD expansion would disproportionately benefit larger or better-positioned cities, amplifying factor agglomeration and returns to scale; potentially at the expense of smaller cities whose GDP per capita and efficiency could decline.

The event-study evidence (Section 4.3) supports this hypothesis. As shown in Figure 3, incumbents (Cohort 1)—which entered before 2013 and are generally larger—exhibit the expected post-expansion rise in GDP per capita that strengthens over time. By contrast, the 2013-entrants and neighboring non-members show negative effects, albeit statistically insignificant.

This pattern suggests that market-access frictions were relaxed in ways that primarily reinforced incumbent advantages. We, therefore, examine whether treatment effects vary systematically with baseline city size, using size-event-time interactions to quantify the gradient of "Winner-Takes-More" and to access how strongly larger cities capture the post-2013 gains.

4.4.1. Empirical approach.

Given sample-size constraints, we adopt a parsimonious multivariate specification rather than threshold or cross-validated split methods. We augment the event-study framework with a small set of city characteristics and allow for nonlinearities by including each characteristic and its square. Let $k \in \{L, K\}$ index the characteristics, where $X_{L,it} \equiv L_{it}$ (non-agricultural employment, i.e., city size) and $X_{K,it} \equiv K_{it}$ (capital stock). The estimating equation is:

$$\mathrm{TE}_{it} = \alpha + \sum_{k\in\{L,K\}} \left(\theta_{k,1} X_{k,it} + \theta_{k,2} X_{k,it}^2\right) + \gamma_i + \gamma_t + u_{it}. \tag{4.2}$$

4.4.2. Results

Table 1 relates baseline size proxies to the SCM-based treatment effect. All models include city fixed effects; cols. (3)-(4) additionally include year fixed effects.

Capital—The capital gradient is robustly convex. In linear-only specifications the sign is sensitive to common shocks (negative in col. 1, positive in col. 3), but once we allow for non-linearity the squared-capital term is positive and significant in both col. 2 and col. 4, while the linear term becomes insignificant. Hence the marginal effect of capital rises with scale,

$$\frac{\partial \widehat{\mathrm{TE}}}{\partial K} = \beta_K + 2\beta_{K^2} K,$$

with an implied turning point $K^\star = -\beta_K/(2\beta_{K^2}) \approx 0.5$ (in the units of the capital variable in our specification). For most observed cities, the marginal effect is, therefore, positive and increasing in capital, consistent with a "Winner-Takes-More" pattern in which capital-rich cities capture disproportionately larger gains after enlargement.

Employment—Employment provides weaker evidence. The coefficient is negative and weakly significant in linear models (cols. 1 and 3), but both the level and the square are insignificant once non-linearity is allowed (cols. 2 and 4), indicating that total employment is a noisier proxy for "size"—likely due to multicollinearity with capital and measurement/scale issues. A plausible interpretation is that internal-migration constraints under China's *hukou* system slow labor reallocation, weakening employment-based gradients relative to capital.

Year fixed effects—Adding year FEs absorbs common shocks and stabilises inference: the convex capital pattern survives (col. 4), whereas employment gradients remain fragile. Consistent with (*H5*), treatment effects rise with baseline capital scale/centrality. Complementary moderation evidence (Appendix H, Table H1, Panel C) shows attenuation where pre-2013 advancement is already high, indicating limited headroom for further upgrading.

Taken together, the evidence supports centre-periphery reinforcement rather than uniform gains: larger, capital-intensive cities benefit more, while labor-based size proxies convey weaker gradients—consistent with the slower labor adjustment documented elsewhere in this section.

Finally, moderation using the misallocation indices (Panels A-B of Table H1) corroborates a "Winner-Takes-More" pattern among incumbents and indicates greater friction-mitigation where pre-2013 distortions were larger; full estimates are reported in Appendix H.

4.5. Resource (mis)allocation and industrial structure

Here we construct the indices for resource misallocation (capital and labor) and for industrial-structure advancement. Details for the capital and labor misallocation indices are in Section 3.3.1 and Appendix F; the construction of the industrial-structure advancement index is in Section 3.3.2. Figures G1-G3 plot cohort-average time paths—solid line with shaded ± 2 s.e. bands—for the capital-misallocation index (τ_K), labor-misallocation index (τ_L), and the advancement index across incumbents, 2013-entrants, neighboring non-members, and the overall agglomeration. These visuals are relegated to Appendix G due to page constraints.

First, consider the capital-misallocation index, τ_K (Figure G1). For 2013 entrants

Table 1. Effects of heterogeneity factors on estimated treatment effects

Variable	Without year FEs		With year FEs	
	(1)	(2)	(3)	(4)
L	-18.547*	5.482	-28.724*	-9.607
	(10.806)	(27.029)	(15.129)	(31.945)
K	-0.006***	0.001	0.009**	-0.001
	(0.002)	(0.003)	(0.004)	(0.006)
L^2		-0.038		-0.041
		(0.028)		(0.027)
K^2		0.001**		0.001**
		(0.001)		(0.001)
Year FE	NO	NO	YES	YES
City FE	YES	YES	YES	YES
Observations	150	150	150	150

Notes: Robust standard errors in parentheses; city FE in all columns; year FE where indicated. K is capital stock (scaled by 10^8 RMB); L is non-agricultural employment (10,000 persons). The implied turning point for K in col. (4) is $K^\star = -\beta_K/(2\beta_{K^2}) \approx 0.5$ in the scaled units. ***, **, * denote $p < 0.01$, 0.05, 0.10.

and neighboring non-members, we observe a clear post-2013 decline relative to their pre-trends. Because their initial levels lie below zero—indicating capital overuse—this decline signals a further deterioration in allocative efficiency. By contrast, incumbents and the aggregate exhibit a mild upward trajectory that appears to flatten after 2013; however, the corresponding confidence bands include zero throughout, so changes are not statistically distinguishable from zero and we refrain from strong causal claims. Overall, these descriptive patterns are partially consistent with (*H2*): within the expanded YRD boundary, capital reallocation appears to improve—or at least not deteriorate—for incumbents, while outside the boundary it is limited and may worsen.

Second, consider the labor-misallocation index, τ_L (Figure G2). Incumbents remain close to zero with modest post-2013 easing; because the confidence band includes zero, we refrain from strong causal inference. The 2013-entrants show an upward movement—suggesting deterioration in labor-allocation efficiency—however, the wide confidence band also contains zero, so we cannot make a decisive statement. Neighboring non-members trend upward throughout; the trend is statistically significant, as zero lies below the confidence band (labor underuse). We observe a sharp increase in slope at 2013, followed by a decline from 2014 onward. For the overall agglomeration, changes in labor misallocation are flat and statistically insignificant. These patterns are partially consistent with (*H3*): incumbents exhibit a small improvement that is not statistically distinguishable from zero; 2013-entrants show an upward (worsening) movement that is likewise imprecisely estimated; and neighboring non-members experience a statistically significant deterioration.

Third, for the industrial-structure advancement index (Figure G3), all cohorts exhibit steady upgrading over 2004-2017, with the upward trend strengthening after 2013. This is partially consistent with (*H4*): upgrading intensifies within the enlarged system. However, panel (iii) of Figure G3 shows a marked increase for neighboring non-members. This pattern suggests that factors beyond the YRD expansion may also be driving industrial upgrading in peripheral regions. Further investigation—controlling for additional covariates—is warranted. More generally, industrial upgrading is a secular feature of economic development, so part of the post-2013 acceleration likely reflects broader, economy-wide forces rather than the expansion alone.

Furthermore, because the ± 2 s.e. envelopes summarize cross-sectional dispersion, they are descriptive rather than formal tests. Formal cohort-specific estimates in Table 2 corroborate these figure-based impressions—capital misallocation declines for members but not for neighbors ((*H2*)), labor misallocation falls for incumbents and is smaller/imprecise for new entrants (*H3*), and advancement rises inside the boundary (*H4*). We further assess heterogeneity via moderation (Appendix H).

Finally, our indices assume Hicks-neutral technical change and CRS because they provide a parsimonious, standard mapping from observables (Y, K, L) to relative distortions: Hicks-neutral shifts scale A_{it} and cancel in share-based τ indices, while CRS implies factor shares exhaust output and that efficient cross-city allocations are proportional to elasticities—which we allow to vary by city and estimate from the pre-period. Given limited city-level price/markup data and following established practice (*e.g.*, Hsieh and Klenow, 2009; Aoki, 2012), these restrictions are empirically reasonable over 2004-2017.

5. Economic development mechanism

We examine whether the 2013 enlargement operated through (i) changes in factor (mis)allocation and or (ii) industrial upgrading. Accordingly, we estimate the cohort-specific reduced-form mechanism regressions, introduced in Section 3.3.3, Eqs. (3.1)-(3.2), separately for the overall agglomeration, incumbents, 2013-entrants, and neighboring non-members, using the full control set with city and year FEs; standard errors are clustered at the city level.

Table 2 reports the estimated coefficients on $\mathrm{Exp}_{it}^{(c)}$; cols. (1)-(3) correspond to capital misallocation ($|\tau_K|$), labor misallocation ($|\tau_L|$), and industrial-structure advancement, respectively. These regressions complement the city-specific SCM by showing channels that comove with the policy.

Overall agglomeration (Panel A). Enlargement is associated with lower misallocation—$|\tau_K|$ -0.0695^{***} and $|\tau_L|$ -0.0844^{***}—and higher advancement $+0.0061^{***}$, indicating both reallocation and upgrading.

Incumbents (Panel B). Incumbents see sizable declines in misallocation ($|\tau_K|$ -0.0459^{***}; $|\tau_K|$)-0.1428^{***}) and a rise in advancement ($+0.0046^{**}$), consistent with deepening of established production networks and thicker labor markets.

2013-entrants (Panel C). For new members, $|\tau_K|$ falls sharply (-0.1576^{***}) and advancement rises ($+0.0083^{**}$), while the estimate for $|\tau_L|$ is negative but imprecise (-0.0905, n.s.). This pattern suggests faster adjustment on investment and composition margins than on labor re-sorting.

Neighboring non-members (Panel D). Coefficients on enlargement are small and statistically indistinguishable from zero across all three outcomes, implying that benefits were largely internalized within the policy boundary rather than diffusing to proximate non-members.

Taken together, Table 2 maps cleanly to our hypotheses: ((*H2*)) capital misallocation falls for incumbents (-0.0459^{***}) and for 2013-entrants (-0.1576^{***}) but not for neighboring non-members (-0.0144, n.s.); (*H3*) labor misallocation declines for incumbents (-0.1428^{***}) yet is smaller and imprecise for 2013-entrants (-0.0905, n.s.). This result is consistent with slower labor adjustment; and (*H4*) industrial-structure advancement rises inside the boundary (members: +0.0046** and +0.0083**), with limited change for neighbors (+0.0035, n.s.).

Table 2. Mechanisms of the 2013 YRD expansion by cohort

	(1) Capital mismatch ($\|\tau_K\|$)	(2) Labor mismatch ($\|\tau_L\|$)	(3) Advancement
	Panel A. Overall agglomeration		
Exp	-0.0695***	-0.0844***	0.0061***
	(0.0166)	(0.0205)	(0.0012)
Controls, City FE, Year FE	Yes	Yes	Yes
Observations	728	728	728
R^2	0.6198	0.2334	0.9985
	Panel B. Incumbents		
Exp	-0.0459***	-0.1428***	0.0046**
	(0.0133)	(0.0304)	(0.0016)
Controls, City FE, Year FE	Yes	Yes	Yes
Observations	560	560	560
R^2	0.7035	0.1715	0.9988
	Panel C. 2013-entrants		
Exp	-0.1576***	-0.0905	0.0083**
	(0.0441)	(0.0519)	(0.0028)
Controls, City FE, Year FE	Yes	Yes	Yes
Observations	168	168	168
R^2	0.6460	0.6401	0.9987
	Panel D. Neighboring non-members		
Exp	-0.0144	0.0112	0.0035
	(0.0099)	(0.0343)	(0.0042)
Controls, City FE, Year FE	Yes	Yes	Yes
Observations	336	336	336
R^2	0.7932	0.3675	0.9934

Notes: Standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$. Negative coefficients for $|\tau_K|$ or $|\tau_L|$) indicate reductions in misallocation (improvements in allocation). All regressions include the full control set and city and year fixed effects. "n.s." = not statistically significant at conventional levels ($p \geq 0.10$).

5.1. Capital allocation channel

Consistent with (*H2*) (capital reallocation internal to the boundary), Table 2 shows sizable declines in capital misallocation for existing members (-0.0459^{***}) and 2013 new entrants (-0.1576^{***}), but not for neighboring non-members (-0.0144, n.s.). In parallel, industrial-structure advancement rises for members (Panels B-C) and is statistically indistinguishable from zero for neighbors (Panel D).

These patterns are consistent with enlargement reducing within-system coordination and finance frictions—through unified procedures, thicker buyer-supplier networks, and deeper regional credit—so that capital flows toward higher-MRPK uses and cities reweight toward more knowledge-intensive activities. The absence of comparable changes for neighbors indicates that these gains are largely internalised within the policy boundary.

For 2013 new entrants (Panel C), the combination of a sharp fall in capital misallocation (-0.1576^{***}) and a rise in advancement ($+0.0083^{**}$), alongside an imprecise labor-mismatch estimate (-0.0905, n.s.), points to an invest-first, workforce-later adjustment—exactly the timing we expect when financial and supply-chain integration adjust faster than local labor markets.

These results complement the cohort SCM gaps and event-time profiles (Sections 4.1-4.3) and are robust to random donor samples and permutation tests (Appendix E). The convex capital gradient in Table 1 (Section 4.4) further shows that reallocation gains are stronger where baseline capital scale and centrality are larger, in line with (*H5*).

5.2. Labor-market channel: **hukou***, housing, and training frictions*

China's *hukou* system conditions access to public services and parts of the formal labor market, affecting the speed and cost of settlement for migrants (Chan, 2010). These institutional frictions interact with domestic market segmentation across jurisdictions (Poncet, 2005) and with city-size constraints that limit the efficient reallocation of workers (Au and Henderson, 2006). This context helps rationalize the cohort patterns in Table 2. In incumbents (Panel B), deep labor markets and long-standing employer networks reduce search and matching frictions, so enlargement coincides with sizeable declines in labor misallocation alongside improvements in capital allocation and industrial upgrading. This aligns with (*H3*): thicker markets in incumbents speed matching and reduce labor wedges.

