“Does financial center strength drive smart city development? Evidence from global panel data”

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DOES FINANCIAL CENTER STRENGTH DRIVE SMART CITY DEVELOPMENT? EVIDENCE FROM GLOBAL PANEL DATA

Abstract

The accelerating digital and green transition has intensified the role of financial centers as investment conduits, making the relationship between financial strength and smart city development both timely and policy-relevant. This study aims to examine whether and to what extent the Global Financial Centres Index (GFCI) explains variation in the Smart Centres Index (SCI) across a global sample of cities. The analysis relies on panel data covering 78 cities from 2019 to 2025, with all calculations performed in R Studio using fixed effects, random effects, and robust error-corrected estimators. The findings reveal a sharp contrast between specifications: while the fixed-effects model detects no significant relationship (β = 0.0013, p = 0.963), the random-effects model identifies a positive and statistically significant link (β = 0.0858, p < 0.001), explaining about 56% of SCI variation (R^2 = 0.557). Robustness checks with clustered and Driscoll–Kraay standard errors confirm the stability of this result. City-level effects highlight London (+60.24), New York (+54.39), and Singapore (+39.46) as leading overperformers, while New Delhi (–74.49) and Mumbai (–68.15) emerge as underperformers. These outcomes demonstrate that financial strength matters for smart city advancement, but local governance, infrastructure, and innovation ecosystems critically shape whether financial capacity translates into smart development.

Keywords financial centers, smart cities, Global Financial Centres Index, Smart Centres Index, panel data analysis

JEL Classification R11, R58, O16, O18, C23

INTRODUCTION

Cities sit at the intersection of two capital-intensive transitions – digitalization and decarbonization – while financial centers increasingly function as the channels through which that investment is raised, priced, and allocated. Global energy-transition investment reached a record USD 2.1 trillion in 2024 and continued to accelerate into 2025, highlighting the scale of funds now flowing through markets intermediated by leading hubs (Bloomberg Finance L.P., 2025). In parallel, the multi-trillion-dollar financing needs for resilient, low-carbon urban development through 2050 point to sustained demand for market-based solutions and blended public–private finance, which tend to concentrate in areas where advanced financial services, risk management, and deep capital markets are most developed (Deuskar et al., 2025).

Policy momentum further tightens the finance–city nexus. The EU's Mission Cities estimate puts required investment at €650 billion for 112 cities targeting net-zero by 2030, an ambition that, by its sheer magnitude, implies reliance on sophisticated intermediation and green-labelled instruments typically designed and scaled in top financial hubs (Abnett & Jessop, 2024). At the same time, smart-city delivery is

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increasingly shaped by data governance and standards, which affect both investability and implementation capacity, and therefore interact directly with how capital is mobilized and monitored (OECD, 2023).

These dynamics are reflected in the metrics used to benchmark global hubs. The Global Financial Centres Index (GFCI 37, March 2025) explicitly integrates technology- and city-readiness elements (including smart-city measures) alongside business-environment fundamentals, signaling that financial competitiveness and urban "smartness" are increasingly assessed as co-evolving attributes (Z/Yen, n.d.). The Smart Centres Index (SCI 11, May 2025) similarly tracks a center's capacity to create, deploy, and commercialize technology, capabilities often reinforced by deep capital markets and specialized financial services (Z/Yen, n.d.). Recent shifts at the top of the GFCI, including London narrowing the gap with New York in 2025, further suggest active policy competition among hubs to attract innovation finance and talent, which are central to smart-city trajectories (Cruise, 2025).

Contemporaneous market signals, multilateral assessments, and policy initiatives converge on a clear scientific problem: although financial-center strength plausibly shapes the cost, speed, and governance of urban investment, and smart-city readiness conditions how effectively that capital is absorbed, the extent and structure of this linkage remain insufficiently pinned down empirically in a way that is comparable across centers and over time. The combined evolution of GFCI and SCI makes this relationship especially salient in the current phase of the green and digital transition.

1. LITERATURE REVIEW

The nexus between financial development and smart city advancement has been increasingly studied through diverse disciplinary perspectives, highlighting how financial centers provide the institutional, fiscal, and infrastructural conditions for urban innovation. Transparency of local authorities and the mitigation of corruption are preconditions for efficient capital allocation and smart city governance (Artyukhov et al., 2024; Vasylieva et al., 2023). Strengthening public trust and accountability ensures that financial resources channeled through global and regional centers translate into tangible improvements in urban living standards.

Fiscal frameworks and local taxation mechanisms also enable cities to mobilize resources for technological transformation. Evidence from Peru demonstrates how tax culture enhances local development and formalizes informal markets (Chávez-Inga et al., 2025). Similar dynamics are confirmed by panel data analyses of public investment drivers in Morocco, which underscore the importance of fiscal policies for municipal infrastructure (El Bakkali & Guati, 2025). Bibliometric mapping of local government finance research shows that municipal-level financial innovations and fiscal decentralization are critical themes in shaping sustainable urban trajectories (Darmawati et al., 2024). Broader considerations of national financial security under conditions of change management highlight the systemic role of governance in economic resilience (Klochan & Filipov, 2023).

