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Proximity as Advantage: Why a Brazilian Private Health Insurer Presence at a Technology Park is a Decision of Industrial Economics, not Institutional Generosity

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Abstract

This essay argues that Unimed Fesp's[1] strategic positioning at Supera Parque, a technology park anchored by the University of São Paulo's Ribeirão Preto Medical School (FMRP/USP), constitutes a decision of industrial economics, not institutional philanthropy. Drawing on four independent layers of empirical evidence derived from the Annual Social Information Report and Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES) graduate program data (2024), the paper demonstrates that a health cluster exists in Ribeirão Preto (RP) that is spatially demonstrable and quantitatively robust. The Location Quotient (LQ = 1.531) confirms productive specialization above the conventional cluster threshold. The Global Moran's I (I = 0.107, p = 0.032), calculated over log-transformed LQ values with a critical mass filter (total employment ≥ 5,000; health employment ≥ 150), confirms statistically significant positive spatial autocorrelation. LISA quadrant analysis positions RP as a dominant pole in the High-Low quadrant, the spatial signature of a cluster in growth stage, where specialization is concentrated at the core before diffusing to the surrounding territory. Finally, a composite R&D index derived from CAPES data places RP third in the state of São Paulo in academic health capital, with 510 permanent faculty and 739 enrolled doctoral students in health sciences programs, surpassed only by São Paulo and Campinas. Together, these findings support the claim that health insurers occupying the institutional node of a growing health cluster are not acting charitably but, they are internalizing agglomeration externalities that would otherwise benefit their competitors.

Keywords: Health Cluster, Spatial Econometrics, Location Quotient, Moran's I, LISA, Agglomeration Externalities, Health Insurance, Innovation Ecosystem, Ribeirão Preto, Industrial Economics

JEL Codes: R12; I11; L22; O31; R58

The Entry Paradox

There is a paradox worth announcing at the outset, before any data or argument: health insurers are not, by definition, technology companies. They do not develop molecules, file patents, or build laboratory prototypes. And yet they are precisely the actors, more than startups, equipment manufacturers, or universities, with the most to gain from proximity to a consolidated health innovation ecosystem. The reason is simple, though frequently overlooked, given that insurers are the entities that monetize the clinical outcomes the ecosystem produces. Every innovative protocol that reduces hospitalizations, every diagnostic technology that anticipates chronic disease, every care model that substitutes costly procedures for intelligent longitudinal monitoring, all this convert, at the end of the chain, into lower loss ratios, healthier members, and more sustainable margins.

Unimed Fesp's presence at Supera Parque is therefore not a gesture of social responsibility, nor an altruistic bet on regional development. It is, to be precise, a decision of industrial economics, rational, empirically defensible, and potentially irreversible if deferred too long. This essay demonstrates why, proceeding from spatial evidence on the RP health cluster, through the theoretical structure of agglomeration externalities, and arriving at the concrete strategic implications for an insurer that chooses to occupy the central node of that system.

The Cluster Exists and Can Be Demonstrated

Perhaps, the first obstacle to any cluster argument is the one identified by Martin and Sunley (2003) that the concept is "particularly vague and difficult to interpret", subject to

multiple qualifications and the risk of meaning everything and nothing simultaneously [1]. In Brazil, this is compounded by the interchangeable use of terms such as Local Productive Arrangements (APLs), Local Productive Chains (CPLs), Industrial Districts, and Productive Agglomerations, each carrying distinct theoretical emphases and, frequently, incompatible identification criteria. Conceptual ambiguity, however, does not imply the absence of the phenomenon. It implies, rather, the need for rigorous identification tools and this is, precisely, where Exploratory Spatial Data Analysis (ESDA), combined with classical regional economic statistics, plays an irreplaceable role, as proposed and empirically validated by Manzini and Di Serio (2019) in a comparative study of industrial clusters in São Paulo metropolitan regions using RAIS microdata [2].