In contrast, 2013-entrants exhibit a slower labor response. Three frictions are particularly relevant: (i) *hukou*-mediated settlement costs (residence conversion, school access for migrant children, portability of social insurance) that raise fixed relocation costs (Chan, 2010); (ii) housing and rental costs (limited public rental housing, incomplete portability of the housing provident fund) that compress job-search radii and delay matches; and (iii) skills and training cycles (meeting higher requirements in advanced manufacturing, logistics, and producer services entails on-the-job training, certification lags, and firm-specific human capital). These processes operate over months to years, so industrial advancement can outpace labor re-sorting. The Panel C estimates—clear gains in advancement but an imprecise labor-mismatch effect—fit this timing. The absence of effects for neighboring non-members (Panel D) is also consistent: because eligibility for service access and most settlement pathways depend on administrative boundaries, benefits from enlargement are largely internalized within the policy area (Poncet, 2005). Consistent with (*H3*), labor reallocation among 2013-entrants is smaller and statistically imprecise in the short run; we do not expect systematic labor effects for neighboring non-members.

Mechanisms and identification—Reductions in capital ($|\tau_K|$) and labor misallocation ($|\tau_L|$) indicate tighter dispersion of marginal products within a city—consistent with lower within-city frictions, improved credit allocation, and better matching—while a higher advancement index reflects compositional upgrading toward more technology- and knowledge-intensive activities. Because Eqs. (3.1)-(3.2) include rich controls and TWFEs, and are estimated by cohort, the enlargement coefficient compares treated cities to their SCM-consistent counterfactual trajectories defined by the donor pool. Robustness to donor composition (placebo/permutation test) is shown in Appendix E.

6. Discussion and conclusion

The 2013 enlargement of the YRD megaregion raised aggregate performance within the system, but those gains were spatially uneven. Relative to city-specific synthetic controls, per-capita GDP growth increased most for incumbents (on average approximately 1.6 pp/year). For 2013 entrants the gains were modest and heterogeneous (approximately 0.5 pp/year), while for neighboring non-members the effect was weakly negative (approximately -0.4 pp/year). Pre-treatment gaps center near zero and permutation checks support a causal interpretation. These patterns are not merely differences in level: cohort-specific event-time paths show a discrete and persistent step-up for members after 2013 and, at most, transitory responses for neighbors, consistent with internalization at the policy boundary.

Read through the lens of New Economic Geography and quantitative spatial models (Fujita, Krugman, and Venables, 1999; Krugman, 1991; Redding and Rossi-Hansberg, 2017), the evidence aligns with a mega-region enlargement that relaxes coordination and finance wedges inside the boundary, amplifies advantages where scale and centrality are already high, and allows composition to adjust before labor. In that sense, our results are the institutional-governance counterpart to well-known transport quasi-experiments (Donaldson, 2018; Donaldson and Hornbeck, 2016; Faber, 2014; Redding and Sturm, 2008) and to the governance-integration steps highlighted earlier—regional coordination bodies, customs facilitation, and FTZ-led easing of transactions (see Section 3.1)—lowering transaction, compliance, and financing frictions raises aggregate output while tilting gains toward better-situated nodes. The key difference is that here the shock is not a new national link, but a formal widening and deepening of governance within a polycentric megaregion with pre-existing dense linkages.

These findings confirm the incidence pattern anticipated in H1: enlargement primarily reinforced incumbents' centrality rather than delivering uniform gains inside and outside the boundary. Two elements of the mechanism are aligned with H2-H4. First, capital misallocation declines for both member cohorts whilst industrial-structure advancement increases within the enlarged system and remains limited just outside the boundary. Second, labor reallocation is slower and asymmetric: labor misallocation declines for incumbents but is small and statistically imprecise for 2013 entrants in the short run, consistent with *hukou*, housing, and skills/training frictions that impede rapid mobility. Taken together, this sequencing (capital and composition ahead of labor) is precisely what the model predicts when mobility wedges are only weakly relieved by institutional integration.

Heterogeneity is systematic rather than idiosyncratic. A convex capital gradient—effects rising with baseline scale and centrality—supports H5 and is more "winner-takes-more" than "winner-takes-all." Moderation results also show attenuation where advancement is already high, suggesting limited headroom in service-intensive cities. These gradients are consistent with selection/sorting emphasized in the agglomeration empirics (Combes, Duranton, and Gobillon, 2011) and with polarization forces in classic regional theory (Friedmann, 1967; Myrdal, 1957). They also fit the Chinese institutional context: mobility and segmentation frictions (*e.g.*, Au and Henderson, 2006; Chan, 2010; Poncet, 2005) naturally delay labor re-sorting, so capital and composition margins move first.

Two potential threats merit discussion. First, interference and spatial spillovers. Cross-boundary spillovers could contaminate donors or attenuate neighbor effects. To address this, we confine donors to never-exposed, non-adjacent cities, implement permutation tests, and probe random-donor robustness; results are stable in direction and magnitude. The absence of gains for neighboring non-members suggests that most benefits were internalized through the policy boundary, although some leakage is inevitable. If anything, such leakage biases against strong internal effects. Second, measurement and construction validity. City GDP per capita and capital stocks inherit the usual limitations of local accounts and PIM-based reconstructions; output elasticities are estimated with an LSDV varying-coefficient panel and normalized to CRS. Our misallocation indices are reduced-form summaries of relative wedges rather than structural estimates of markups or taxes—informative about reallocation but not diagnostic about micro-sources. The cosine-angle advancement index is transparent and scale-invariant but abstracts from product complexity; it should be read as a three-sector reweighting measure rather than a fine-grained sophistication metric. These choices follow standard practice and are accompanied by extensive robustness checks.

While such threats cannot be fully eliminated in an observational policy setting, our design stacks the deck against spurious findings: long pre-trend matching, a restricted donor pool with explicit adjacency exclusions, pre-fit screens, permutation tests, and random-donor robustness all point in the same direction. Any residual interference is more likely to attenuate than inflate effects, so our estimates should be read as conservative.

The enlargement appears to have diminished coordination/finance frictions at the core and among newly admitted members; capital moved toward higher-MRPK uses; producer services and advanced manufacturing expanded; labor followed more slowly where settlement and skills constraints bind. This is a concrete instance of center-periphery reinforcement in an already integrated polycentric megaregion. It nuances a common narrative: institutional integration can lift aggregate output and productivity, but unless labor-market and peripheral-access frictions are addressed, the spatial distribution of those gains will remain skewed toward established hubs.

From a welfare perspective, output gains in the core may coincide with higher land rents, congestion, or distributional shifts that we do not observe. A fuller accounting would layer in price indices, housing costs, and commuting burdens at worker and household level. Event-time patterns suggest that short-run winners are capital-rich, central locations; equity-motivated policy should broaden access to those returns rather than suppressing the forces that generate them.

Policy implications follow directly. First, ease labor-market frictions that slow resorting: targeted *hukou* facilitation for qualified migrants; portability of social insurance and housing funds; affordable rental supply; and scaled TVET aligned with producer services and advanced manufacturing. Second, enhance peripheral connectivity and access to business services—logistics, finance (including supply-chain finance), data, IP, testing/certification—so boundary cities can integrate more tightly with core supply chains, expanding effective market access and counteracting centripetal forces. Third, where spillover risks are material, consider compensatory transfers (revenue- and tax-base sharing; project co-financing) or the strategic siting of tradable-service platforms (*e.g.*, bonded logistics hubs, financial service nodes) in boundary cities to internalize gains beyond the core. These measures preserve agglomeration economies while broadening the geography of gains.

External validity requires care. The YRD is large, mature, and institutionally coordinated; extrapolating to less integrated regions or greenfield corridors should proceed cautiously. That said, the mechanisms—internalized reductions in coordination/finance wedges, sequencing of capital/composition ahead of labor, and convex responses in scale and centrality—are not China-specific. The comparative evidence on European Union enlargements (*e.g.*, Badinger, 2005; Baldwin, Francois, and Portes, 2014; Camagni et al., 2020; Campos, Coricelli, and Moretti, 2019; Niebuhr, 2008; Rodríguez-Pose, Dijkstra, and Poelman, 2024) suggests similar mechanism-conditional predictions: where labor is highly mobile and redistributive capacity is strong (free movement, cohesion funds), diffusion to entrants and periphery is more likely; where mobility is constrained and fiscal transfers are limited, gains concentrate in incumbents. Our results thus speak to megaregion integration beyond China—from Greater Bay Area-type initiatives to polycentric corridors elsewhere.

Two empirical extensions are especially promising. *First, micro data and welfare mapping.* Firm- and worker-level data would allow tests of match quality, network formation, and adjustment costs, and would map reduced-form effects into welfare incidence (earnings, prices/rents, commuting burdens). *Second, model-linked counterfactuals.* Coupling our reduced-form estimates with a quantitative spatial model calibrated to the YRD would enable policy counterfactuals for alternative enlargement designs—for example, stronger peripheral producer-service platforms or deeper *hukou* reforms—and quantify trade-offs between aggregate efficiency and distributional equity.

In summary, the 2013 megaregion enlargement improved efficiency and accelerated structural upgrading within the YRD, with gains skewed toward core and capital-rich members, modest average improvements for new entrants, minimal persistent spillovers to neighbors, and labor adjustment lagging capital and composition. Institutional integration can lift aggregate performance; to make the geography of gains more inclusive, policy must tackle mobility frictions and expand peripheral access to the inputs that make upgrading profitable.

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Appendix A. Economic-geography model, hat algebra, and numerical illustration

There are locations (prefecture-level cities) $i \in \mathcal{I}$, sectors $s \in \mathcal{S} = \{\text{Primary}, \text{Manuf}, \text{Services}\}$,[3] and discrete time t. A subset $\mathcal{R} \subset \mathcal{I}$ forms an agglomeration region (YRD). The 2013 enlargement is a policy change ($\mathcal{R}_{2012} \to \mathcal{R}_{2013}$) that modifies internal trade/mobility/finance frictions for members. Households in i supply one unit of labor; L_i denotes residents (workers). Capital is owned by a national investor and allocated across (i, s) subject to city–sector user-cost wedges—location- and sector-specific distortions to the effective cost of using factors (e.g., χ^K_{is} and χ^L_{is}); hereafter we refer to these simply as user-cost wedges.

A.1. Preferences and price indices

Final demand in i is constant elasticity of substitution (CES) across sectors and, within each sector, CES across *origins*:

$$U_i = \left(\sum_{s \in \mathcal{S}} \omega_s^{\frac{1}{\eta}} C_{is}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}, \qquad C_{is} = \left(\sum_{j \in \mathcal{I}} X_{jis}^{\frac{\sigma_s-1}{\sigma_s}} \right)^{\frac{\sigma_s}{\sigma_s-1}}. \tag{A1}$$

The sectoral price index and composite price are

$$P_{is} = \left(\sum_{j \in \mathcal{I}} \left(p_{js}\, \tau^s_{ji} \right)^{1-\sigma_s} \right)^{\frac{1}{1-\sigma_s}}, \quad P_i = \left(\sum_s \omega_s\, P_{is}^{1-\eta} \right)^{\frac{1}{1-\eta}}. \tag{A2}$$

Notation and symbols: $i \in \mathcal{I}$ indexes destination cities and $j \in \mathcal{I}$ indexes origin cities; $s \in \mathcal{S}$ indexes sectors. $\tau^s_{ab} \geq 1$ denotes delivery from origin a to destination b; thus τ^s_{ji} in (A2) is delivery from j to i, while τ^s_{ij} in (A7) is delivery from i to j. U_i is the overall CES consumption/utility index in city i. C_{is} is the sector-s CES consumption composite in city i (aggregating across origins j). X_{jis} is consumption/expenditure on the sector-s variety sourced from origin j and consumed in i. P_{is} is the sector-s CES price index in city i (minimum cost of one unit of C_{is}) based on delivered prices $p_{js}\tau^s_{ji}$, where p_{js} is the producer price in origin j and $\tau^s_{ji} \geq 1$ is the iceberg trade cost from j to i in sector s. P_i is the overall cost-of-living index in city i (minimum cost of one unit of U_i). $\omega_s \geq 0$ are sector expenditure/taste weights (often normalized so $\sum_s \omega_s = 1$). $\eta > 1$ is the elasticity of substitution across sectors, and $\sigma_s > 1$ is the elasticity of substitution across origins within sector s. E_{js} (introduced below) denotes destination j's total expenditure on sector s. P_{iS} (introduced below) denotes the *producer-services* price index for i and is distinct from the Armington index for $s = \text{Services}$.

Clarification. P_{is} (lowercase s) is the final-demand Armington price for sector s in city i; P_{iS} (uppercase S) labels the producer-services input price index entering costs —distinct from the final-demand $s = \text{Services}$ index.

[3] For readability we keep the shorthand *Manuf* for Manufacturing.

A.2. Technology, producer services, and wedges

Each location-sector (i, s) produces a differentiated variety under monopolistic competition with markup $\mu_s = \frac{\sigma_s}{\sigma_s - 1}$ (Dixit and Stiglitz, 1977). Unit cost is

$$c_{is} \;=\; \frac{w_i^{1-\alpha_s-\xi_s}\,\left(r\,\chi_{is}^K\right)^{\alpha_s}\,\left(P_{iS}\right)^{\xi_s}}{A_{is}\,B_i^{\phi_s}}, \qquad \alpha_s \geq 0,\ \xi_s \geq 0,\ \alpha_s+\xi_s < 1,\ \phi_s \in [0,1), \tag{A3}$$

where w_i is the local wage, r the capital rental rate, and $\chi_{is}^K \geq 1$ a capital user-cost wedge. P_{iS} is the producer-services input price index (distinct from the consumer Armington index for $s =$ Services); A_{is} is Hicks-neutral productivity; B_i is a regionally internalized business-services externality with sector intensity ϕ_s.

We define the producer-services input price used in (A3) as a CES Armington index across origins:

$$P_{iS} = \left(\sum_{j\in\mathcal{I}} \left(p_{jS}\,\tau_{ji}^S\right)^{1-\sigma_S^{\mathrm{IO}}}\right)^{\frac{1}{1-\sigma_S^{\mathrm{IO}}}}, \qquad \sigma_S^{\mathrm{IO}} > 1,$$

which is conceptually distinct from the consumer Armington index for $s =$ Services. The parameter σ_S^{IO} is the elasticity of substitution across *origins* for producer services entering firms' costs and need not equal the final-demand elasticity for Services; for parsimony one may set $\sigma_S^{\mathrm{IO}} = \sigma_{\mathrm{Services}}$.

Under (A3), variable inputs exhibit effective constant returns, since

$$(1 - \alpha_s - \xi_s) \;+\; \alpha_s \;+\; \xi_s \;=\; 1,$$

while A_{is} and $B_i^{\phi_s}$ act as multiplicative efficiency shifters.