The competitiveness of port and urban economies in the Baltic region has been assessed in terms of economic security, with findings indicating that strong financial connectivity underpins resilience and integration into global flows (Činčikaitė et al., 2023). In parallel, the efficiency and transparency of financial markets remain important contextual factors, as inefficiencies create risks for urban investment and hinder the adoption of modern financial theory in practice (Kobiyh & El Amri, 2023). Bibliometric evidence confirms that the decentralization of energy sources and their renewability are tightly coupled, with implications for how financial centers can support decentralized urban energy solutions (Belgibayeva et al., 2025). Efficiency trends in the insurance industry also highlight how financial services evolve to manage risk and allocate resources more effectively, providing a crucial foundation for urban investment (K. Kumar & J. Kumar, 2024). National-level approaches to innovation and investment security analytics reinforce the argument that systemic financial planning is a prerequisite for urban and smart development (Prokopenko et al., 2019; Bagirzade, 2024).

Smart city financing has emerged as a distinct field, with analyses emphasizing the role of innovative funding instruments and blended public–private solutions. Smart city project financing studies highlight the importance of diverse investment allocation models, including green-labelled bonds and impact finance, in sustaining digital and sustainable transitions (Hedegaard et al., 2024; Filipava & Murshudli, 2023; Murshudli, 2023). Broader analyses of rankings and startup ecosystems suggest that high financial standing does not automatically translate into top smart city performance, as inverse correlations highlight structural trade-offs between investment attraction and ecosystem maturity (Kuzior et al., 2025). Smart cities are increasingly positioned as engines of sustainable development, with exponential modelling and Google Trends data showing a clear alignment between urban innovation and broader development objectives (Hrytsenko et al., 2024). In addition, integrating sustainable logistics and passenger transport is recognized as a critical enabler of smart development and requires strong financial and governance backing (Prokopenko et al., 2024).

Digitalization and fintech are recurrent drivers of the smart finance–smart city link. Research on digital financial literacy highlights its role in expanding peer-to-peer lending platforms, enhancing financial inclusion, and creating pathways for urban entrepreneurial growth (Khan et al., 2025). Blockchain and smart contracts offer opportunities for SMEs and the insurance sector to integrate trust and automation into their financial transactions, which can have a ripple effect on urban economies (Polishchuk et al., 2019; Zulaikha et al., 2024). Reviews of fintech trajectories and emerging peer-to-peer systems show that cities with financial literacy and digital ecosystems are better positioned to support innovative financial tools (Polishchuk, 2023; Parajuli et al., 2024). Regional smart specialization studies confirm that tailoring innovation strategies to specific territorial strengths can amplify the effectiveness of smart initiatives, directly linking to how financial capital is deployed (Ivashchenko et al., 2020; Sadigov et al., 2025). At a broader scale, the role of financial inclusion in driving sustainable economic growth highlights the social foundations of smart development (Saienko et al., 2025).

Smart governance and e-governance frameworks are critical enablers. Global assessments emphasize that transparency, resilience, and trust must be integrated into e-governance to maximize smart outcomes (Kuzior et al., 2022, 2023). Comparative analyses of urban development indices and city rankings underscore the economic determinants of smart and sustainable growth, as well as the importance of evidence-based benchmarking (Mańka-Szulik et al., 2024; Maricuț et al., 2025). Broader smart city planning emphasizes integrating safety, public health, and technological infrastructure, particularly in US contexts, confirming that financing and governance are interdependent (Springs, 2024a, 2024b). Artificial intelligence applications are now also entering the field of smart city management, with promising evidence that AI-based feedback systems can enhance citizen participation and improve service quality (Kildei et al., 2025). Entrepreneurial dynamics and adaptive strategies further shape how financial centers contribute to smart growth in an era of globalization and uncertainty (Bielialov & Gechbaia, 2023).

The resilience of cities in crises has also been linked to their financial bases. Smart cities have demonstrated greater resilience to shocks, such as COVID-19, when supported by robust financial ecosystems and effective governance frameworks (Kuzior et al., 2022; Świadek & Gorączkowska, 2024). Urban economic ecosystems that integrate entrepreneurial development and digitalization benefit from mutually reinforcing dynamics, particularly during post-crisis recovery (Mursalov et al., 2023). At the macro level, financial network resilience since the global financial crisis has continued to influence re-globalization prospects, which in turn shape the stability of flows into urban infrastructure (Gaigaliene & Jurakovaite, 2024). Collaborative approaches to innovation also highlight that hybrid “Five-Helix” models provide frameworks for sustainable smart city development in Industry 4.0 contexts (Megits et al., 2022).