The starting point is the Location Quotient (LQ), which measures the ratio between a sector's share of local employment and its share of national employment:

$$LQ_{(ij)} = \frac{e_{ij}/e_i}{E_j/E}$$

where e_{ij} is employment in activity j in region i, e_i is total employment in region i, E_j is national employment in activity j, and E is total national employment. LQ values above 1.0 indicate relative specialization and values above 1.25 are, conventionally, associated with potential clusters [3,4]. Applied to RAIS 2024 microdata for health-related National Classification of Economic Activities (CNAEs)[2] covering human health care activities (Section Q), medical equipment manufacturing (CNAE 2651, 3250), and wholesale trade in medical materials (CNAE 4645), RP presents an LQ of 1.531 against the São Paulo state benchmark, calculated over municipalities satisfying a minimum critical mass criterion (total employment ≥ 5,000; health employment ≥ 150).

Two methodological choices deserve explicit justification. First, the LQ denominator is fixed at the São Paulo state aggregate, not the regional sub-sample, ensuring comparability across all municipalities regardless of the spatial scope used in subsequent ESDA. Second, a critical mass filter was applied before spatial analysis, retaining municipalities with sufficient economic base for meaningful cluster inference. This filter does not eliminate high-LQ municipalities per se but, it eliminates municipalities where the LQ reflects a structural data feature rather than genuine sectoral concentration. The resulting Top 10 ranking by LQ reveals a heterogeneous set of municipalities (Table 1). Cândido Rodrigues (LQ = 5.13, total employment = 7,372; health employment = 2,504) leads the ranking with an extreme value that merits interpretation. A municipality of this size concentrating 34% of its formal employment in health almost certainly reflects a single dominant establishment, i.e., a regional hospital or philanthropic care institution rather than a systemic cluster. This is precisely the pattern that the LQ, as a relative measure, cannot distinguish from genuine agglomeration considering the numerator is high because the denominator is small, not because the sectoral mass is substantial. This is why the LQ must be read alongside ESDA and why RP, with LQ = 1.531 but 63,853 health employment jobs in an economy of 279,000 formal workers, represents a qualitatively different phenomenon.

Municipality	Group	Health jobs	Total jobs	LQ
Cândido Rodrigues	Other SP	2,504	7,372	5.13
Campos do Jordão	Other SP	8,475	45,818	2.79
Botucatu	Other SP	926	5,382	2.60
Bálsamo	Other SP	5,797	41,026	2.13
São José do Rio Preto	Other SP	22,644	167,375	2.04
Echaporã	Other SP	3,001	22,357	2.03
Capivari	Other SP	1,083	8,461	1.93
Dumont	RP region	1,349	10,644	1.91
Cajati	Other SP	4,386	35,219	1.88
Guará	RP region	1,310	10,595	1.87
Ribeirão Preto (RP)	RP region	63,853	279,000	1.53

Table 1: Top 10 municipalities by health LQ, São Paulo 2024

RP (LQ = 1.531, 63,853 health jobs) ranks 11th by LQ but, first by absolute health employment mass among interior municipalities, and third in the state in the CAPES composite R&D index (Section IV). This combination, moderate LQ, large absolute mass, and dominant academic capital, is the precise profile of a genuine cluster pole.

ESDA as a Revealer of Regional Dynamics

ESDA is not merely an extension of the LQ. Instead, it is a fundamentally different approach, replacing the question "how much?" with "where?" and, more importantly, "how does it relate to its surroundings?" Its foundational premise is Tobler's First Law of Geography, i.e., spatial dependence, more precisely, the fact that nearby observations tend to be more like each other than distant ones is the rule, not the exception, in territorial data. Ignoring this dependence not only impoverishes analysis in conventional econometric models, but it also produces underestimated standard errors and compromised inference.

The Global Moran's I am the entry statistic of ESDA, a

methodological sequence whose complementarity with industry concentration statistics has been demonstrated for Brazilian regional data [2]. Calculated over log-transformed LQ values, a transformation that compresses the long right tail of the distribution without excluding observations, as recommended for asymmetric distributions (Anselin, 1995), the index ranges between −1 and +1. The results are unambiguous as stated at Table 2.