Labor frictions appear as a wage wedge $\chi_{is}^L \geq 1$. Let Y_{is} denote revenue (value of output) in (i, s) and K_{is}, L_{is} the capital and labor inputs. Cost minimization equates the marginal revenue products of capital and labor (MRPK, MRPL) to their effective factor prices:

$$\mathrm{MRPK}_{is} = \alpha_s\,\frac{Y_{is}}{K_{is}} \;=\; r\,\chi_{is}^K, \tag{A4}$$

$$\mathrm{MRPL}_{is} = (1 - \alpha_s - \xi_s)\,\frac{Y_{is}}{L_{is}} \;=\; w_i\,\chi_{is}^L. \tag{A5}$$

A.3. Producer-services externality and internalization

Let S_j denote the scale of producer services in origin j (*e.g.*, employment or value added in business services). City i's effective access to these services is

$$B_i \;=\; \left(\sum_{j\in\mathcal{I}} \varphi_{ij}\,S_j^{\theta}\right)^{1/\theta}, \qquad \theta \in (0,1), \tag{A6}$$

a CES/power-mean aggregator with access weights $\varphi_{ij} \geq 0$. The weights φ_{ij} capture how easily i can tap services in j (distance/frictions/institutional integration): they are *higher within the policy boundary* and *decay across it.* The curvature parameter θ governs how services from different origins combine; the implied elasticity of substitution across origins is $1/(1-\theta)$, so smaller θ means stronger complementarity (diminishing returns to piling services in a single j and a greater value to diversified access).

In applications, S_j is proportional to producer-services value added or employment in j. In the short run we hold S_j fixed; in the medium run we set $\hat{S}_j \approx \lambda_j^{\text{new}}/\lambda_j$ (or $\hat{S}_j \propto \hat{Y}_{j,\text{Services}}$), consistent with the update in (A14).

A.4. Pricing and gravity

With $p_{is} = \mu_s c_{is}$ and CES demand with iceberg trade costs, bilateral[4] expenditure follows a gravity system (Anderson and Van Wincoop, 2003; Head and Mayer, 2014):

$$X_{jis} \;=\; \frac{\left(p_{is}\,\tau_{ij}^{s}\right)^{1-\sigma_s}}{\sum_k \left(p_{ks}\,\tau_{kj}^{s}\right)^{1-\sigma_s}}\, E_{js} \;\equiv\; \pi_{jis}\, E_{js}, \tag{A7}$$

where π_{jis} is origin i's market share in destination j's sector-s expenditure, increasing in delivered-price competitiveness $(p_{is}\tau_{ij}^{s})^{-(\sigma_s-1)}$ and decreasing in bilateral costs τ_{ij}^{s}. The denominator equals $P_{js}^{1-\sigma_s}$, so $\pi_{jis} = (p_{is}\tau_{ij}^{s})^{1-\sigma_s}/P_{js}^{1-\sigma_s}$. Aggregate revenue is $Y_{is} = \sum_j X_{jis}$. Here E_{js} is destination j's total expenditure on sector s.

Destination j' s sector-s expenditure is $E_{js} = \tilde{\omega}_{js}\, E_j$, where $\tilde{\omega}_{js}$ denotes the (baseline) within-city sectoral expenditure share $\left(\sum_{s\in\mathcal{S}} \tilde{\omega}_{js} = 1\right)$ and $E_j = w_j L_j + r\sum_s K_{js}$ is total expenditure/income (profits rebated). In our short-run counterfactuals we hold L_j fixed and set $\hat{w}_j = \hat{r} = 1$, implying $\hat{E}_{js} = \hat{E}_j = 1$; given $\{\pi_{jis}\}$ and $\{\tilde{\omega}_{js}\}$, the gravity system then pins down $\{\hat{P}_{js}, \hat{P}_j\}$.

A.5. Mobility and policy

Capital reallocates quickly (via the user-cost wedge χ^K), whereas labor adjusts gradually due to *hukou*, housing, and training frictions. Let $\bar{L}$ denote total workers and a_i a fixed amenity/migration shifter for city i. Workers choose locations based on (indirect) utility $\ln w_i - \ln P_i + a_i$ plus idiosyncratic tastes; with i.i.d. Type-I extreme-value shocks and scale parameter $\kappa > 0$, the implied logit allocation of labor is

$$L_i \;=\; \frac{\exp\{\kappa\,[\ln w_i - \ln P_i + a_i]\}}{\sum_\ell \exp\{\kappa\,[\ln w_\ell - \ln P_\ell + a_\ell]\}}\,\bar{L}, \qquad \kappa > 0, \tag{A8}$$

so a larger κ means labor is more responsive to real-wage differences w_i/P_i (and $\kappa \to 0$ approaches immobility). In the short-run counterfactuals, we hold L_i fixed (effectively small κ); the medium-run update in Section A.9.2 applies Equation (A8).

The enlargement shifts primitives for $i, j \in \mathcal{R}_{2013}$:

$$\begin{aligned} &\tau_{ij}^{s}\downarrow \text{ (lower internal trade costs)}, \quad \varphi_{ij}\uparrow \text{ (greater within-boundary service access)},\\ &\chi_{is}^{K}\downarrow \text{ (easier capital finance)}, \quad \chi_{is}^{L}\downarrow \text{ (weakly; hiring/mobility frictions ease)}. \end{aligned} \tag{A9}$$

[4]We use "bilateral" to mean origin – destination (city – pair) relationships within the YRD. We also say "internal" for pairs with both cities in $\mathcal{R}$ and "cross-boundary" for pairs that span $\mathcal{R}$ and its neighbors.

These changes improve delivered price competitiveness and raise B_i, increasing members' real wages w_i/P_i and, with finite κ, gradually rebalancing L_i toward better-situated cities.

Lower internal τ and higher within-boundary φ_{ij} jointly reduce P_{iS} and raise B_i, tilting costs toward knowledge-intensive sectors when $\xi_s > 0$ and $\phi_s > 0$; this underpins the upgrading patterns highlighted below.

A.6. Equilibrium and hat algebra

An equilibrium is $\{w_i, P_{is}, P_i, L_i, K_{is}, Y_{is}, p_{is}, \pi_{jis}\}_{i,j,s}$ satisfying Equations (A2)–(A7), factor demands with wedges in Equation (A5), market clearing for goods and factors, pricing, and (if activated) migration in Equation (A8). Profits are rebated to households.

For counterfactuals, we use exact hat algebra relative to a base year (2012). Let $\hat{x}$ denote the ratio of a variable in the counterfactual to its base value. Using base import shares π_{jis} and expenditure shares, sectoral price hats obey:

$$\hat{P}_{js}^{1-\sigma_s} = \sum_i \pi_{jis} \left(\hat{p}_{is}\, \hat{\tau}_{ij}^{s}\right)^{1-\sigma_s}, \qquad \hat{p}_{is} = \hat{w}_i^{1-\alpha_s-\xi_s} \left(\hat{r}\, \hat{\chi}_{is}^{K}\right)^{\alpha_s} \hat{P}_{iS}^{\xi_s}\, \hat{B}_i^{-\phi_s}\, \hat{A}_{is}^{-1}. \quad \text{(A10)}$$

Given $\hat{\tau}, \hat{\chi}^K, \hat{B}, \hat{A}$ from the policy in (A9), (A10) pins down $\hat{P}_{js}, \hat{p}_{is}$; then $\hat{Y}_{is}$ and real wages $\hat{w}_i/\hat{P}_i$ follow from demands and market clearing. Medium-run labor re-sorting uses (A8). *Implementation note:* For the short run we set $\hat{w}_i = \hat{r} = \hat{A}_{is} = 1$; we repeat this convention in the numerical subsection for clarity.

A.7. Link to empirical indices and outcomes

A.7.1. GDP per capita (SCM outcome)

Model real income in city i is $\mathcal{Y}_i = w_i L_i + r \sum_s K_{is}$ (profits rebated). Per-capita GDP growth gaps versus the synthetic are matched by $\Delta \ln(\mathcal{Y}_i/P_i)$ implied by Equation (A10) and, if used, Equation (A8).

A.7.2. Misallocation indices

From Equation (A5), dispersion in marginal products across i is driven by wedges:

$$\mathrm{MRPK}_{is} = r\, \chi_{is}^{K}, \qquad \mathrm{MRPL}_{is} = w_i\, \chi_{is}^{L}.$$

The Hsieh–Klenow-style city misallocation indices map to

$$\tau_i^K \propto \mathrm{Disp}\left(\{\chi_{is}^K\}_s\right), \qquad \tau_i^L \propto \mathrm{Disp}\left(\{\chi_{is}^L\}_s\right),$$

where $\mathrm{Disp}(\cdot)$ denotes a dispersion operator (*e.g.*, variance or interquartile range; see main text for the exact choice). Thus $\chi^K \downarrow$ inside $\mathcal{R}$ reduces $|\tau^K|$, and (slower) $\chi^L \downarrow$ reduces $|\tau^L|$ more clearly in incumbents.

A.7.3. Industrial advancement

Let sectoral expenditure shares in i be x_{i1}, x_{i2}, x_{i3} implied by equilibrium prices/incomes. Our geometric advancement index (Section 3.3.2) is a deterministic transform of $\boldsymbol{x}_i$; in the model, $\boldsymbol{x}_i$ shifts with $\hat{B}_i^{\phi_s}$ and $\hat{P}_{iS}^{-\xi_s}$, which tilt demand and costs toward knowledge-intensive sectors, raising advancement for members.

A.8. Comparative-statics propositions

Define market access $\mathsf{MA}_{is} \equiv \sum_j E_{js}\,(\tau_{ij}^s P_{js}^{-1})^{1-\sigma_s}$, which parallels the market-access concept in Redding and Venables (2004). Then:

Proposition A.1 (Incumbent advantage and "Winner-Takes-More")**.** *Suppose (i)* $\phi_{Manuf}, \phi_{Services} > 0$*, (ii)* φ_{ij} *rises primarily for pairs* $i, j \in \mathcal{R}$*, and (iii) internal* τ_{ij}^s *falls sufficiently. Then* $\Delta \ln(\mathcal{Y}_i/P_i)$ *is increasing and locally convex in pre-2013* $\mathsf{MA}_{i,Manuf}$ *and baseline* B_i*. Larger/more central* incumbents *capture disproportionately larger gains than entrants or neighbors.*

Proposition A.2 (Sequencing: capital, composition, then labor)**.** *Under fast capital reallocation (a* χ^K *relief) and slow labor mobility (finite* κ*), the short-run response to* (A9) *features: (i)* $\Delta|\tau_i^K| < 0$ *for members; (ii) industrial advancement rises for members; (iii)* $\Delta|\tau_i^L| < 0$ *is stronger in incumbents than entrants; (iv) spillovers to neighbors are limited if* $\Delta\varphi_{ij} \approx 0$ *across the boundary.*

Proposition A.1 maps directly to (*H1*) and (*H5*): it predicts that enlargement shifts average gains toward incumbents (incidence) and that effects rise convexly with baseline scale/centrality (heterogeneity). Proposition A.2 underpins (*H2*) − (*H4*) by implying within-boundary capital reallocation and structural upgrading that precede—and exceed—labor re-sorting, with limited spillovers to neighbors.

A.8.1. Sketch proofs

Prop. A.1. With CES and iceberg trade,

$$\frac{\partial P_{is}}{\partial \tau_{ji}^s} = P_{is}^{\sigma_s} \frac{\left(p_{js}\tau_{ji}^s\right)^{1-\sigma_s}}{\tau_{ji}^s}, \qquad \frac{\partial \ln P_{is}}{\partial \ln \tau_{ji}^s} = \frac{\tau_{ji}^s}{P_{is}} \frac{\partial P_{is}}{\partial \tau_{ji}^s} = \underbrace{\frac{\left(p_{js}\tau_{ji}^s\right)^{1-\sigma_s}}{\sum_k \left(p_{ks}\tau_{ki}^s\right)^{1-\sigma_s}}}_{\omega_{jis}} > 0.$$

so the elasticity of the sector-s price index in i with respect to the bilateral cost from origin j is exactly i's import share from j. Hence changes in internal costs for core origins (large ω_{jis}) move P_{is} more. With $\phi_s > 0$ and an internal $\Delta\varphi_{ij}$, the induced $\Delta \ln B_i$ is a concave aggregator of S_j with higher weights on central j, magnifying incumbent gains; convexity follows from the CES index composed with $B_i(\cdot)$.
Prop. A.2. From Equation (A5), a fall in χ^K equalizes MRPK quickly; labor MRPL equalization is delayed by Equation (A8). Upgrading follows from $\phi_s > 0, \xi_s > 0$ and lower internal τ shifting costs/demand toward knowledge-intensive sectors; boundary internalization limits neighbor effects.

A.9. Numerical illustration

A.9.1. Hat algebra and empirical objects (short run)

For counterfactuals relative to 2012, let $\hat{x} \equiv x'/x$. With base import shares π_{jis} and within-city sector weights $\tilde{\omega}_{js}$, the short-run fixed point (holding L_i fixed; as noted above, we set $\hat{w}_i = \hat{r} = \hat{A}_{is} = 1$) is:

$$\text{(i) } \hat{p}_{is} = \hat{w}_i^{\,1-\alpha_s-\xi_s} (\hat{r}\, \hat{\chi}_{is}^{K})^{\alpha_s}\, \hat{P}_{iS}^{\xi_s}\, \hat{B}_i^{-\phi_s}\, \hat{A}_{is}^{-1},$$

$$\text{(ii) } \hat{P}_{js}^{1-\sigma_s} = \sum_i \pi_{jis}\, (\hat{p}_{is}\, \hat{\tau}_{ij}^{s})^{1-\sigma_s}, \qquad \text{(iii) } \hat{P}_j^{1-\eta} = \sum_s \tilde{\omega}_{js}\, \hat{P}_{js}^{1-\eta}. \tag{A11}$$

With L_i fixed and $\hat{w}_i = \hat{r} = 1$, we also hold nominal city income $\mathcal{Y}_i = w_i L_i + r \sum_s K_{is}$ at its base level (no short-run reallocation of the city' s capital income); hence changes in real income reduce to $\Delta \ln(\mathcal{Y}_i/P_i) = -\ln \hat{P}_i$.

Relation to (A10)*:* Equations (A11)(i) – (iii) restate the equilibrium hat system in (A10) in a form convenient for computation.