At the intersection of social and technological contexts, smart living and sustainability are fostered by targeted investments into IoT, digital agency, and community resilience. Case studies demonstrate how IoT-driven automation, vertical urban agriculture, and digital twins contribute to sustainability and health, thereby linking tech-

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nological advancements with smart living outcomes (Orel et al., 2024; Ylipulli et al., 2025; Oe et al., 2025; Orbelyan, 2024). The Cities in Motion Index and similar frameworks confirm that socioeconomic determinants guide how financial resources are converted into sustainable growth (Mańka-Szulik et al., 2024). Emerging literature also explores the evolution of green finance, the role of mega-projects, and stock market dynamics under global trade tensions, reinforcing the macroeconomic and financial backdrop of urban innovation (Sang, 2024; Özyeşil & Tembelo, 2025; Pozovna et al., 2025). Conceptual perspectives further demonstrate how business cultures and design approaches can inform smart strategies and organizational readiness for change (Saariluoma, 2009). The role of e-commerce in stimulating innovative business development within European integration adds another dimension to how financial flows contribute to digital-smart growth (Verbivska et al., 2023).

Social and cultural dimensions further illustrate that local tax culture, business intelligence tools, marketing capabilities, and conflict management all mediate the effectiveness of financial flows into urban innovation (Chávez-Inga et al., 2025; Khaddam, 2024; Khraim, 2024; Stadniichuk, 2025). Studies on credit unions and cooperative finance in Poland confirm that financial inclusion at the community level directly supports local development, thereby reinforcing the foundations of smart cities (Náñez Alonso et al., 2023). Emerging geopolitical analyses also remind us that occupied or marginalized cities may be overlooked in research, despite facing critical structural challenges that shape their developmental potential (Suchikova, 2025).

The literature demonstrates that financial center strength provides the infrastructure, governance, and fiscal frameworks needed to support smart city development, but local institutional quality, socio-cultural factors, and technological readiness critically determine whether financial advantages translate into smart outcomes (Midor et al., 2021; Springs, 2024a; Wolniak, 2024; Zahidi et al., 2025). The research landscape highlights both the potential and limitations of financial development as a driver of smart city transformation, underscoring a complex interplay among finance, governance, innovation, and resilience.

The reviewed scholarship confirms that financial centers have a significant enabling role in shaping the pathways of smart city development, primarily by providing access to capital, fostering innovation ecosystems, and facilitating governance reforms. However, the conversion of financial strength into smart performance is uneven and mediated by local conditions, suggesting that while finance matters, policy, institutional, and social dimensions remain equally decisive.

This paper aims to investigate whether and to what extent the level of development of global financial centers contributes to the advancement of smart city capacities, measured across a panel of international cities.

2. METHODOLOGY

This paper investigates the relationship between the Global Financial Centres Index (GFCI) and the Smart Centres Index (SCI) across a panel of international cities. The data were obtained from official publications of the Long Finance initiative, available at Z/Yen (n.d.). The Global Financial Centres Index has been published semi-annually since 2007, while the Smart Centres Index has been released since 2020 (covers 2019). For this study, the sample covers the period from 2019 to 2025, reflecting the overlap during which both indices are available. This ensures comparability between the two measures.

The unit of analysis is the city–year observation, with data included only for those cities for which both GFCI and SCI evaluations were available. This matching procedure yielded an unbalanced panel of 78 cities, observed over a period of two to six years, depending on data availability. The complete list of included cities is provided in Appendix A.

2.1. Data preparation and transformation

Both indices are originally published as numeric scores. Descriptive statistics and distributional tests were conducted before analysis to examine central tendency, dispersion, skewness, and kurtosis. The Shapiro-Wilk test confirmed significant deviations from normality for both variables.

Box-Cox and Yeo-Johnson transformations were applied to address this issue. These improved the distributional properties of the data, although full normality was not achieved. Consequently, subsequent econometric models relied on robust methods to account for potential violations of classical assumptions.

2.2. Model specification

Given the panel structure of the data, econometric modelling was conducted using fixed-effects (FE) and random-effects (RE) estimators. The dependent variable is SCI, and the independent variable of interest is GFCI. The FE specification controls for time-invariant city characteristics by focusing on within-city variation, whereas the RE specification assumes that unobserved city effects are random and uncorrelated with the regressors.

Results from both FE and RE models were compared to determine the more appropriate specification. The FE model yielded no significant relationship, whereas the RE model revealed a positive, statistically significant association between GFCI and SCI. Given the relatively short time horizon (2020–2025) and the substantive interest in both within- and between-city differences, the RE model was selected as the main analytical framework.

2.3. Robustness checks

To ensure the reliability of the estimates, several robustness checks were performed. Heteroskedasticity-consistent (HC1) standard errors were calculated by clustering by city and year. In addition, Driscoll–Kraay standard errors were applied to account for heteroskedasticity, serial correlation, and cross-sectional dependence simultaneously. Across all specifications, the positive effect of GFCI on SCI remained robust and statistically significant. By employing fixed- and random-effects models with robust standard-error adjustments, the study captures city-year dynamics and evaluates systematic over- or underperformance through city-specific random effects. This enables the identification of the general relationship between finance and smart development, benchmarking individual cities, and highlighting persistent structural advantages or constraints.