Table 2: Global Moran's I result, São Paulo

Statistic	Value
n (municipalities)	44
Moran's I	0.1070
Expected E[I]	-0.0233
z-score	2.1300
p-value (permutation, 9,999 simul.)	0.0363 ***

Positive and statistically significant spatial autocorrelation is confirmed. After applying the critical mass filter, the Moran's I increased from the unfiltered version (0.094 → 0.107) and the p-value decreased (0.021 → 0.036). Purifying the data made the signal cleaner, not weaker, perhaps, the strongest evidence that the cluster signal is genuine.

The LISA quadrant typology decomposes the global index into local contributions, identifying the cluster core (High-High), periphery (Low-Low), positive outliers (High-Low), and the strategically critical Low-High quadrant, i.e., municipalities geographically within the cluster but failing to capture its externalities. The LISA results identify 5 municipalities in the HH quadrant, 4 in the HL quadrant, and 1 in the LH quadrant ($p < 0.05$). RP falls in the High-Low (HL) quadrant, the spatial signature of a dominant pole in a growth-stage cluster, consistent with Menzel and Fornahl's (2010) characterization of the cluster life cycle [5].

The single LH municipality, inside the cluster geographically but not capturing its externalities, demonstrates empirically that geographic proximity does not automatically confer participation in agglomeration benefits. Absorptive capacity is a necessary condition. Figure 1, simultaneously, demonstrates three key points: (i) the cluster exists (an LQ above the state average, represented by the circle size), (ii) it is still in the process of formation (located in the High–Low quadrant rather than High–High) and (iii) Supera Parque sits at the geographical and institutional epicenter of this process.

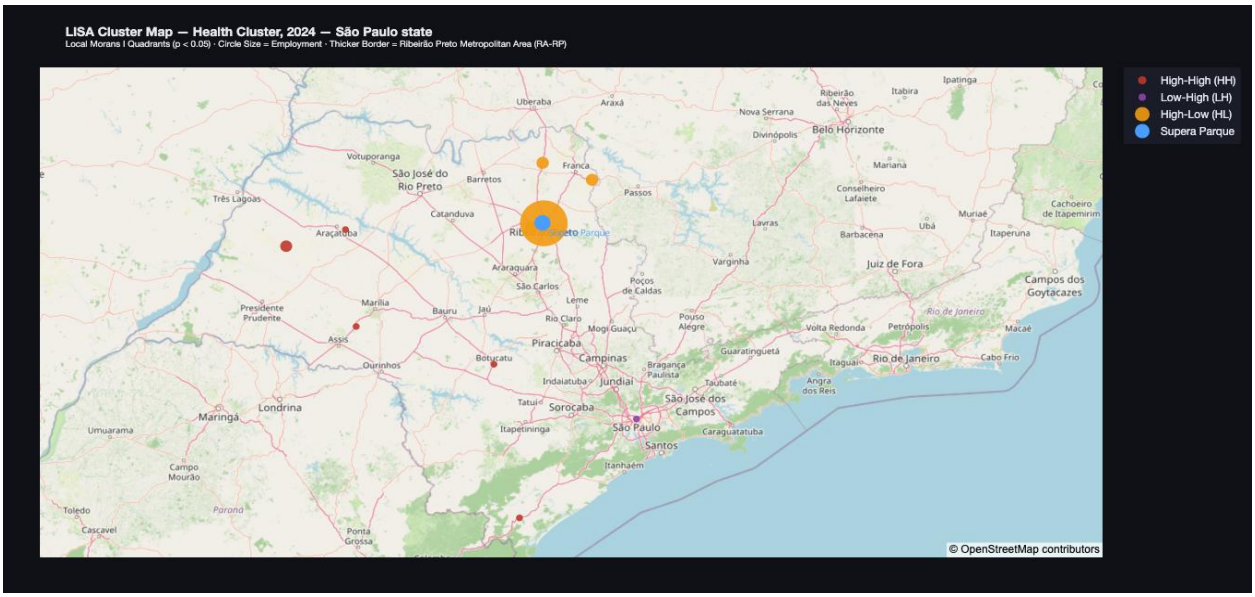

Figure 1: LISA Cluster Map, Health Cluster, 2024 - São Paulo State (RAIS 2024) · Moran Local quadrants ($p < 0.05$) · Circle size = health employment