A.9.1.1. Optional share update. If post-shock import shares are needed,

$$\pi'_{jis} = \frac{\pi_{jis}\, (\hat{p}_{is} \hat{\tau}_{ij}^{s})^{1-\sigma_s}}{\sum_k \pi_{kjs}\, (\hat{p}_{ks} \hat{\tau}_{kj}^{s})^{1-\sigma_s}}. \tag{A12}$$

A.9.2. Optional medium-run migration and B_i update

Let baseline population shares $\lambda_i = L_i / \sum_\ell L_\ell$. With logit elasticity $\kappa > 0$ and fixed amenities a_i,

$$\lambda_i^{\text{new}} = \frac{\lambda_i (\hat{w}_i/\hat{P}_i)^\kappa}{\sum_\ell \lambda_\ell (\hat{w}_\ell/\hat{P}_\ell)^\kappa}. \tag{A13}$$

If $B_i = \big(\sum_j \varphi_{ij} S_j^\theta\big)^{1/\theta}$ with $S_j \propto L_j$ (or services employment), feed back

$$\hat{B}_i = \left(\frac{\sum_j \varphi_{ij} S_j^\theta\, \hat{S}_j^\theta}{\sum_j \varphi_{ij} S_j^\theta} \right)^{1/\theta}, \qquad \hat{S}_j \;\approx\; \frac{\lambda_j^{\text{new}}}{\lambda_j}. \tag{A14}$$

Re-solve the short-run system with updated $\hat{B}_i$.

A.9.3. Numerical implementation (summary)

A.9.3.1. Purpose. Compute short-run counterfactual "hat" variables from (A11) and (optionally) a medium-run update with migration and B_i feedback. This is *not* a calibration and is conceptually distinct from the annual growth gaps (pp/yr) identified by SCM; it is used to interpret mechanisms (incumbent advantage; internalized upgrading; limited spillovers).

A.9.3.2. Inputs/outputs. As in Sections A.9.1 and A.9.2: base Armington shares π_{jis}, within-city sector weights $\tilde{\omega}_{js}$, elasticities (σ_s, η), cost shares $(\alpha_s, \xi_s, \phi_s)$, and policy hats $(\hat{\tau}^s_{ij}, \hat{\chi}^K_{is}, \hat{B}_i)$; defaults set $\hat{A}_{is} = \hat{w}_i = \hat{r} = 1$. Outputs are $\{\hat{p}_{is}, \hat{P}_{js}, \hat{P}_j\}$ and short-run real-income changes $-\ln \hat{P}_j$; the medium-run wrapper also returns updated $\hat{B}_i$ and population shares λ^{new}.

A.9.3.3. Algorithm. Initialize all hats at 1 and iterate (A11)(i)→(ii)→(iii) with level damping until $\max|\Delta| < 10^{-8}$. For the optional medium run, update $\lambda^{\text{new}} \propto (\hat{w}_j/\hat{P}_j)^{\kappa}$ via (A13), map services scale to $\hat{S}_j \approx \lambda^{\text{new}}_j/\lambda_j$, refresh $\hat{B}_i$ via (A14), and re-solve the short-run system until both prices and λ converge.

A.9.3.4. Implementation in R. A compact solver mirrors these steps: a short-run function computes $(\hat{p}, \hat{P}_{js}, \hat{P}_j)$ given $(\pi, \tilde{\omega}, \hat{\tau}, \hat{\chi}^K, \hat{B})$, and a wrapper adds the migration/B_i loop. Tolerances and damping are user-set. The complete R script is available from the authors upon request.

Appendix B. Synthetic control: identification, estimation, and inference

B.1. Setup and notation

Let cities be indexed by $i = 1, \ldots, J+1$ and years by $t = 1, \ldots, T$. The enlargement occurs at $T_0 < T$. For city i, let Y^l_{it} denote the realized outcome and Y^c_{it} the counterfactual outcome in the absence of enlargement. The (city-, time-specific) treatment effect is

$$\text{TE}_{it} = Y^l_{it} - Y^c_{it}, t > T_0.$$

We estimate TE_{1t} one treated city at a time, re-indexing the treated city to $i = 1$ and forming a donor pool of controls $i = 2, \ldots, J+1$ that are never exposed in 2004-2017 (neither incumbents nor 2013-entrants nor immediate neighbors).

Following Abadie, Diamond, and Hainmueller (2010), potential outcomes satisfy a factor model in the pretreatment period:

$$Y^c_{it} = \delta_t + \theta_t^{\top} Z_i + \gamma_t^{\top} \mu_i + \varepsilon_{it}, \tag{B1}$$

where δ_t is a common time effect, Z_i are observed predictors, μ_i are unobserved factors with time varying loadings γ_t, and ε_{it} are mean-zero errors.

B.2. Estimator

Let $W = (w_2, \ldots, w_{J+1})^{\top}$ be non-negative weights summing to one. Without loss of generality, we consider city 1, its synthetic control is the convex combination of donors:

$$\widehat{Y}^C_{1t} = \sum_{j=2}^{J+1} w_j Y_{jt}, \quad t \leq T_0, \tag{B2}$$

with weights chosen to match pre-treatment predictors and outcomes. Stack the treated city's predictors and pre-treatment outcomes into X_1, and the corresponding donor matrices into X_0. For a positive semi-definite weighting matrix V (chosen by nested optimization to minimize the pre-treatment prediction error), the weights solve

$$\min_{W} (X_1 - X_0 W)^\top V (X_1 - X_0 W) \quad \text{s.t. } w_j \geq 0, \quad \sum_{j=2}^{J+1} w_j = 1. \tag{B3}$$

Given $\widehat{W}$, the post-treatment counterfactual and effect are

$$\widehat{Y}_{1t}^c = \sum_{j=2}^{J+1} \widehat{w}_j Y_{jt}, \quad \widehat{\mathrm{TE}}_{1t} = Y_{1t} - \widehat{Y}_{1t}^c, \quad t > T_0. \tag{B4}$$

Under Eq. (B1), if the pre-period T_0 is sufficiently long and $X_0\widehat{W} \approx X_1$, Abadie, Diamond, and Hainmueller (2010) show

$$Y_{1t}^c - \sum_{j=2}^{J+1} \widehat{w}_j Y_{jt} = o_p(1) \quad \text{for } t \leq T_0, \tag{B5}$$

so the post-treatment gap Eq. (B4) is an approximately unbiased estimator of TE_{1t}.

B.3. Diagnostics and exclusion rule

Pre-treatment fit is summarized by Pre-RMSPE:

$$\text{Pre-RMSPE} = \sqrt{\frac{1}{T_0} \sum_{t=1}^{T_0} \left(Y_{1t} - \sum_{j=2}^{J+1} \widehat{w}_j Y_{jt} \right)^2}. \tag{B6}$$

Consistent with Abadie, Diamond, and Hainmueller (2010), treated units with poor pre-fit are excluded from causal interpretation.

B.4. Why not use Difference-in-Differences?

We do not rely on DID for identification. Our choice is performance-driven: in our data, the SCM delivers a markedly better pre-2013 fit than DID (Figure B1). For incumbents there is no clean untreated pre-period—2013 represents an intensification of exposure—so DID's parallel-trends requirement is ill-defined. With few treated units and pronounced cross-city heterogeneity, DID averages can also conceal large, offsetting unit-level responses.

SCM instead constructs, for each treated city, a data-driven convex combination of never-exposed donors that closely matches long pre-2013 outcome paths and predictors, thereby relaxing parallel trends in favor of demonstrated pre-fit and making selection transparent via weights and diagnostics (Abadie, Diamond, and Hainmueller, 2010; Abadie and Gardeazabal, 2003). SCM preserves unit-level heterogeneity and supports placebo-in-space permutation inference; units with weak pre-fit are disclosed and excluded from causal interpretation (Appendix B.3).

Substantively, the YRD expansion exhibits a "Winner-Takes-More" pattern: larger/-central cities capture disproportionate gains, while smaller/peripheral cities benefit less or not at all. A traditional DID targets an average treatment effect and would therefore obscure this distribution of responses. By constructing a synthetic control for each treated city, we retain—and make explicit—the heterogeneity of impacts. Figure B1 summarizes the superior pre-period fit of SCM relative to DID in our setting.

We do not rely on DID for identification. Our choice is performance-driven: in our data, the SCM delivers a markedly better pre-2013 fit than DID (Figure B1). For incumbents there is no clean untreated pre-period—2013 represents an intensification of exposure—so DID's parallel-trends requirement is ill-defined. With few treated units and pronounced cross-city heterogeneity, DID averages can also conceal large, offsetting unit-level responses.

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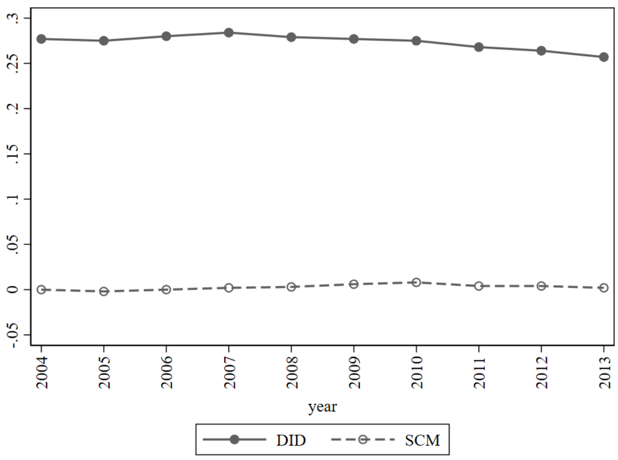


Figure B1. Pre-treatment goodness-of-fit (through 2012): DID vs. SCM

Appendix C. Data, Variable Definitions, and Descriptive Statistics

This appendix documents the construction of the city-year panel and the variables used in the analysis. Table C1 defines each variable, reports the transformation applied. Nominal GDP, industrial structure, population density, fixed asset investment, FDI, employment, retail sales, public expenditure and transport infrastructure are taken from successive editions of the *China City Statistical Yearbook* (CCSY); patent counts are from *China National Research Data Service Platform* (CNRDS). Fixed-asset investment is deflated with provincial fixed-asset investment price indices owing to the absence of city-level series. The outcome is the log of real GDP per capita. The predictor set used in the synthetic-control design comprises industrial structure, population density, investment and openness measures, innovation, labor force participation, market activity, fiscal expenditure and road area per capita.

Table C1. Variables, label and calculation

Category	Variable	Label	Calculation
Predictors	Economic development	Eco	Logarithm of real GDP per capita
	Industrial structure	Second	The proportion of secondary industry
		Third	The proportion of the tertiary industry
	Population density	Population	Number of people per square kilometer
	Fixed capital formation	Investment	Fixed Asset Investment/GDP
	Innovation	Innovation	The number of patent grants
Controls	Openness of the economy	Open	FDI/GDP
	Labor force participation rate	Labor	Unit employed population/total population
	Market activities	Market	Total retail consumption/GDP
	Government spending	Government	General Public Budget Expenditure/GDP
	Transport infrastructure	Road	Logarithm of urban road area per capita

Table C2 summarises the full sample (2004-2017). Table C3 reports pre-expansion characteristics by cohort—overall agglomeration, original members, 2013-entrants and neighboring non-members—to make clear the baseline differences that motivate separate estimation. We begin the series in 2004 to balance data availability with institutional stability; administrative boundary change are flagged, and affected units are retained for transparency but subjected to the pre-fit screen described in Appendix B.3. Missing single-year observations are interpolated only where this is innocuous for levels; no trend-break corrections are imposed. The choice of 2013 as the treatment year reflects both policy salience and empirical tractability: it delivers long pre-treatment trajectories to identify donor weights and a clean post-2013 evaluation window ($2014-2017$) before the national reinforcement of YRD integration in $2018-2019$.

Table C2. Descriptive statistics, full sample (2004-2017)

Variable	Mean	SD	Minimum	Maximum
Eco	10.17	0.79	7.96	12.19
Second	50.82	8.32	23.97	82.28
Third	36.71	7.81	13.59	69.84
Population	6.23	0.58	4.75	7.74
Investment	66.72	23.30	22.38	146.88
Innovation	7.00	1.72	2.40	11.42
Open	2.59	2.06	0.10	14.53
Labor	12.00	8.84	2.61	66.21
Market	36.13	8.38	5.31	62.10
Government	13.00	5.41	4.27	37.85
Road	2.38	0.51	0.52	3.61
Observations	1,386	1,386	1,386	1,386

Note: SD = standard deviation.

Table C3. Descriptive statistics by cohort

Variable	Overall agglomeration		Original members		2013 entrants		Neighboring non-members	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Eco	10.64	0.71	10.84	0.63	9.95	0.51	9.63	0.68
Second	50.10	6.00	50.86	6.30	47.56	3.93	45.01	7.89
Third	41.99	7.20	42.80	7.30	39.31	6.18	37.01	5.08
Population	6.43	0.49	6.51	0.42	6.17	0.60	6.06	0.68
Investment	59.83	17.58	56.68	14.53	70.34	22.27	71.36	27.12
Innovation	8.36	1.64	8.64	1.54	7.45	1.64	6.30	1.42
Open	3.37	2.38	3.76	2.38	2.07	1.86	2.18	1.62
Labor	15.71	10.16	18.17	10.26	7.51	3.05	6.29	2.80
Market	35.97	6.98	35.45	6.42	37.70	8.42	38.93	8.08
Government	11.90	4.62	10.95	3.96	15.04	5.26	16.04	6.87
Road	2.56	0.42	2.57	0.42	2.49	0.44	2.17	0.57
Observations	364	364	280	280	84	84	210	210

Appendix D. SCM construction, weights, and pre-treatment fit

D.1. Donor selection and predictors

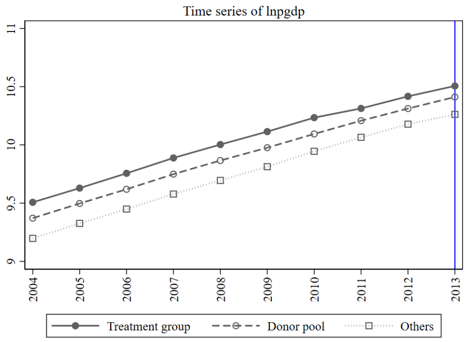
Table D1 lists the YRD sample by cohort—incumbents (pre-2013), cities admitted in 2013, and neighboring non-members just outside the boundary—used, respectively, for core, entrant, and spillover analyses.