2.4. City-level effects

Finally, city-specific random effects (Best Linear Unbiased Predictors, BLUPs) were estimated from the RE model. These capture systematic deviations of each city's SCI score from the global average once financial development is considered. The analysis of BLUPs allows the identification of overperforming and underperforming cities, thereby highlighting structural factors beyond financial strength that may shape smart city performance.

All data cleaning, transformations, descriptive analysis, and inferential modelling were performed in RStudio using the *plm, car, lmtest*, and *sandwich* packages.

3. RESULTS

The descriptive statistics highlight distinct patterns across the four variables. The city variable, representing the number of observations per city, has a mean of 40.56 and a median of 41, with values ranging from 1 to 78. The very low skewness (–0.06) indicates a nearly symmetric distribution, while the negative kurtosis (–1.16) suggests that the distribution is flatter than a normal curve, with fewer extreme values.

The year variable is tightly clustered around recent years, with a mean of 2021.75 and a median of 2022, spanning from 2019 to 2024. Its skewness (–0.16) and kurtosis (–1.16) also point to a symmetric, platykurtic distribution, reflecting the balanced nature of the dataset across the time range.

The Global Financial Centres Index (x) shows a much more distinctive pattern. The mean score is 674.93, but the median is higher at 686, suggesting a left-skewed distribution, as confirmed by the skewness of –2.31. The high kurtosis (13.03) indicates a leptokurtic distribution, characterized by a sharp peak and heavy tails, suggesting that some cities perform exceptionally well compared to the majority.

The Smart Centres Index (y) has a mean of 662.00 and a median of 664, with a skewness of –1.21, confirming moderate left skew. Its kurtosis value of 5.14 indicates a leptokurtic distribution, although

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Table 1. Descriptive statistics

Variable	City	Year	Global Financial Centres Index (x)	Smart Centres Index (y)
n	395	395	395	395
Mean	40.56	2021.75	674.93	662
SD	22.29	1.63	63.66	37.74
Median	41	2022	686	664
Trimmed	40.74	2021.81	681.22	663.7
MAD	28.17	1.48	53.37	32.62
Min	1	2019	206	462
Max	78	2024	794	760
Range	77	5	588	298
Skew	–0.06	–0.16	–2.31	–1.21
Kurtosis	–1.16	–1.16	13.03	5.14
SE	1.12	0.08	3.2	1.9

less extreme than that of the Global Financial Centres Index, with results clustering around the median but still with some extreme outliers.

The Shapiro–Wilk test results indicate that both variables deviate significantly from a normal distribution. For the Global Financial Centres Index (x), the test statistic is W = 0.85 with a p-value < 0.0001, clearly rejecting the null hypothesis of normality. Similarly, for the Smart Centres Index (y), the result of W = 0.93 with a p-value < 0.0001 confirms non-normality. These findings suggest that subsequent analyses should either rely on methods robust to non-normality or apply appropriate transformations to the data.

For x, the estimated power parameter (λ) is 4.61 (95% CI: 3.70-5.52). Both likelihood ratio tests are highly significant ($p < 0.0001$), rejecting the hypotheses that a log transformation ($\lambda = 0$) or no transformation ($\lambda = 1$) would be sufficient. This indicates that a strong power transformation around $\lambda \approx 4.6$ is required to approximate normality. For y, the estimated λ is 4.48 (95% CI: 3.38–5.59). Again, both likelihood ratio tests are significant, with p-values well below 0.001. This suggests that neither the log transformation nor keeping the variable untransformed adequately normalizes the data. A Box–Cox transformation with λ close to 4.5 is recommended.

For the transformed Global Financial Centres Index (x_bc), the Shapiro–Wilk statistic is $W = 0.99$, with a p-value ≈ of approximately 0.024. While the test remains formally significant at the 5% level, the p-value is now much larger than before the transformation (previously < 0.0001). This indicates a clear improvement in normality, despite minor deviations remaining detectable. For the transformed Smart Centres Index (y_bc), the test yields $W = 0.98$ with a p-value ≈ 0.00023. Although this indicates a significant departure from perfect normality, the improvement relative to the untransformed data (previously $p < 0.0001$) is also evident.

For the Global Financial Centres Index (x_yj), the Shapiro–Wilk test yields $W = 0.99$ with a p-value ≈ 0.025. This is identical to the Box–Cox result ($W = 0.99$, $p \approx 0.024$). Thus, Yeo–Johnson does not provide a noticeable improvement in normality compared with the Box-Cox approach for x. For the Smart Centres Index (y_yj), the result is $W = 0.98$ with a p-value ≈ 0.00023, again essentially identical to the Box–Cox outcome. The data remain significantly non-normal, although the deviation is less extreme than in the raw values.