The distribution is striking in its sparsity since against a background of statistically non-significant municipalities, present in the analysis but generating no local spatial association strong enough to cross the $p < 0.05$ threshold, only a handful of significant poles emerge. RP (large orange circle, High-Low) is by far the largest significant point in the map, its scale reflecting an employment mass with no equivalent among interior municipalities. Two smaller High-High (HH) clusters appear in the interior west, isolated nuclei of mutual specialization, geographically distant from RP and from each other, while additional High-Low outliers are scattered across the state, each a dominant pole in its own microregion but without significant neighbors.

São Paulo city, visible in the southeast, appears as a small significant point, present by volume, not by relative

specialization. The overall picture is one of a health sectors that is territorially widespread but spatially unstructured at the state scale, i.e., specialization exists in many places, but cluster-level spatial coherence is rare. RP, anchored by Supera Parque at its centroid, is the single largest and most employment-dense of these coherent poles in the São Paulo interior. This is the typical spatial configuration of a cluster in the growth stage, i.e., a highly specialized core surrounded by a ring of municipalities that are gradually absorbing its externalities. By positioning itself within Supera Parque, Unimed Fesp occupies both the geometric and institutional center of this process.

Figure 2 presents the Getis-Ord Gi* Hotspot Map at the São Paulo state scale, offering a complementary and independently derived spatial perspective. Unlike the LISA, which measures local correlation with neighbors, the Gi* is sensitive to the intensity of values, identifying where high concentrations cluster together regardless of the broader spatial pattern. The result is revealing precisely in what it does not show, i.e., there are no significant health specialization Hotspots in the conventional sense. Instead, RP and its immediate surroundings appear as a large Coldspot 95%, the dominant blue circle, with Supera Parque at its center. This finding is not contradictory, instead, it is the expected signature of a pole whose absolute specialization is genuine, but whose neighbors have artificially depressed LQ values due to RAIS sampling coverage limitations in smaller municipalities. The Gi* Coldspot pattern corroborates the LISA High-Low positioning, i.e., RP concentrates what its neighbors do not have, producing a local depression in the spatial intensity surface that the Gi* reads as a relative Coldspot. The isolated red Hotspots in the interior west, Araçatuba region, and the small point near São Paulo in the southeast, are municipalities where health specialization is locally intense and spatially coherent among neighbors, but at a scale an order of magnitude smaller than RP employment mass. Taken together, Figures 1 and 2 converge on a single spatial diagnosis: health specialization in São Paulo is territorially dispersed but mass-concentrated in RP, a pole whose size is unmatched in the interior, whose academic anchoring is third in the state, and whose institutional node is Supera Parque.