Table D1. Lists of treatment cities (incumbents and 2013-entrants) and neighboring non-members

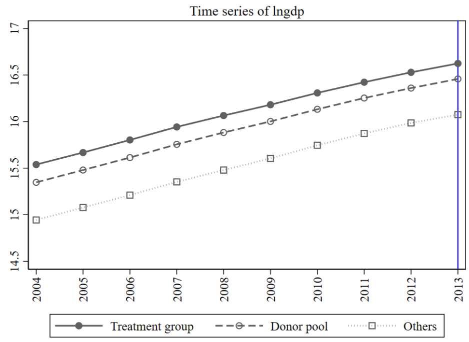
Incumbents	2013-entrants	Neighboring non-members
Shanghai	Xuzhou	Rizhao
Wuxi	Suqian	Linyi
Suzhou (苏州)	Lianyungang	Zaozhuang
Yangzhou	Lishui	Jining
Nanjing	Wenzhou	Heze
Nantong	Wuhu	Suzhou (宿州)
Taizhou (泰州)	Chuzhou	Bengbu
Changzhou	Huainan	Bozhou
Zhenjiang		Fuyang
Hangzhou		Lu'an
Shaoxing		Tongling
Huzhou		Chizhou
Jiaxing		Xuancheng
Ningbo		Huangshan
Zhoushan		Shangrao
Taizhou (台州)		Nanping
Yancheng		Ningde
Huaian		Anqing
Jinhua		
Quzhou		
Hefei		
Ma'anshan		

Note: The lists shown are broader than the final analytic samples; some cities are later excluded: (i) Hefei and Ma'anshan (incumbents): major administrative boundary changes; (ii) Wuhu and Huainan (2013 entrants): similar boundary changes; (iii) Lu'an, Tongling, and Anqing (neighboring non-members): boundary changes; (iv) Heze, Bozhou, and Fuyang: synthetic controls collapsed to a single donor (100% weight) and/or high pre-treatment RMSPE. City names follow official English spellings; Chinese characters are provided when two cities share the same pinyin but have different official spellings.

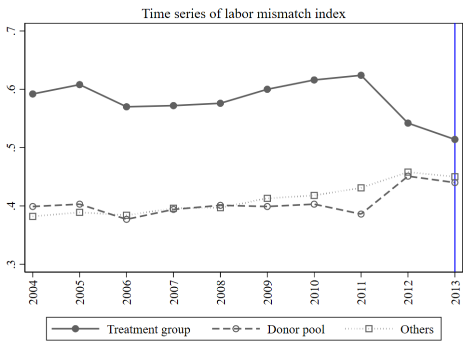
The donor pool consists of cities from the provinces where the YRD megaregion is located and geographically adjacent provinces, excluding those in the treatment group, based on the following considerations. First, these cities are not members or neighboring cities of the YRD after the 2013 expansion, so they are not exposed to the intervention—consistent with standard synthetic control guidance to restrict the donor pool to untreated units without anticipatory or spillover exposure (Abadie, Diamond, and Hainmueller, 2010, 2015). Second, guided by the distance-decay of economic interactions, cities at moderate geographic distance tend to share stronger market linkages and more comparable pre-trends than far-away units (Fujita, Krugman, and Venables, 1999; Krugman, 1996). Figure D1 provides empirical support for this choice. Before 2013, cities in the donor pool track the treatment group much more closely than the nationwide “others” (all mainland Chinese cities outside the treatment group and the donor pool) across both outcomes and mechanisms. In particular, in panels (i)-(ii) (log real GDP per capita and log GDP), the donor pool and treatment group have nearly parallel pre-trends.



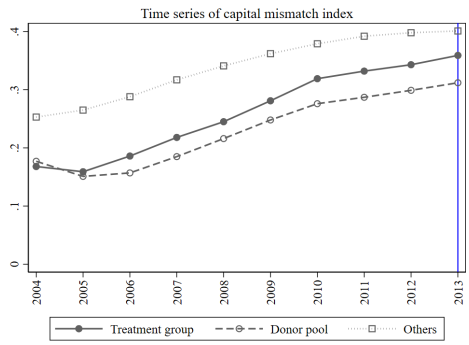
(i) Mean of logarithm of GDP per capita



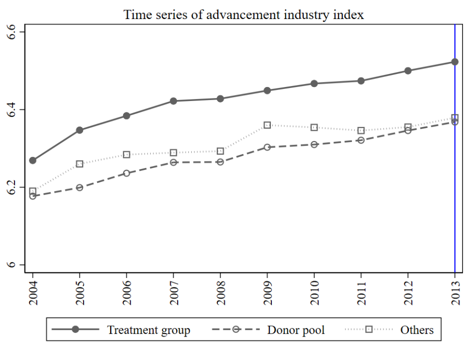
(ii) Mean of logarithm of GDP



(iii) Mean of labor mismatch index



(iv) Mean of capital mismatch index



(v) Mean of advancement industry index

Figure D1. Comparison between treatment group, donor pool, and other cities in mainland China

Table D2 lists the donor pool of prefecture-level cities (2004-2017) used to construct synthetic controls.

Table D2. Donor Pool (2004-2017): Prefecture-level Cities

Cities				
Sanming	Sanmenxia	Dongying	Jiujiang	Xinyang
Shiyan	Nanchang	Nanyang	Xiamen	Ji'an
Zhoukou	Xianning	Shangqiu	Weihai	Xiaogan
Anyang	Yichang	Yichun (宜春)	Pingdingshan	Kaifeng
Dezhou	Fuzhou (抚州)	Xinxiang	Xinyu	Jingdezhen
Wuhan	Quanzhou	Tai'an	Luoyang	Jinan
Zibo	Huaibei	Binzhou	Luohe	Zhangzhou
Weifang	Puyang	Yantai	Jiaozuo	Fuzhou (福州)
Liaocheng	Jingzhou	Jingmen	Putian	Laiwu
Pingxiang	Xuchang	Ganzhou	Zhengzhou	Ezhou
Suizhou	Qingdao	Zhumadian	Hebi	Yingtan
Huanggang	Huangshi	Longyan		

Figures D2-D4 display the optimal positive weights used to construct the synthetic controls for incumbents, 2013-entrants, and neighboring non-members, respectively. In each case, the donor weights are chosen to best replicate pre-2013 trajectories, providing the synthetic counterparts for post-treatment comparisons and spillover evaluation. For clarity, each pie chart reports only the six donor cities with the largest positive weights.

Figure D2. Composition of the synthetic cities for incumbents

Figure D3. Composition of the synthetic cities for 2013-entrants

Figure D4. Composition of the synthetic cities for neighboring non-members

D.2. Pre-RMSPE table

This appendix reports Pre-RMSPE for each treated city. Following Appendix D4, units with poor pre-fit are reported for transparency but excluded from causal interpretation.

Table D3. Pre-treatment fit diagnostics (Pre-RMSPE)

Panel A. Original YRD members

City	Pre-RMSPE	City	Pre-RMSPE
Shanghai	0.018	Nanjing	0.001
Suzhou (苏州)	0.065	Wuxi	0.007
Changzhou	0.018	Nantong	0.011
Yangzhou	0.010	Zhenjiang	0.002
Taizhou (泰州)	0.010	Hangzhou	0.005
Ningbo	0.013	Zhoushan	0.015
Shaoxing	0.002	Huzhou	0.010
Jiaxing	0.012	Taizhou (台州)	0.010
Yancheng	0.010	Huaian	0.003
Jinhua	0.002	Quzhou	0.010

Summary: N=20, median = 0.010, p25 = 0.003, p75 = 0.012.

Panel B. 2013-entrants

City	Pre-RMSPE	City	Pre-RMSPE
Xuzhou	0.021	Suqian	0.005
Lianyungang	0.001	Lishui	0.001
Wenzhou	0.014	Chuzhou	0.011

Summary: N=6, median = 0.008, p25 = 0.001, p75 = 0.014.

Panel C. Neighboring non-members

City	Pre-RMSPE	City	Pre-RMSPE
Rizhao	0.013	Linyi	0.011
Zaozhuang	0.010	Jining	0.009
Heze†	0.059	Suzhou (宿州)	0.033
Bengbu	0.010	Bozhou†	0.152
Fuyang†	0.495	Xuancheng	0.004
Huangshan	0.009	Shangrao	0.030
Nanping	0.001	Ningde	0.002
Chizhou	0.018		

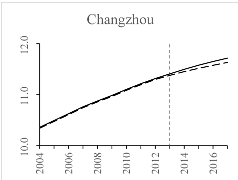
Summary (excl. †): N=12, median = 0.010, p25 = 0.004, p75 = 0.013.

Notes: Pre-RMSPE is computed from the pre-2013 fit of each treated city's synthetic control. Wuhu and Huainan (2013 entrants), Hefei and Ma'anshan (incumbents), and Lu'an, Tongling, and Anqing (neighboring non-members) are omitted owing to administrative boundary changes. Bozhou, Fuyang, and Heze exhibit poor pre-treatment fit because their synthetic controls collapse to a single donor (100% weight). These cities are flagged with † and are reported for transparency but excluded from causal interpretation.

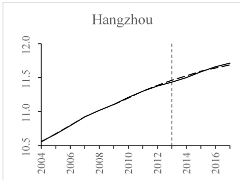
D.3. City-by-city synthetic control plots

This appendix plots unit-level time series used in our synthetic-control analysis. For each treated city, we show the realized path (solid) and its synthetic counterfactual (dashed) over the 2004-2017 time-frame; the 2013 enlargement is marked by a vertical dashed line. The outcome is log GDP per capita, so vertical gaps approximate percentage differences. Figures D5, D6, and D7 report results for the incumbents, the 2013 entrants, and the neighboring non-members, respectively.

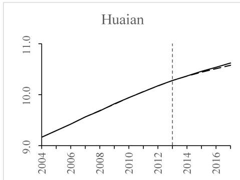
Hereafter, we exclude cities with major administrative boundary changes and those with poor pre-treatment fit; the corresponding plots are available from the authors upon request. See Appendix B.3 for the pre-treatment fit rule and additional diagnostics.



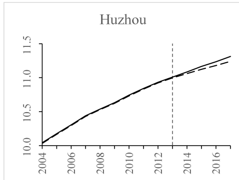
(i) Changzhou



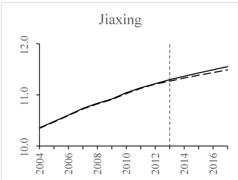
(ii) Hangzhou



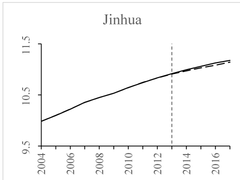
(iii) Huaian



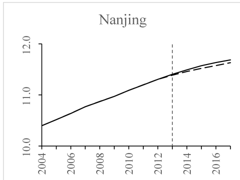
(iv) Huzhou



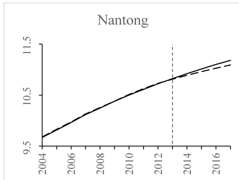
(v) Jiaxing



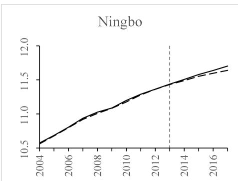
(vi) Jinhua



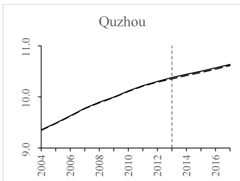
(vii) Nanjing



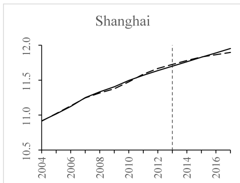
(viii) Nantong



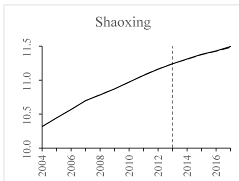
(ix) Ningbo



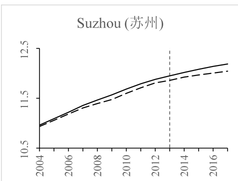
(x) Quzhou



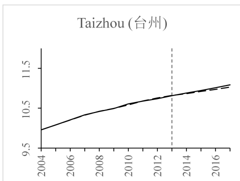
(xi) Shanghai



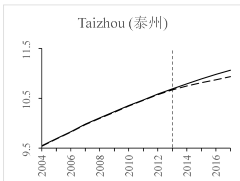
(xii) Shaoxing



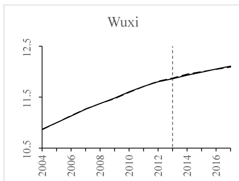
(xiii) Suzhou (苏州)



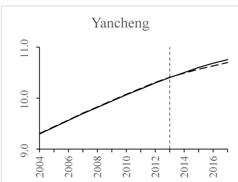
(xiv) Taizhou (台州)



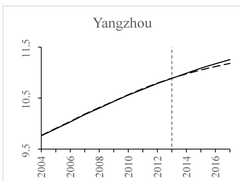
(xv) Taizhou (泰州)



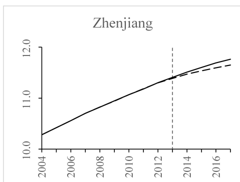
(xvi) Wuxi



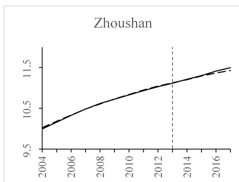
(xvii) Yancheng



(xviii) Yangzhou

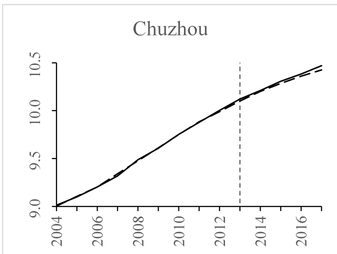


(xix) Zhenjiang

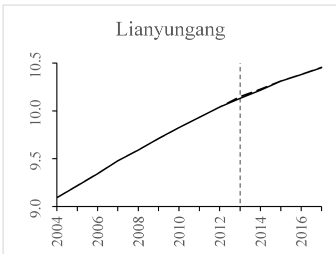


(xx) Zhoushan

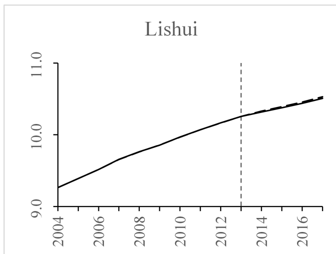
Figure D5. Incumbents: actual (solid) and synthetic (dashed) log GDP per capita, 2004-2017. The vertical line marks 2013.



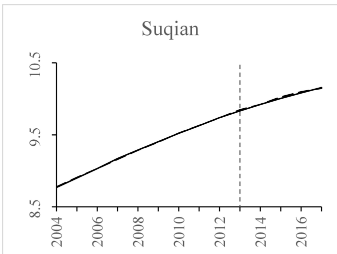
(i) Chuzhou



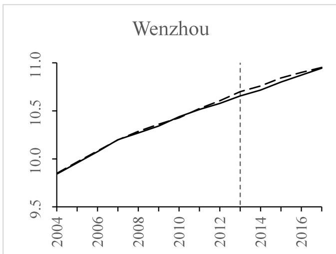
(ii) Lianyungang



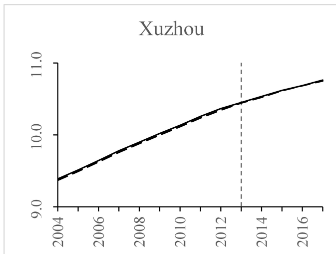
(iii) Lishui



(iv) Suqian

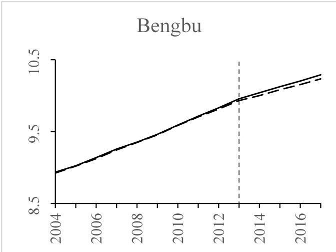


(v) Wenzhou

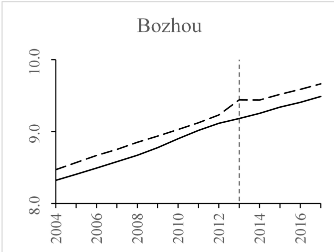


(vi) Xuzhou

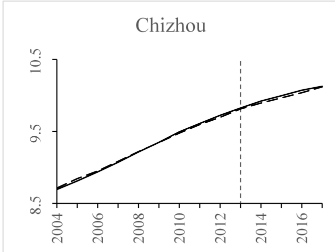
Figure D6. 2013-entrants: actual (solid) and synthetic (dashed) log GDP per capita, 2004-2017. The vertical line marks 2013.