Box-Cox and Yeo-Johnson transformations improved the normality of x and y relative to the untransformed data. However, strict normality has not been fully achieved, particularly for the Smart Centres Index (y). This suggests that while the transformed variables are closer to normal, robust or non-parametric methods may still be preferable in downstream analyses.

The FE model shows no significant relationship between the Global Financial Centres Index (x) and the Smart Centres Index (y). The coefficient of x is extremely small (0.0013) with a p-value ≈ 0.96, indicating no explanatory power once city-specific effects are controlled for. The R^2 is virtually zero (≈ 0.000007), and the F-statistic is insignificant, suggesting that within-city variation in x does not help explain variation in y.

By contrast, the RE model indicates a statistically significant positive relationship. The coefficient for x is 0.0858 ($p < 0.001$), implying that higher Global Financial Centres Index values are associated with higher Smart Centres Index scores. The RE model also has a relatively high R^2 of 0.557, indicating that the model explains about 56% of the variance in y.

The difference between the FE and RE outcomes suggests that the effect of x on y may be driven more by between-city variation rather than by within-city changes over time. A Hausman test would be required to decide formally between the two models. However, the contrasting results already highlight the importance of testing whether unobserved city effects are correlated with x.

Table 2. Panel regression

Model	Fixed Effects (FE)	Random Effects (RE)
Coefficient for x	0.0013	0.0858***
Std. Error	0.0268	0.0258
t/z-value	0.047	3.33
p-value	0.963	0.00087
R^2	0	0.557
Adj. R^2	–0.247	0.556
F/Chi² statistic	0.002 (F)	11.087 (Chi²)
p-value (F/Chi²)	0.963	0.00087

Note: Dependent variable: y (Smart Centres Index), Independent variable: x (Global Financial Centres Index). Signif. codes: '***' – 0.001; '**' – 0.01; '*' – 0.05; '.' – 0.1; 'no symbol' – insignificant.

The RE specification was chosen as the next analysis step based on the preliminary panel estimations. The RE model is preferred because it captures both within- and between-city variation while allowing unobserved heterogeneity across cities to be treated as random rather than fixed. This approach is appropriate given the relatively short time dimension of the panel ($T = 2–6$ years) and the research interest in assessing how differences in the Global Financial Centres Index are associated with variations in the Smart Centres Index across a broad sample of cities. The RE model also displayed a substantially higher explanatory power than the FE model, suggesting that the key dynamics of interest are more strongly driven by cross-sectional rather than purely within-city changes over time.

Table 3 shows that across all robust SE adjustments, the effect of x on y remains positive and statistically significant, with the strongest precision under Driscoll–Kraay corrections.

When applying heteroskedasticity-consistent standard errors clustered by city ("group"), the coefficient for the Global Financial Centres Index (x) remains positive and statistically significant at the 1% level (β = 0.0858, $p = 0.009$). However, the standard error increases (0.0329 compared with 0.0258 in the unadjusted model), making the effect less precisely estimated. This suggests that clustering by city accounts for within-group correlation and inflates uncertainty, but the relationship between x and the Smart Centres Index (y) remains robust.

When clustering by time, the effect becomes much more precise (SE = 0.0108) and highly significant ($p < 0.001$). The t-value rises to 7.97, indicating a strong association. This implies that year-to-year correlation across cities is weaker than within-city correlation, and accounting for time-based clustering reduces the noise in estimation.

Finally, with Driscoll–Kraay (SCC) standard errors, which adjust simultaneously for heteroskedasticity, serial correlation, and cross-sectional dependence, the relationship between x and y becomes even stronger and more precisely estimated (β = 0.0858, SE = 0.0081, $t = 10.54$, $p < 0.001$). This confirms that the positive link between financial and smart city performance is robust to multiple forms of dependence in panel data.

The estimated random intercepts reveal considerable heterogeneity across cities, indicating systematic differences in Smart Centres Index performance that the Global Financial Centres Index does not fully account for.

Some cities stand out with large positive effects, meaning their Smart Centres Index scores are systematically above the global average once financial development is accounted for. The strongest performers are London (+53.43), followed by New York (+47.61), Singapore (+34.53), Zurich (+34.00), and San Francisco (+33.79).

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Table 3. Robustness checks for the random-effects model

Robust SE method	Coefficient for x	Std. Error	t-value	p-value
Clustered by city	0.0858	0.0329	2.609	0.0094**
Clustered by time	0.0858	0.0108	7.967	<0.0001***
Driscoll–Kraay (SCC)	0.0858	0.0081	10.541	< 0.0001***

Note: Dependent variable = y (Smart Centres Index). Independent variable = x (Global Financial Centres Index). Signif. codes: '***' – 0.001; '**' – 0.01; '*' – 0.05; '.' – 0.1; 'no symbol' – insignificant.