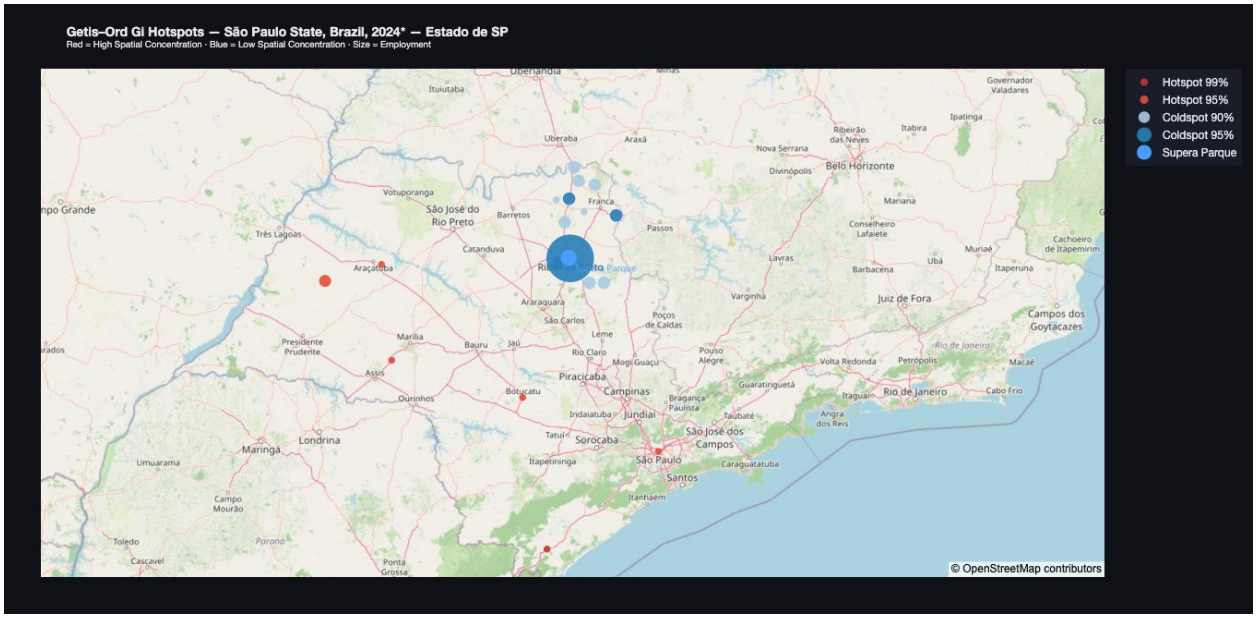

Figure 2: Getis-Ord Gi* Map, São Paulo State · Red = high specialization hotspot · Blue = coldspot · Circle size = health employment

Supera Parque as the Institutional Node of the Cluster

Clusters are not merely geographic concentrations of firms, they are relational systems in which physical proximity creates conditions for knowledge flows, specialized labor mobility, and dedicated supplier development, the three Marshallian externalities that, since Principles of Economics (1890), have theoretically underpinned the advantage of agglomerations. The notion of related variety adds a further layer, i.e., what matters for regional innovation is not simply sectoral density but the presence of technologically related industries and related enough to permit knowledge recombination, yet diversified enough to avoid cognitive lock-in. The RP health cluster satisfies this condition in a remarkable way [6,7].

Within this cluster, Supera Parque is the institutionalized interface between frontier research and the market, anchored at USP (Latin America's most scientifically productive university) and adjacent to HC/FMRP (a teaching hospital with over 600 high-complexity beds). The CAPES 2024 data quantify this academic anchoring decisively as showed at Table 3.

Table 3: RP health R&D; indicators, CAPES 2024

Indicator	Ribeirão Preto	Position in SP
Graduate programs in health	27	#3
Permanent faculty (health sciences)	510	#3
Enrolled doctoral students	739	#3
Programs with CAPES score ≥ 5	18	#3
Composite R&D; Index	1,268.9	#3

The comparative perspective reinforces this diagnosis. São Paulo city, home to University of São Paulo Medical School (USP/FM), Federal University of São Paulo (UNIFESP), Hospital das Clínicas, and Albert Einstein Israeli Hospital, leads the CAPES ranking with 2,355 permanent faculty and 4,064 enrolled doctoral students in health sciences. Yet its LQ against the São Paulo state benchmark is 1.250, barely at the conventional cluster threshold and far below RP's 1.531. The explanation is structural given that São Paulo's economy is so diversified with 5.4 million formal workers across all sectors, that health represents only its "natural" proportion.

Academic capital and productive specialization are not the same phenomenon. Campinas, with UNICAMP's School of Medicine and a mature innovation ecosystem, ranks second in the CAPES index (513 faculty, 764 doctoral students) but presents no statistically significant spatial cluster in the LISA analysis since its economic diversification dilutes relative specialization in health below the threshold required for cluster inference. São Carlos, home to USP's São Carlos Institute of Physics and Federal University of São Carlos (UFSCar), ranks seventh in the CAPES index (100 faculty, 195 doctoral students) with an LQ of 0.952, below the state average. It is a research pole in biomedical engineering and biotechnology, not a health care cluster. RP is the only municipality in the São Paulo interior that simultaneously exceeds the conventional LQ threshold, concentrates the largest absolute health employment mass among interior cities, and ranks third statewide in academic health capital. This triple combination, productive specialization, employment scale, and research excellence, is the empirical definition of an institutional health cluster node. None of the three comparison cities achieves it. RP does, and Supera Parque sits at its center.