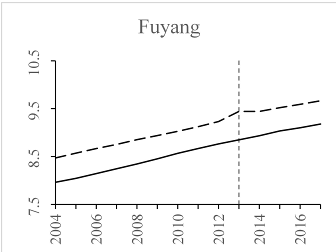
(i) Bengbu



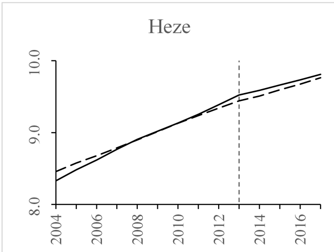
(ii) Bozhou



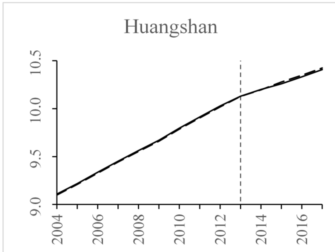
(iii) Chizhou



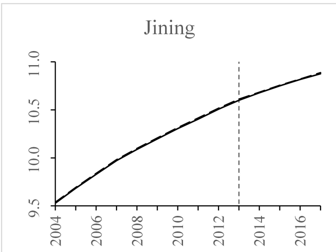
(iv) Fuyang



(v) Heze



(vi) Huangshan



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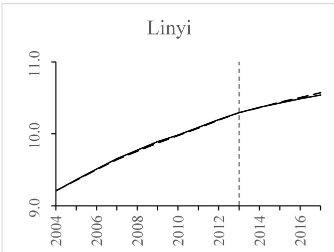
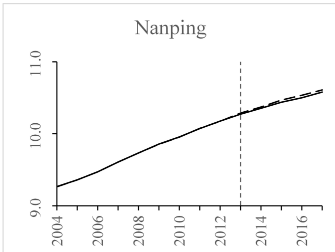
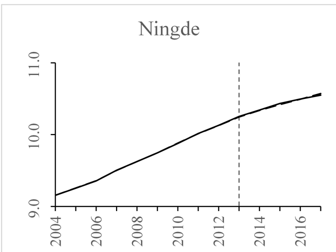


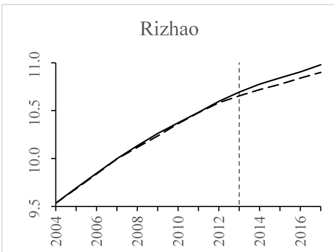
(viii) Linyi



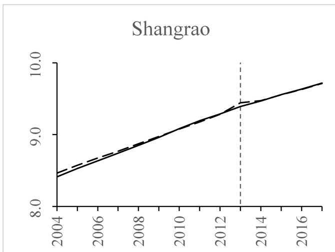
(ix) Nanping



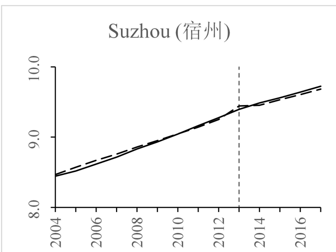
(x) Ningde



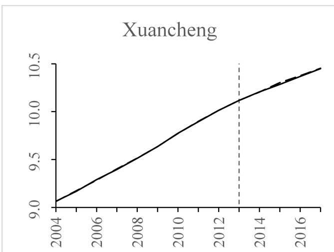
(xi) Rizhao



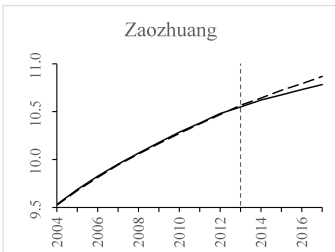
(xii) Shangrao



(xiii) Suzhou (宿州)



(xiv) Xuancheng



(xv) Zaozhuang

Figure D7. Neighboring non-members: actual (solid) and synthetic (dashed) log GDP per capita, 2004-2017. The vertical line marks 2013.

D.4. City-by-city growth-rate effects (synthetic control)

This appendix reports the city-level synthetic-control estimates of post-expansion growth-rate effects. For each treated city i, we compute the mean annual difference between the observed and synthetic log GDP per capita growth over 2014-2017:

$$\overline{\mathrm{TE}}_i^g = \frac{1}{4} \sum_{t=2014}^{2017} \left[\Delta \ln Y_{it} - \Delta \ln \widehat{Y}_{it}^c \right] \times 100,$$

expressed in percentage points per year. Positive values indicate faster growth than the synthetic counterfactual. Cities failing the pre-fit criterion in Appendix B.3 are flagged and not used for causal interpretation.

Table D4. City-by-city post-2013 growth-rate effects (percentage point (pp)/year)

Panel A. Original YRD members

City	Δ growth (pp)	**City**	Δ growth (pp)
Shanghai	2.604	Zhoushan	2.204
Nanjing	0.738	Shaoxing	0.335
Suzhou (苏州)	1.773	Huzhou	1.660
Wuxi	1.344	Jiaxing	1.085
Changzhou	1.403	Taizhou (台州)	1.390
Nantong	2.115	Yancheng	1.628
Yangzhou	2.204	Huaian	1.493
Zhenjiang	2.670	Jinhua	0.527
Taizhou (泰州)	3.119	Quzhou	-0.041
Hangzhou	1.828		
Ningbo	1.715		

Summary: mean=1.590; p25=1.279; median=1.644; p75=2.137.

Panel B. 2013-entrants

City	Δ growth (pp)	**City**	Δ growth (pp)
Xuzhou	0.028	Wenzhou	1.191
Suqian	0.413	Chuzhou	1.231
Lianyungang	0.318		
Lishui	-0.247		

Summary: mean=0.489; p25=0.101; median=0.366; p75=0.997.

Panel C. Neighboring non-members

City	Δ growth (pp)	**City**	Δ growth (pp)
Rizhao	0.796	Chizhou	-0.783
Linyi	-1.334	Xuancheng	-0.184
Zaozhuang	-2.290	Huangshan	-0.793
Jining	-0.148	Shangrao	0.446
Heze †	-1.040	Nanping	-0.417
Suzhou (宿州)	0.302	Ningde	-0.829
Bengbu	0.574		
Bozhou†	0.342		
Fuyang†	0.740		

Summary (excl. †): mean=−0.388; p25=−0.802; median=−0.301; p75=0.338.

Notes: Values are averages over 2014-2017 of the annual difference between observed and synthetic growth in GDP per capita. †denotes High pre-RMSPE; excluded from causal inference per Appendix B.3.

Appendix E. Sensitivity analysis

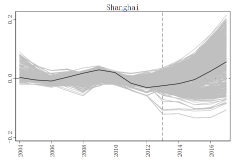
E.1. Random donor samples

Spillovers from the YRD enlargement could bias synthetic controls via contaminated donors. Following Campos, Coricelli, and Moretti (2019), we enlarge the donor pool to all mainland prefectures established before 2004, excluding YRD members and their neighbors. From this pool we repeatedly (1,000 times) draw 58 cities—the size of the original donor set—rebuild each synthetic control (predictors fixed), and re-estimate effects. For comparability we keep only replications with pre-treatment fit no worse than twice the benchmark Pre-RMSPE.

In Figure E1, the light-gray curves show the resampled trajectories from these re-estimations, while the black curve plots the benchmark estimate. Two facts stand out: (i) the post-2013 direction of the treatment effect is preserved across essentially all donor-pool variants; and (ii) the benchmark path lies well inside the resampled envelope—it does not hug the edges-so it is not an extreme draw driven by a handful of donors. Hence, our baseline results are robust to donor-pool composition and to potential spillover contamination.

E.2. Permutation test

Following Abadie, Diamond, and Hainmueller (2010), we apply the SCM to each city in the donor pool. As above, only replications with Pre-RMSPE within twice that of the benchmark are retained. Figures E2-E4 present city-level permutation tests of the SCM estimates: the black curve is the benchmark treatment effect, while the light-gray curves trace the estimated paths from repeated donor-pool permutations. The baseline effect is substantially larger than those obtained from permutation tests, indicating that the observed treatment effect for YRD cities cannot be attributed to chance but rather reflects the true impact of agglomeration expansion.



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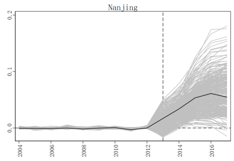
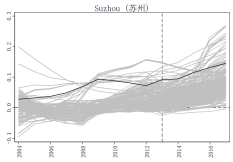
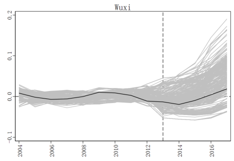


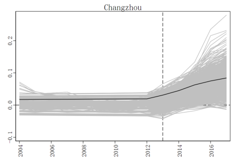
(ii) Nanjing



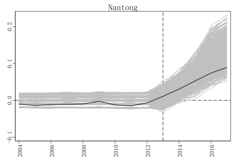
(iii) Suzhou (苏州)



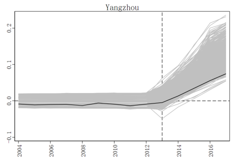
(iv) Wuxi



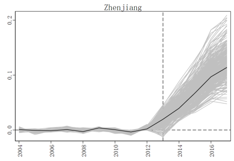
(v) Changzhou



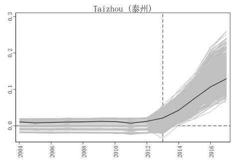
(vi) Nantong



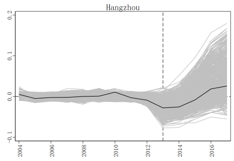
(vii) Yangzhou



(viii) Zhenjiang



(ix) Taizhou (泰州)



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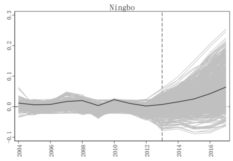

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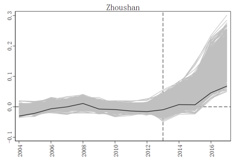
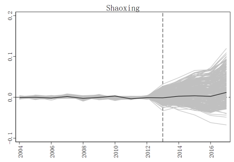


(xii) Zhoushan



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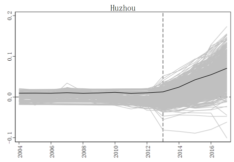
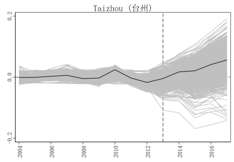
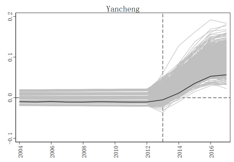


(xiv) Huzhou

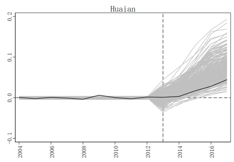
(xv) Jiaxing



(xvi) Taizhou (台州)



(xvii) Yancheng



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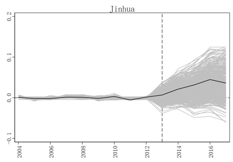

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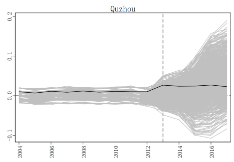

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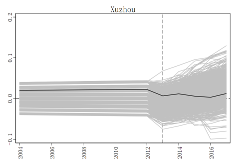

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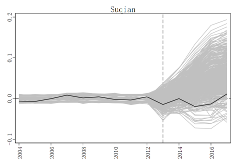
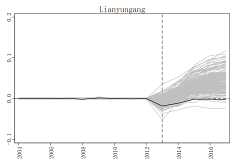


(xxii) Suqian



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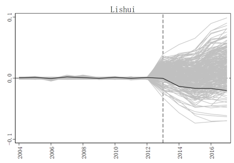
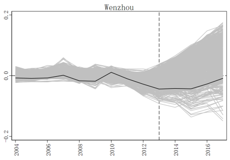
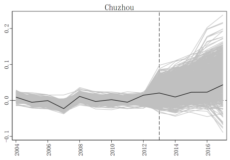


(xxiv) Lishui

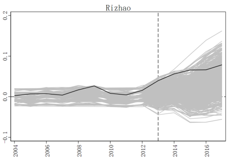
Figure E1. Random donor sample by city (continued)



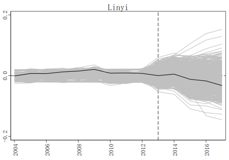
(xxv) Wenzhou



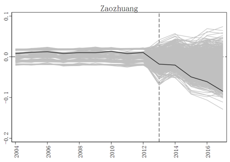
(xxvi) Chuzhou



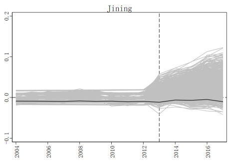
(xxvii) Rizhao



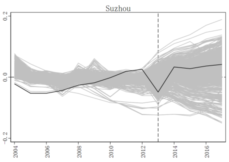
(xxviii) Linyi



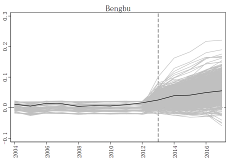
(xxix) Zaozhuang



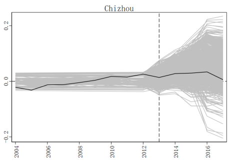
(xxx) Jining



(xxxi) Suzhou (宿州)



(xxxii) Bengbu



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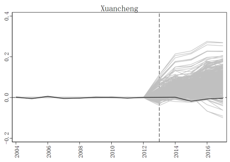
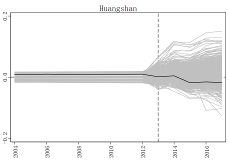
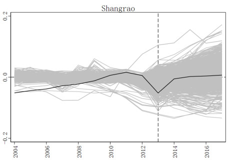