These cities are global leaders in both finance and innovation, suggesting that their smart city development benefits from broader ecosystem advantages, including technology, infrastructure, and policy support.

Other cities exhibit moderate positive deviations, including Hong Kong (+29.89), Tel Aviv (+28.59), Los Angeles (+28.82), Copenhagen (+28.22), and Stockholm (+26.78). These findings suggest that these locations have additional institutional, technological, or cultural advantages boosting their smart performance even beyond financial strength.

Conversely, several cities exhibit strong negative effects, meaning they underperform in smart city development relative to what would be expected from their financial center standing. The largest negative deviations are observed for New Delhi (–67.63), Mumbai (–62.17), Moscow (–26.22), and Rome (–33.08). These results highlight structural constraints such as infrastructure bottlenecks, governance challenges, or regulatory inefficiencies that limit the translation of financial capacity into smart city outcomes.

Other consistent underperformers include Athens (–23.00), Johannesburg (–17.87), Mexico City (–18.57), and Stuttgart (–29.91). Such results illustrate that smart city success is not automatically guaranteed by financial center status, and local institutional, social, and technological dynamics play a decisive role.

Table 4. City-specific random effects (BLUPs)

City	Effect	City	Effect	City	Effect
Abu Dhabi	11.44	Gibraltar	–7.73	New York	47.61
Amsterdam	20.04	GIFT City	–3.30	Osaka	–11.98
Astana	–3.38	Glasgow	15.87	Paris	–6.27
Athens	–23.00	Guangzhou	3.13	Prague	–4.50
Bahrain	–31.97	Guernsey	–0.73	Riyadh	–24.80
Bangkok	0.07	Hamburg	–2.27	Rome	–33.08
Beijing	8.75	Hong Kong	29.89	San Francisco	33.79
Berlin	14.44	Isle of Man	–25.16	Seoul	7.65
Bermuda	–6.75	Istanbul	–27.57	Shanghai	8.50
Boston	23.62	Jersey	11.00	Shenzhen	8.10
BVI	–22.57	Johannesburg	–17.87	Singapore	34.53
Brussels	7.61	Kuala Lumpur	–23.86	Sofia	6.25
Budapest	–14.30	London	53.43	Stockholm	26.78
Busan	8.94	Los Angeles	28.82	Stuttgart	–29.91
Cape Town	–9.85	Luxembourg	17.83	Sydney	4.63
Cayman Islands	–27.69	Madrid	–21.38	Taipei	–17.41
Chengdu	–2.55	Malta	24.81	Tallinn	0.86
Chicago	22.28	Manila	–15.82	Tel Aviv	28.59
Copenhagen	28.22	Mauritius	–5.06	Tianjin	–12.70
Cyprus	–1.27	Melbourne	–6.39	Tokyo	10.22
Doha	13.29	Mexico City	–18.57	Toronto	14.44
Dubai	15.49	Milan	–22.48	Vancouver	11.93
Dublin	14.57	Moscow	–26.22	Vienna	–3.06
Edinburgh	0.17	Mumbai	–62.17	Warsaw	–27.34
Frankfurt	–9.74	Munich	–8.40	Washington DC	9.72
Geneva	25.40	New Delhi	–67.63	Zurich	34.00

Table 5. City-specific random effects (BLUPs) with standard errors

City	Effect	SE	City	Effect	SE	City	Effect	SE
Abu Dhabi	13.06	9.01	GIFT City	–4.41	9.77	New Delhi	–74.49	9.01
Amsterdam	23.10	9.77	Glasgow	17.15	12.10	New York	54.39	9.01
Astana	–4.39	12.10	Guernsey	–1.76	9.01	Osaka	–12.81	9.77
Athens	–27.63	10.75	Hamburg	–2.22	10.75	Paris	–5.60	9.01
Bahrain	–36.95	10.75	Hong Kong	34.51	9.01	Prague	–6.16	10.75
Bangkok	–0.74	9.01	Isle of Man	–28.52	9.01	Riyadh	–28.70	9.77
Beijing	11.13	9.01	Istanbul	–31.61	9.77	Rome	–36.33	9.01
Berlin	16.71	10.75	Jersey	14.37	14.14	San Fran.	38.33	9.01
Bermuda	–8.67	14.14	Johannesburg	–20.37	9.01	Seoul	9.70	9.77
Boston	26.94	9.01	Kuala Lumpur	–25.98	9.01	Shanghai	11.15	9.01
Brussels	8.40	9.01	Warsaw	–30.91	9.77	Shenzhen	10.35	9.01
Budapest	–17.44	9.77	Vienna	–3.48	9.77	Singapore	39.46	9.01
Busan	10.47	9.77	London	60.24	9.01	Sofia	5.33	10.75
Cape Town	–11.59	9.01	Los Angeles	32.85	9.01	Stockholm	29.47	9.01
Cayman Is.	–30.64	9.01	Luxembourg	18.32	9.01	Stuttgart	–36.67	14.14
Chengdu	–3.02	12.10	Madrid	–22.80	9.01	Sydney	6.25	9.01
Chicago	25.63	9.01	Malta	26.17	9.77	Taipei	–19.83	10.75
Copenhagen	32.23	10.75	Manila	–19.50	9.77	Tallinn	–0.05	12.10
Cyprus	–1.91	14.14	Mauritius	–5.70	14.14	Tel Aviv	31.64	9.77
Doha	14.90	12.10	Melbourne	–6.08	9.77	Tianjin	–15.75	9.77
Dubai	18.18	9.01	Mexico City	–21.62	9.77	Tokyo	12.78	9.01
Dublin	16.32	9.01	Milan	–24.19	9.01	Toronto	16.93	9.01
Edinburgh	1.09	9.01	Moscow	–29.78	9.01	Vancouver	13.97	9.01
Frankfurt	–9.11	9.01	Mumbai	–68.15	9.01	Washington	11.77	9.01
Geneva	28.83	9.01	Munich	–8.89	9.01	Zurich	38.33	9.01
Gibraltar	–10.20	10.75						