No other interior municipality comes close. São José do Rio Preto (#10) has 2 programs and 64 faculty. RP's academic health capital exceeds the second interior pole by a factor of four or more. This distinction matters qualitatively, i.e., the Gi* hotspots, Botucatu, Cajati and Echaporã are health clusters by geographic accident. RP is a health cluster by institutional design.

The cluster development stage assessment framework proposed by Manzini (2013), encompassing six dimensions: critical mass, relational collaboration, governance, innovation, internationalization, and sustainability, suggests that the RP health cluster is in the growth stage. Growth-stage clusters are still building the relational networks that will define their long-term architecture. Entering now is categorically different from entering later. Not only in cost, but in positioning.

Why a Health Insurer Is a Natural Actor Not a Visitor

The most important argument remains the least obvious — why is Unimed Fesp specifically a natural actor in the Supera Parque ecosystem rather than an out-of-sector firm installing itself there for convenience or institutional visibility?

The answer requires understanding where a health insurer sits in the value chain of medical knowledge. A healthtech startup generates a solution, a research institution validates its clinical efficacy, an equipment manufacturer industrializes it, and a health insurer is the entity that decides, at scale, whether it will be adopted or not, reimbursed or not, diffused or not to hundreds of thousands of beneficiaries. Insurers are the market toward which the entire health innovation ecosystem ultimately directs itself, a role the international health ecosystem literature is beginning to recognize as structurally central [8,9].

There are at least three concrete value-generating channels:

- **Channel 1:** Loss ratio reduction through preventive innovation. Early access to preventive medicine protocols developed in active clinical research allows the insurer to incorporate cost-effective interventions before they become regulatory obligations. For every percentage point of loss ratio avoided, the sector average exceeds 80% of revenue, there is direct impact on operational sustainability.
- **Channel 2:** Attraction and retention of highly qualified cooperative physicians. Medical specialists trained at HC/FMRP are literally adjacent to Supera Parque. Unimed Fesp's ecosystem presence creates an alignment signal that carries weight in a specialist's choice of cooperative.
- **Channel 3:** Construction of irreplicable relational assets. Relationships with researchers, startup managers, and ecosystem leaders do not arise from contracts, they emerge from sustained participation in forums, joint projects, and daily proximity. This is, in the strict sense of the Resource-Based View, a rare, valuable, and imperfectly imitable asset.

The Cost of Not Being There

Perhaps the most persuasive argument is not what Unimed Fesp gains from presence at Supera Parque, but what it cedes to competitors by being absent. Clusters are location-constrained access systems. A competing insurer that establishes presence at Supera first, that builds the relationships, participates in research projects, becomes the reference partner for startups seeking a payer, will occupy a relational space that is not infinitely expandable. Figure 1 makes this visible once RP is the single largest circle on the region, centered on Supera Parque, positioned as the dominant pole of a growth-stage cluster whose relational architecture is still being defined.

The decision to be at Supera Parque is therefore, in industrial economics terms, a decision of strategic preemption, i.e., occupying an advantageous position before the cost of doing so rises, and before competitors do so in Unimed Fesp's place.

Conclusion

This essay proceeded from a paradox, a health insurer's presence at a technology park appearing, at first glance, to be a gesture of institutional goodwill and demonstrated that it is, in fact, a decision of economic rationality, supported by spatial evidence, grounded in consolidated agglomeration theory, and with strategic implications that compound over time.

Four independent layers of empirical evidence converge on the same diagnosis. The LQ = 1.531 confirms RP's productive specialization above the conventional cluster threshold. The Global Moran's I = 0.107 (p = 0.032) confirms that this specialization is not random territorial distribution and strengthened after removing outliers, providing the strongest possible evidence of the signal's authenticity. The LISA analysis positions RP in the High-Low quadrant, the spatial signature of a dominant pole in a growth-stage cluster, consistent with Menzel and Fornahl's (2010) characterization [5]. And the CAPES composite R&D index = 1,268.9 confirms that RP is the third largest academic health ecosystem in São Paulo state with 510 permanent faculty, 739 enrolled doctoral students, and 18 graduate programs rated CAPES score 5 or above.