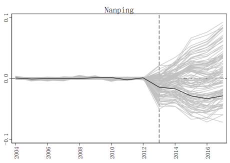
(xxxiv) Xuancheng



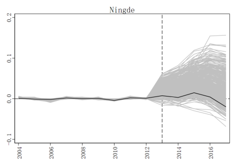
(xxxv) Huangshan



(xxxvi) Shangrao

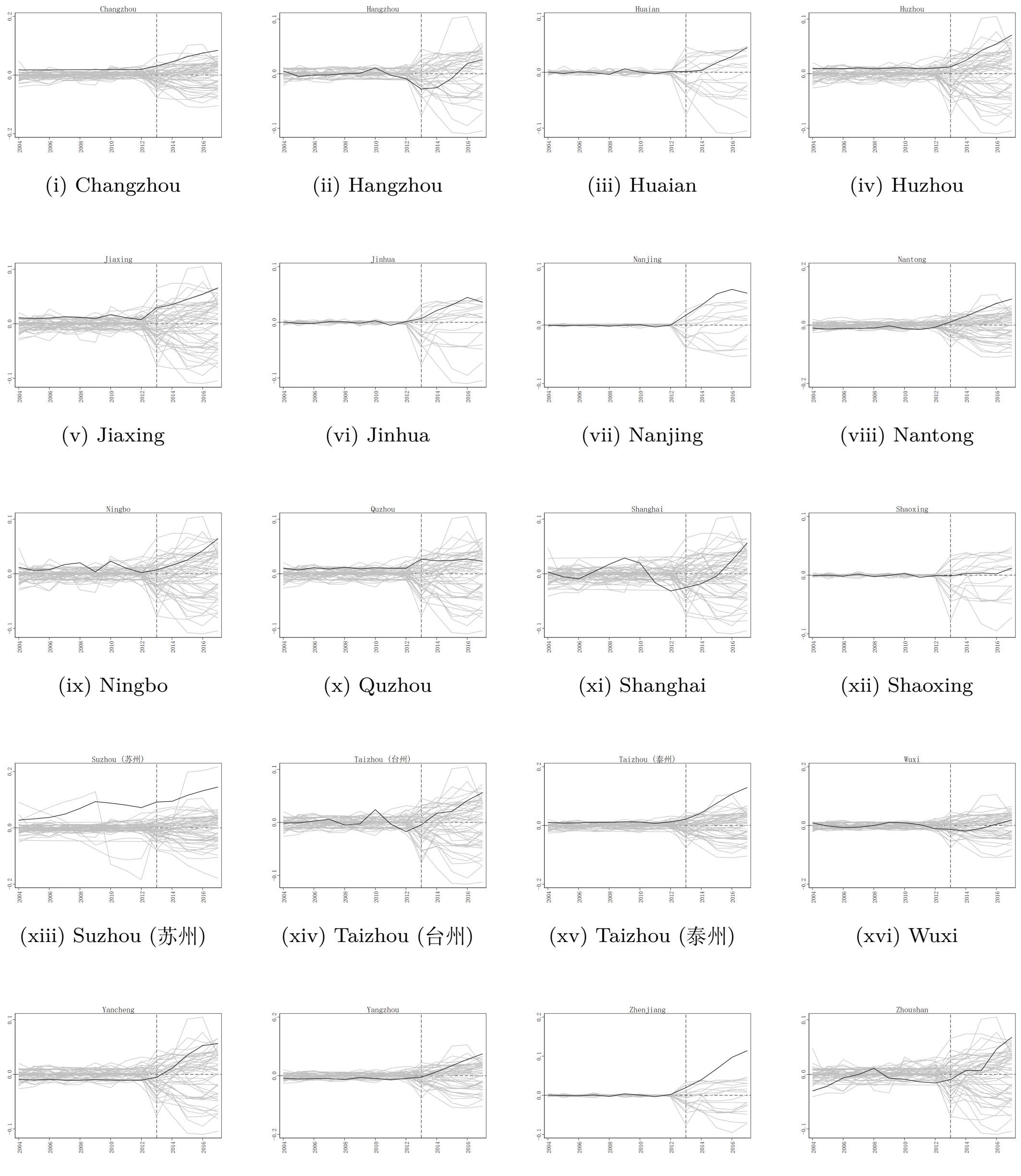


(xxxvii) Nanping



(xxxviii) Ningde

Figure E1. Random donor sample by city (continued)



(i) Changzhou (ii) Hangzhou (iii) Huaian (iv) Huzhou

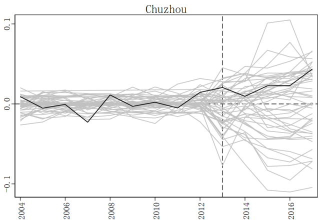
(v) Jiaxing (vi) Jinhua (vii) Nanjing (viii) Nantong

(ix) Ningbo (x) Quzhou (xi) Shanghai (xii) Shaoxing

(xiii) Suzhou (苏州) (xiv) Taizhou (台州) (xv) Taizhou (泰州) (xvi) Wuxi

(xvii) Yancheng (xviii) Yangzhou (xix) Zhenjiang (xx) Zhoushan

Figure E2. Permutation test (incumbents).



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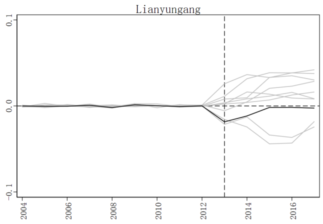

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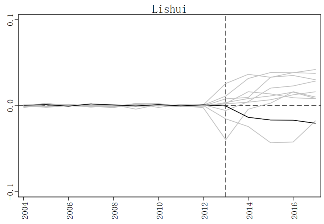
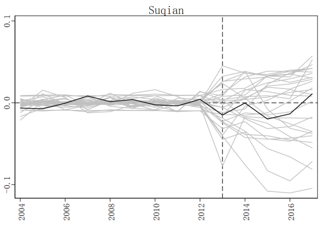


(iii) Lishui



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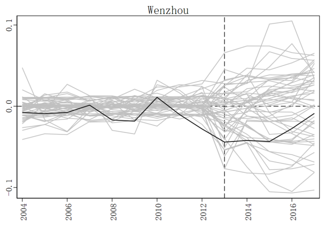
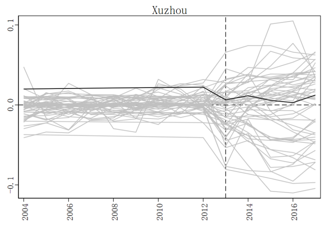
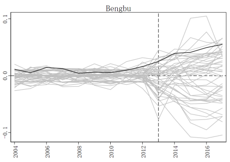


(v) Wenzhou

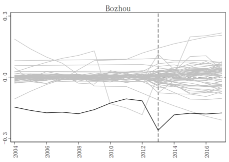


(vi) Xuzhou

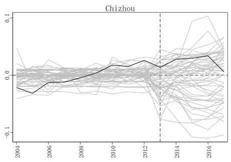
Figure E3. Permutation test (2013-entrants).



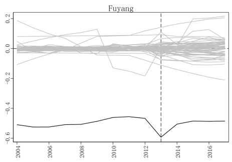
(i) Bengbu



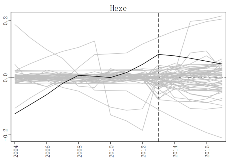
(ii) Bozhou



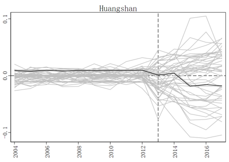
(iii) Chizhou



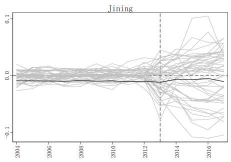
(iv) Fuyang



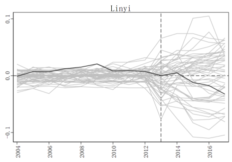
(v) Heze



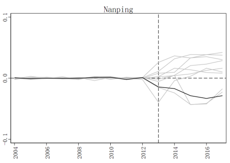
(vi) Huangshan



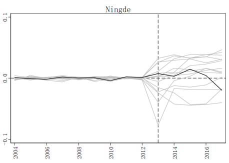
(vii) Jining



(viii) Linyi



(ix) Nanping



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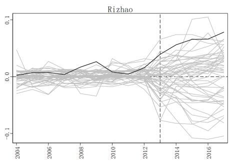
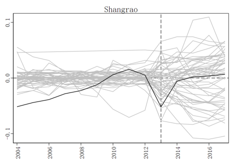
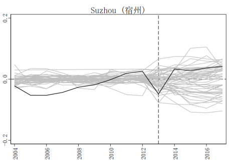


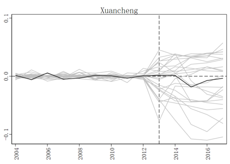
(xi) Rizhao



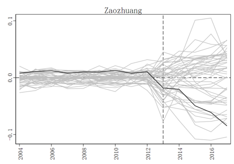
(xii) Shangrao



(xiii) Suzhou (宿州)



(xiv) Xuancheng



(xv) Zaozhuang

Figure E4. Permutation test (neighboring non-members).

Appendix F. Resource (mis)allocation: data construction, and elasticity estimation

F.1. Data construction

F.1.1. Output (Y_i)

The outcome is real GDP per capita at the prefecture level. We first obtain prefecture-level nominal GDP per capita from the CCSY and then deflate it using prefecture-level GDP deflators from the CNRDS to obtain a real series. Output shares $\delta_i \equiv \frac{P_i Y_i}{\sum_\ell P_\ell Y_\ell}$ are computed using real (deflated) GDP.

F.1.2. Capital (K_i)

City-level fixed capital stocks are built by the PIM:

$$K_{i,t} = I_{i,t}^{\text{real}} + \left(1 - \delta^K\right) K_{i,t-1}, \quad \delta^K = 0.1096 \quad \text{(Shan, 2008)}.$$

We adopt the PIM parameters from Shan (2008), who reconstructs national and provincial capital stocks (1952-2006) with an internally consistent PIM—re-estimating the initial stock, investment deflators, and depreciation using National Bureau of Statistics (NBS) post-economic-census revisions—and derives a benchmark geometric-depreciation rate of 0.1096. To our knowledge, Shan (2008) is the most recent publicly available, PIM-consistent rebuild of China's capital stock series; because it extends reasonably close to 2013—the policy-shock year—and newer (city-level) estimates are unavailable, we adopt this calibration as our baseline.

Real investment, I_{it}^{real}, is measured as fixed-asset investment from the CCSY, deflated by the provincial fixed-asset investment price index from the CNRDS, as no city-level index is available.

The initial stock is

$$K_{i,2004} = \frac{I_{i,2004}^{\text{real}}}{g_i + \delta^K},$$

where g_i is the average real investment growth over 2004-2006.

F.1.3. Labor (L_i)

We measure labor by the number of on-post employed persons in each city from the CCSY.

F.1.4. Prices and elasticities

The price treatment used for δ_i is as noted above; elasticities α_i and the aggregate α are constructed in Appendix F.2.

F.2. Estimating output elasticities: an LSDV varying-coefficient panel with CRS normalization

To allow factor elasticities to differ across locations, we estimate a least-squares dummy-variable (LSDV) varying-coefficient panel on the levels specification of the Cobb-Douglas production function:

$$\ln Y_{it} = \sum_i \alpha_i (D_i \times \ln K_{it}) + \sum_i \beta_i (D_i \times \ln L_{it}) + \sum_i \mu_i D_i + \sum_t \lambda_t D_t + \varepsilon_{it},$$

where i indexes cities (or provinces) and t years; D_i and D_t denote location and year dummies; Y_{it} is real GDP, K_{it} the real capital stock (PIM), and L_{it} employment. Standard errors are clustered at the location level. This regression yields one capital elasticity $\hat{\alpha}_i$ and one labor elasticity $\hat{\beta}_i$ per location.

Because sampling noise can push $\hat{\alpha}_i$ and $\hat{\beta}_i$ away from constant returns, we impose CRS by normalization (a projection onto the CRS simplex):

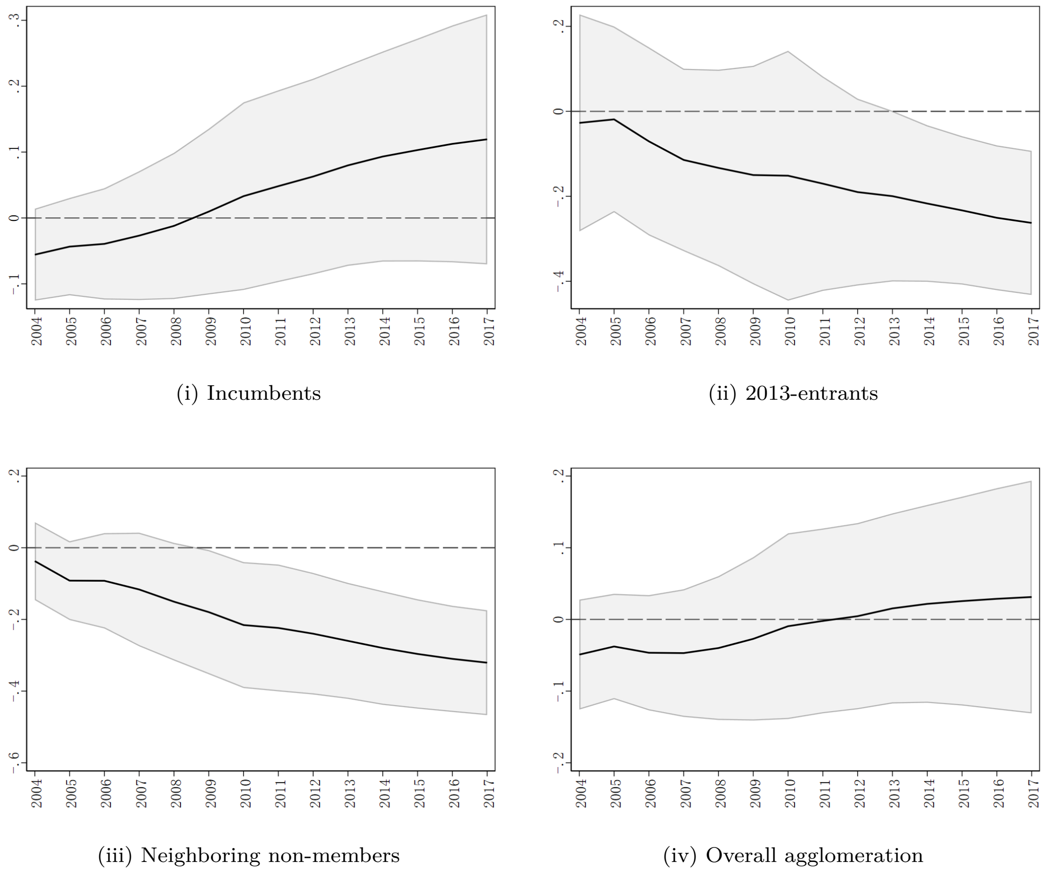
$$\tilde{\alpha}_i \;=\; \frac{\max\{0, \hat{\alpha}_i\}}{\max\{0, \hat{\alpha}_i\} + \max\{0, \hat{\beta}_i\}}, \quad \tilde{\beta}_i \;=\; 1 - \tilde{\alpha}_i.$$

If $\max\{0, \hat{\alpha}_i\} + \max\{0, \hat{\beta}_i\} = 0$ (a rare corner case), we set $(\tilde{\alpha}_i, \tilde{\beta}_i) = (0.5, 0.5)$. All subsequent calculations use the normalized elasticities $(\tilde{\alpha}_i, \tilde{\beta}_i)$, ensuring $\tilde{\alpha}_i, \tilde{\beta}_i \in [0, 1]$ and $\tilde{\alpha}_i + \tilde{\beta}_i = 1$ for every i.