The random effects analysis confirms that while financial development (captured by the Global Financial Centres Index) is positively linked to smart city performance, city-specific unobserved characteristics strongly influence outcomes. These results justify the use of the random-effects specification, which captures global patterns and persistent local differences.

The estimated city effects display wide cross-city heterogeneity. A group of leading overperformers clearly emerges, where Smart Centres Index values are significantly higher than expected, given the financial center's strength. London (+60.24, SE ≈ 9.01) and New York (+54.39, SE ≈ 9.01) stand out as the top cases, confirming their dual dominance as financial hubs and leaders in smart innovation. Other notable positive deviations are observed for Singapore (+39.46), San Francisco (+38.33), Zurich (+38.33), and Hong Kong (+34.51), all of which are globally recognized for their strong technology ecosystems, infrastructure, and policy environments that support digital and smart development.

A second tier of moderate overperformers includes Copenhagen (+32.23), Los Angeles (+32.85), Tel Aviv (+31.64), Stockholm (+29.47), Geneva (+28.83), and Boston (+26.94). These cities demonstrate robust smart city capacities that extend beyond their financial standing, indicating effective governance, strong human capital, and innovation-driven policies.

On the other hand, several cities show large negative deviations, indicating underperformance relative to financial capacity. The most pronounced underperformers are New Delhi (–74.49, SE ≈ 9.01) and Mumbai (–68.15, SE ≈ 9.01), followed by Bahrain (–36.95), Rome (–36.33), and Stuttgart (–36.67). Such results highlight structural challenges, including governance inefficiencies, infrastructure limitations, and institutional bottlenecks, that hinder the translation of financial capital into smart urban outcomes.

Further underperformance is observed in cities like Athens (–27.63), Istanbul (–31.61), Mexico City (–21.62), and Madrid (–22.80). These deviations

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reinforce the finding that being a financial center does not guarantee strong smart city performance.

In between, many cities show relatively small or statistically indistinguishable deviations (e.g., Bangkok, Chengdu, Tallinn, Vienna), reflecting a closer alignment between financial and smart city performance.

The analysis highlights that while financial center strength provides a crucial foundation, city-specific characteristics, including governance, infrastructure, and policy orientation, significantly impact smart city outcomes.

4. DISCUSSION

The empirical results of this study show that the strength of financial centers, as measured by the Global Financial Centres Index, is positively associated with smart city development, as captured by the Smart Cities Index. The random-effects model demonstrated a statistically significant effect ($\beta = 0.0858$, $p < 0.001$), with financial center strength explaining approximately 56% of variation in smart city outcomes. Robustness checks, including heteroskedasticity-consistent errors clustered by city and time and Driscoll-Kraay corrections, confirmed the stability of this result. The city-level analysis revealed substantial heterogeneity: global leaders, such as London, New York, and Singapore, consistently outperformed expectations, while cities like New Delhi and Mumbai underperformed despite their considerable financial potential.

These findings align with previous research, which emphasizes that financial markets provide a critical foundation for mobilizing resources, supporting innovation ecosystems, and enabling governance reforms that underpin smart city development. Studies on smart city financing highlight that innovative financial instruments, including green bonds and blended finance, are indispensable in sustaining digital and sustainable transformations (Hedegaard et al., 2024). The significant role of financial inclusion and literacy in facilitating the adoption of technology, such as peer-to-peer lending platforms, further strengthens the argument that well-functioning financial centers foster smart development pathways (Khan et al., 2025).

At the same time, the results confirm that financial capital alone is not sufficient. The evidence that some financial centers significantly underperform in smart city outcomes aligns with research demonstrating the importance of local governance, transparency, and institutional quality (Artyukhov et al., 2024; Vasylieva et al., 2023). In contexts where governance inefficiencies or infrastructure deficits prevail, the conversion of financial strength into smart capacities is hindered, as illustrated by the underperformance of cities with high financial standing but weak institutional frameworks. This echoes findings that decentralization, fiscal innovation, and regional specialization are crucial for leveraging financial advantages into sustainable outcomes (Belgibayeva et al., 2025; Ivashchenko et al., 2020).