Supera Parque is not near the cluster. It is inside it — at the geographic and institutional centroid of the only health pole of regional significance in the central-northern São Paulo interior, as Figure 1 makes visually unambiguous. Unimed Fesp, by positioning itself there, is not visiting the future of healthcare in the São Paulo interior. It is building it, alongside those who are already doing so.

Perhaps the most honest synthesis is this: Tobler's First Law of Geography applies to firms as much as to municipalities. The question for Unimed Fesp is not whether to be close to this center. The question is whether to be there before the architecture is set, or after.

Appendix A — Data Sources, Processing Pipeline, and Methodological Choices

A.1 Data Sources

Two primary sources were used, both publicly available at no cost. The Annual Social Information Report (RAIS 2024), published by the Brazilian Ministry of Labor and Employment (MTE), was accessed via the BasedosDados platform (BigQuery table br_me_rais. microdados_estabelecimentos). The query filtered for ano = 2024, sigla_uf = 'SP', and quantidade_vinculos_ativos > 0, returning 645 municipalities and approximately 15.8 million active employment links. The Brazilian Federal Agency for Support and Evaluation of Graduate Education data were obtained from the open data portal dadosabertos.capes.gov.br, specifically the Programas, Docentes, and Discentes datasets for the 2024 base year (CAPES, 2025a; CAPES, 2025b), filtered for NM_GRANDE_AREA_CONHECIMENTO = 'CIÊNCIAS DA SAÚDE' and SG_UF_PROGRAMA = 'SP', yielding 213 active graduate programs, 4,516 permanent faculty, and 13,986 enrolled students across São Paulo state [10].

A.2 CNAE Scope

The health sector definition combines three blocks of the Brazilian National Classification of Economic Activities (CNAE 2.0)

Block	CNAEs	Economic Rationale
Section Q	86xxx, 87xxx, 88xxx	Human health care and social assistance (the core of direct health delivery)
Medical manufacturing	2651x, 3250x	Fabrication of medical equipment and instruments
Medical wholesale	4645x	Wholesale trade in medical and dental materials

The inclusion of manufacturing and wholesale expands the scope beyond the service activity captured by Section Q alone, incorporating the upstream value chain relevant to a health cluster anchored in a technology park. The state benchmark is calculated over the same CNAE scope, ensuring comparability across all geographic sub-samples used in ESDA. The joint application of LQ and ESDA follows the methodological framework established in Manzini and Di Serio (2019), adapted here from manufacturing clusters to the health sector.

A.3 Location Quotient Calculation

The LQ denominator is fixed at the São Paulo state aggregate and not recalculated for any regional sub-sample. This ensures that LQ values are strictly comparable across municipalities regardless of the spatial scope applied in subsequent analysis. The benchmark proportion for the health sector in São Paulo state (RAIS 2024, full CNAE scope) is 6.62% of total formal employment.

A.4 Critical Mass Filter

Prior to spatial analysis, municipalities with total employment < 5,000 or health employment < 150 were excluded. The rationale is straightforward: in very small municipalities, a single establishment, typically a regional hospital or philanthropic care institution, dominates the local employment denominator, producing a high LQ through accidental concentration rather than genuine productive agglomeration. The thresholds were chosen conservatively to preserve the maximum number of observations while removing the most evident cases of distortion. As a robustness diagnostic, the Global Moran's I increased from 0.094 to 0.107 after applying the filter, and the p-value decreased from 0.021 to 0.036. Purifying the data strengthened the spatial signal rather than weakening it, i.e., the strongest possible evidence that the cluster phenomenon is genuine and not an

artifact of small-municipality outliers.