For aggregate summaries we report the output-share-weighted capital elasticity $\alpha = \sum_i \delta_i \, \tilde{\alpha}_i$, where $\delta_i \equiv \frac{P_i Y_i}{\sum_\ell P_\ell Y_\ell}$ is the (real) output share. Results are robust to using the per-worker single-coefficient specification; we prefer the two-factor LSDV with CRS normalization because it lets both capital and labor elasticities vary by location while enforcing constant returns in a transparent way.

Appendix G. Visual summary of post-2013 effects and mechanisms (τ-indices)

This appendix assembles cohort-level panel time series for the capital-misallocation index (τ_K), labor-misallocation index (τ_L), and the industrial-structure advancement index.



(i) Incumbents

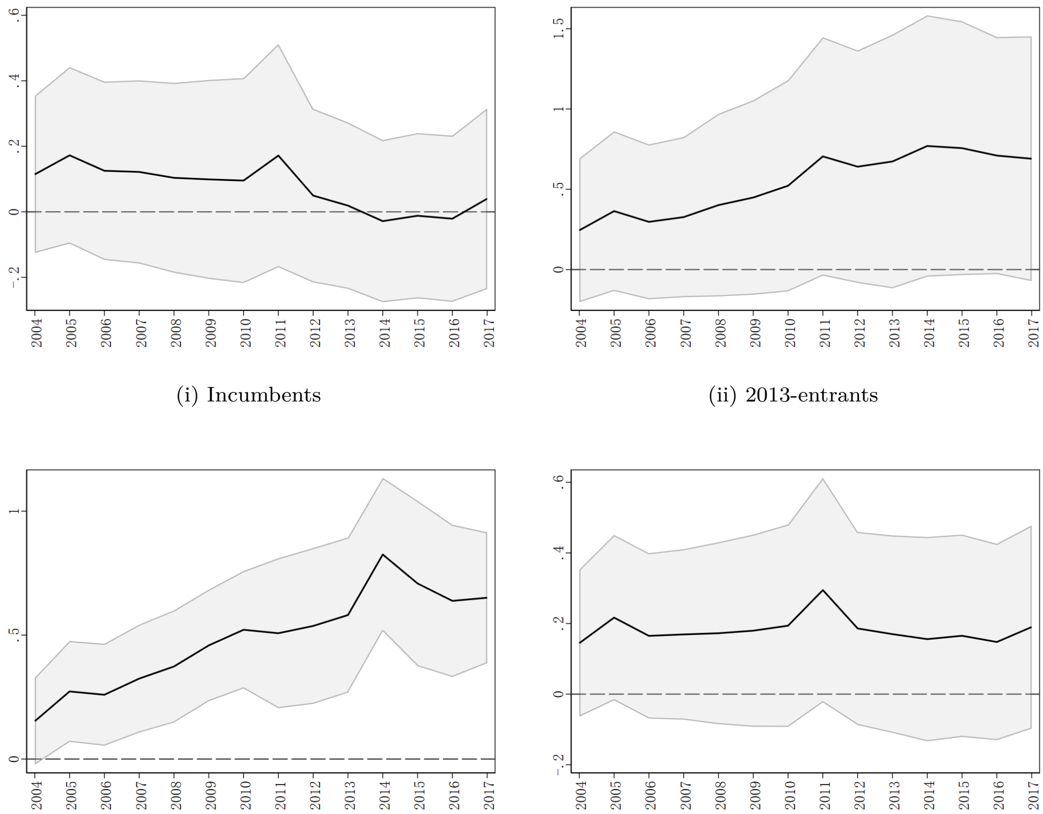
(ii) 2013-entrants

(iii) Neighboring non-members

(iv) Overall agglomeration

Figure G1. Capital-misallocation index (τ_K) panels.

Notes: Shaded regions denote ± 2 s.e. around the cohort mean (approx. 95% confidence bands), computed from cross-sectional dispersion across cities within each cohort and year.



(i) Incumbents

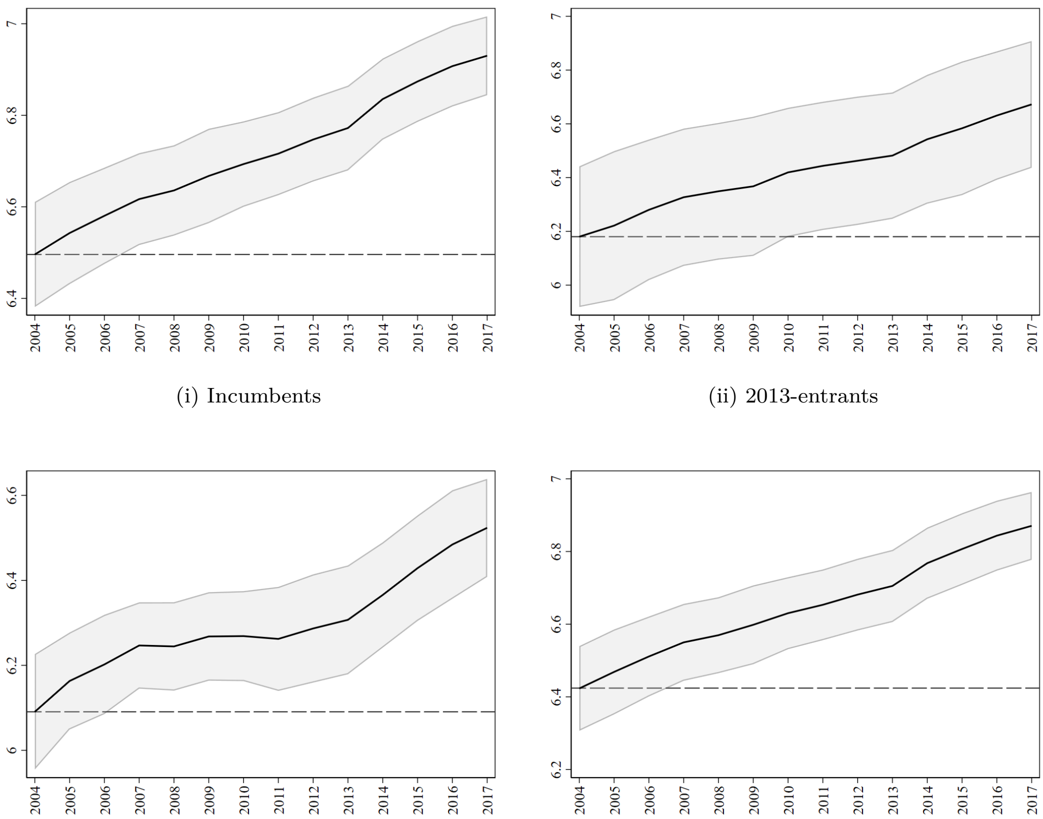
(ii) 2013-entrants

(iii) Neighboring non-members

(iv) Overall agglomeration

Figure G2. Labor-misallocation index (τ_L) panels.

Notes: Shaded regions denote ±2 s.e. around the cohort mean (approx. 95% confidence bands), computed from cross-sectional dispersion across cities within each cohort and year.



(i) Incumbents

(ii) 2013-entrants

(iii) Neighboring non-members

(iv) Overall agglomeration

Figure G3. Industrial-structure advancement index panels.

Notes: Shaded regions denote ±2 s.e. around the cohort mean (approx. 95% confidence bands), computed from cross-sectional dispersion across cities within each cohort and year.

Appendix H. Additional heterogeneity results (moderation)

We use moderation to identify who benefits more from enlargement. With baseline size as the moderator, a positive (and convex) Exp $\times$ Size gradient constitutes "Winner-Takes-More": larger cities capture larger gains. Moderation by misallocation or industrial advancement instead captures friction-mitigation or headroom effects, which complement but are conceptually distinct from the "Winner-Takes-More" pattern.

H.1. Specification

By construction, $\tau_K = 0$ and $\tau_L = 0$ denote efficient allocation; departures from zero indicate misallocation (the sign distinguishing under- vs. over-utilization). To capture the magnitude of misallocation, we use moderators $M_i \in \{|\tau_{K,i}|,\ |\tau_{L,i}|,\ \text{Advancement}_i\}$, where $|\tau_{K,i}|$ and $|\tau_{L,i}|$ are absolute misallocation indices and Advancement_i is the industrial-advancement index.[5] Let $\widehat{\text{TE}}_{it} \equiv Y_{it} - Y_{it}^{\text{SCM}}$ denote the SCM-based treatment effect (log GDP per capita gap). For each moderator in turn, we estimate

$$\widehat{\text{TE}}_{it} = \alpha + \beta\,\text{Exp}_{it} + \delta\,M_i + \theta\left(\text{Exp}_{it} \times M_i\right) + \gamma_i + \gamma_t + \varepsilon_{it}, \tag{H1}$$

where $\text{Exp}_{it} = 1$ for treated units in the post-2013 period and 0 otherwise, and γ_i, γ_t are city and year FEs. In this parameterization, β is the post-2013 treatment effect when $M_i = 0$, while θ measures how the effect varies with the moderator: for a city with $M_i = m$, the post-2013 effect equals $\beta + \theta m$.

H.2. Capital misallocation (Panel A)

Across the overall agglomeration sample and in the neighboring set, the interaction is not statistically different from zero, indicating that the role of capital misallocation is not uniform. Among incumbents, $\theta_K = 0.0693^{*}$ implies that enlargement mitigates the penalty of capital misallocation: where capital misallocation was higher, incumbents experienced larger post-2013 gains from the expansion of the urban agglomeration. A natural reading is that the expansion unlocked financing channels and supply-chain investment within the established core, allowing misallocated capital to be re-sorted toward more productive uses. In contrast, for 2013-entrants, $\theta_K = -0.0997^{**}$ shows that high capital misallocation dampened the returns to entry—consistent with capacity and governance constraints that limit absorptive ability: when capital is badly allocated *ex ante*, joining the YRD does less to raise near-term efficiency.

H.3. Labor misallocation (Panel B)

The interaction is positive and significant in the overall sample (0.0558^{***}), among incumbents (0.0807^{***}), and among entrants (0.0479^{**}): enlargement attenuates the adverse effect of labor misallocation. This pattern is consistent with lower search/-matching frictions and improved cross-jurisdictional mobility along YRD commuting and firm networks. The absence of significance among neighbors suggests that these gains are largely internalized within the institutional boundary rather than diffusing to non-members-echoing the spillover results.

[5] Construction and diagnostics of the indices are in Sections 3.3 and 4.5.

Table H1. Moderation of enlargement effects by misallocation and industrial advancement

	Overall agglomeration	Incumbents	2013-entrants	Neighboring non-members
	Panel A. Capital mismatch			
Exp	-0.0272*	-0.0229	0.0201	0.0054
	(0.0149)	(0.0147)	(0.0131)	(0.0055)
$\lvert\tau_K\rvert$	-0.1305***	-0.1600***	0.0002	-0.0612***
	(0.0283)	(0.0282)	(0.0162)	(0.0190)
Exp × $\lvert\tau_K\rvert$	0.0505	0.0693*	-0.0997**	-0.0164
	(0.0291)	(0.0333)	(0.0422)	(0.0245)
Controls, City FE, Year FE	Yes	Yes	Yes	Yes
Observations	728	560	168	336
R^2	0.9957	0.9963	0.9973	0.9982
	Panel B. Labor mismatch			
Exp	-0.0326***	-0.0309**	-0.0330*	-0.0076
	(0.0108)	(0.0110)	(0.0171)	(0.0072)
$\lvert\tau_L\rvert$	-0.0345***	-0.0443***	0.0066	-0.0416***
	(0.0055)	(0.0074)	(0.0120)	(0.0116)
Exp × $\lvert\tau_L\rvert$	0.0558***	0.0807***	0.0479**	0.0149
	(0.0106)	(0.0177)	(0.0193)	(0.0113)
Controls, City FE, Year FE	Yes	Yes	Yes	Yes
Observations	728	560	168	336
R^2	0.9955	0.9961	0.9973	0.9982
	Panel C. Industrial structure advancement			
Exp	0.4127**	0.0142	0.8606**	0.1651
	(0.1509)	(0.2033)	(0.3205)	(0.1024)
Advancement	-0.7808**	-1.1435**	-0.0627	0.8785***
	(0.2597)	(0.4083)	(0.4150)	(0.1014)
Exp × Advancement	-0.0601**	0.0003	-0.1307**	-0.0261
	(0.0230)	(0.0303)	(0.0487)	(0.0162)
Controls, City FE, Year FE	Yes	Yes	Yes	Yes
Observations	728	560	168	336
R^2	0.9954	0.9958	0.9977	0.9986

Notes: The dependent variable is the SCM-based treatment effect (log GDP per capita gap). "Exp" indicates the post-2013 enlargement period. Robust standard errors in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$. All regressions include the full control set and city and year FEs.

H.4. Industrial advancement (Panel C)

For the overall agglomeration (-0.0601^{**}) and for 2013-entrants (-0.1307^{**}), the interaction with industrial structure advancement is negative: when structures are already more service-oriented, the incremental payoff from enlargement is smaller. This is consistent with a "headroom" mechanism in which integration chiefly amplifies manufacturing- and other tradable-sector supply-chain linkages; cities that have already shifted toward services have less additional margin to exploit these scale and network benefits. Among incumbents the interaction is near zero, consistent with their structures being already well aligned.

H.5. Synthesis and link to "Winner-Takes-More"

Taken together, the moderation results complement the event-study evidence. Incumbents capture disproportionate gains ("Winner-Takes-More"), and the gains are strongest precisely where the expansion relieves binding frictions: capital misallocation among incumbents (mitigation channel) and labor misallocation in both incumbents and entrants (mobility/matching channel). Entrants with severe capital misallocation, however, struggle to convert institutional access into efficiency gains in the short run, indicating absorptive-capacity limits. Finally, advanced industrial structures show diminishing incremental returns to enlargement, especially among entrants, consistent with limited headroom in service-heavy economies.