The heterogeneity observed across cities corresponds to broader evidence that global smart city rankings do not always align with financial hub rankings, reflecting structural trade-offs between financial development and innovation ecosystems (Kuzior et al., 2025). Overperforming cities, such as Singapore and Zurich, exemplify cases where strong financial intermediation is coupled with robust policy environments, innovative infrastructure, and citizen-centric digital strategies. Conversely, underperformers reflect insights from the literature that socio-economic constraints, governance challenges, or insufficient technological readiness hinder the translation of financial resources into effective performance (Maricuț et al., 2025; Mańka-Szulik et al., 2024).

The comparison between empirical findings and the literature suggests that financial center strength is a necessary but not sufficient driver of smart city development. While financial hubs provide the resources and capabilities to support innovation, the degree to which this potential is realized depends on complementary factors such as governance transparency, institutional trust, digital adoption, and policy frameworks. This interplay explains both the robustness of the positive relationship and the persistence of significant cross-city variation.

This study faces two key constraints. First, the SCI has only been available since 2019, which restricts the analysis to a short period (2019–2025) and prevents assessment of longer-term dynamics. Second, the sample is limited to cities in both the SCI and the GFCI. While this ensures comparability, it excludes emerging centers not recognized by both indices, reducing coverage and potentially introducing selection bias. Moreover, as SCI and GFCI are composite indices with their own methodological assumptions, the findings reflect relative rather than absolute performance measures. Although robust panel techniques were applied, residual unobserved factors may still affect results.

CONCLUSION

This study aimed to investigate whether and to what extent the level of development of global financial centers contributes to the advancement of smart city capacities. By linking the GFCI and the SCI across a panel of international cities, the study sought to determine the strength and nature of this relationship, while also identifying systematic over- and under-performance at the city level.

Using Long Finance data (GFCI 2007–2025; SCI 2019–2025), an unbalanced panel of 78 cities (2019–2025) was constructed from centers appearing in both indices and analyzed in R with FE/RE panel models and robust inference (clustered by city/time and Driscoll-Kraay). Results diverged sharply. The FE model finds no within-city association between GFCI and SCI ($\beta = 0.0013$, $p = 0.963$). In comparison, the RE model indicates a strong positive relationship explaining ~56% of SCI variation ($\beta = 0.0858$, $p < 0.001$; $R^2 = 0.557$) that remains robust and reveals marked heterogeneity, with London, New York, Singapore, Zurich, and San Francisco overperforming and New Delhi and Mumbai underperforming relative to their financial potential.

These results have important policy implications. First, they highlight that financial strength provides a solid foundation for smart city development, but it is insufficient. Cities that successfully convert financial capital into smart capacities typically combine robust innovation ecosystems, effective governance, and long-term infrastructure planning. Policymakers in underperforming cities should prioritize regulatory reforms, investment in digital infrastructure, and public–private partnerships that facilitate technology adoption. Second, the global variation underscores the need for context-sensitive strategies: in advanced hubs such as London, New York, and Singapore, policies should focus on maintaining innovation leadership, cybersecurity, and sustainability standards. In contrast, cities like New Delhi, Mumbai, and Rome require targeted interventions to overcome institutional and infrastructural barriers, ensuring that financial development is matched by digital and technological progress. Finally, the results suggest that international benchmarking through indices like GFCI and SCI can be useful for identifying performance gaps, setting policy priorities, and fostering competition among cities to achieve balanced financial and smart city growth.

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APPENDIX A

Table A1. List of cities

Abu Dhabi	Gibraltar	New York
Amsterdam	GIFT City-Gujarat	Osaka
Astana	Glasgow	Paris
Athens	Guangzhou	Prague
Bahrain	Guernsey	Riyadh
Bangkok	Hamburg	Rome
Beijing	Hong Kong	San Francisco
Berlin	Isle of Man	Seoul
Bermuda	Istanbul	Shanghai
Boston	Jersey	Shenzhen
British Virgin Islands	Johannesburg	Singapore
Brussels	Kuala Lumpur	Sofia
Budapest	London	Stockholm
Busan	Los Angeles	Stuttgart
Cape Town	Luxembourg	Sydney
Cayman Islands	Madrid	Taipei
Chengdu	Malta	Tallinn
Chicago	Manila	Tel Aviv
Copenhagen	Mauritius	Tianjin
Cyprus	Melbourne	Tokyo
Doha	Mexico City	Toronto
Dubai	Milan	Vancouver
Dublin	Moscow	Vienna
Edinburgh	Mumbai	Warsaw
Frankfurt	Munich	Washington DC
Geneva	New Delhi	Zurich

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