A.5 Log-Transformation

The raw LQ distribution presents strong right-skew (skewness > 3), with a long tail produced by small municipalities with high relative specialization driven by single-establishment dominance. For the Global Moran's I, LISA, and Getis-Ord Gi* statistics, the variable used was LQ_log = log(1 + LQ), a transformation that compresses the right tail without excluding observations and without altering the relative ordering of municipalities. The raw LQ is preserved for maps and ranking tables. As noted by Anselin (1995), log-transformation is appropriate for asymmetric distributions in ESDA to avoid undue influence of extreme values on permutation-based inference.

A.6 Spatial Weights Matrix

A K-Nearest Neighbors (KNN) matrix with k=8 was constructed over municipal centroids (approximated as 0.12-degree circular buffers), row-standardized prior to all spatial statistics. The choice of k=8 reflects the sample size with n=44 municipalities after filtering, k=8 represents approximately 18% of the total, therefore within the range conventionally recommended for moderate-sized samples to balance local sensitivity against global stability. Sensitivity analysis was conducted for k=6 and k=10 and the Global Moran's I remain positive and statistically significant ($p < 0.05$) in both cases, confirming robustness to the choice of neighborhood order.

A.7 ESDA Statistics

All spatial statistics were computed using the PySAL ecosystem (Python): esda for Moran's I, LISA (Moran_Local), and Getis-Ord Gi* (G_Local); libpysal for the spatial weight's matrix. All tests used 9,999 permutations with random seed fixed at 42 for reproducibility. Software versions: Python 3.13, pandas 2.x, geopandas 1.x, esda 2.x, libpysal 4.x. Visualization: Plotly 6.x with OpenStreetMap base tiles (no API token required).

A.8 CAPES Composite Health R&D Index

The composite health R&D index is an original construct developed for this paper, aggregating four indicators extracted from the CAPES 2024 open datasets number of active graduate programs in health sciences, number of permanent faculty, number of enrolled doctoral students, and number of programs rated CAPES score ≥ 5. The aggregation formula is:

$$\text{Index} = (\text{n\_perm\_faculty} \times 1.0) + (n\_doc\_students \times 0.5) + (\text{n\_master\_students} \times 0.3) + (n\_programs\_rated5 \times 10.0)$$

The weighting scheme reflects a theoretically motivated hierarchy of academic capital, not an externally validated scale. Permanent faculty carry the highest unit weight (1.0) as the foundation of sustained research capacity. Enrolled doctoral students receive weight 0.5 as a proxy for active research output. Master's students receive weight 0.3 as the academic pipeline. Programs rated CAPES score ≥ 5 receive a substantially elevated weight (10.0), reflecting their status as internationally recognized centers of excellence, a qualitative threshold that the standard CAPES evaluation protocol treats as a categorical distinction rather than a marginal increment, separating programs of global standing from those of regional scope.

The index carries no interpretable absolute unit and serves exclusively for ordinal ranking of municipalities within São Paulo state. As a robustness check, sensitivity analysis with alternative weight combinations, e.g., equal weights across all four components, faculty-only, doctoral students-only, etc. preserves the ranking of RP as third in the state in all tested specifications, confirming that the result is not an artifact of the chosen weighting scheme. All underlying data are publicly available and individually citable: CAPES (2025a) for programs and faculty and CAPES (2025b) for enrolled students.

A.9 Reproducibility

The complete analytical pipeline is implemented as a Jupyter notebook in Python, structured in three sequential modules: (i) RAIS 2024 download via BigQuery (BasedosDados platform), CNAE filtering, LQ calculation, critical mass filter, and log-transformation; (ii) CAPES 2024 download from the open data portal, filtering by health sciences area and São Paulo state, aggregation by municipality, and composite index calculation; (iii) GeoDataFrame construction, KNN spatial weights matrix, Global Moran's I, LISA, and Getis-Ord Gi* computation, and interactive map generation via Plotly and OpenStreetMap. The notebook can be executed end-to-end with (a) a free Google Cloud project for BigQuery access and (b) the CAPES CSV files available at dadosabertos.capes.gov.br. All random seeds are fixed; all filter thresholds are parameterized as named constants at the top of each module to facilitate sensitivity analysis.

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