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High-speed rail and innovation: Unpacking the mechanisms

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Abstract

High-Speed Rail (HSR) is increasingly linked to regional innovation, a connection theoretically driven by HSR's enhancement of connectivity and knowledge exchange. However, the specific mechanisms driving this relationship remain largely a 'black box,' with limited understanding of the pathways beyond formal interactions. This study systematically reviews the existing literature to understand the diverse mechanisms connecting HSR and innovation. A systematic literature review following Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines synthesised evidence from 35 key research outputs, confirming the complexity of the HSR-innovation nexus. Two key findings emerge: first, there is a notable lack of empirical evidence on how HSR fosters innovation via informal interactions and serendipity, suggesting a major research gap. Second, the existing empirical literature is overwhelmingly concentrated on the Chinese HSR network, which limits the generalisability of current findings and highlights the need for more geographically diverse research. These findings underscore that a deeper, more contextually nuanced understanding of both formal and informal mechanisms is required.

1 Introduction

The development of high-speed rail (HSR) systems represents a significant global investment in transportation infrastructure, substantially altering intercity travel times and accessibility from Japan's pioneering Shinkansen to China's extensive network and ongoing projects worldwide (Diao, 2018; Vickerman, 2018). Beyond efficient passenger transport, HSR is increasingly viewed as a catalyst for broader economic development and regional growth, widely assumed to foster innovation (Chen & Silva, 2015; Tierney, 2012). The underlying rationale draws heavily from economic geography and innovation theories. By reducing the 'friction of distance' (Chang & Zheng, 2022; Chen et al., 2023), HSR enhances effective proximity between locations. Such proximity is considered fundamental for amplifying agglomeration economies (Krugman, 1991; Marshall, 1890) and facilitating knowledge spillovers These spillovers—the transmission of ideas and expertise between individuals and firms—are widely recognised as a primary input for the creation of new knowledge and, ultimately, measurable innovation (Audretsch & Feldman, 1996; Jaffe et al., 1993). In this context, the exchange of valuable tacit knowledge, which often requires face-to-face interaction, is particularly pertinent (Gertler, 1995; Long & Yi, 2024). By enabling easier movement of people and ideas, HSR is therefore anticipated to stimulate regional innovation and competitiveness.

The concept of innovation itself is multifaceted and notoriously difficult to measure directly. Consequently, the empirical literature—including the studies reviewed in this paper—relies on a range of indicators to act as proxies for innovative activity and its economic consequences. These proxies can be broadly categorised into direct measures of innovative output, such as patent counts and citations (Jaffe, Trajtenberg, & Henderson, 1993), and indirect economic measurements that are considered outcomes of an innovative and productive environment.

The latter category includes increases in Total Factor Productivity (TFP), new firm formation, and the performance of knowledge-intensive firms (Griliches, 1990). While these economic indicators are not synonymous with innovation, they are widely used in the literature on the premise that sustained productivity growth and economic dynamism in knowledge-based sectors are driven by the successful implementation of new ideas and technologies. This review, therefore, considers studies using both direct and indirect indicators to provide a comprehensive overview of the HSR-innovation nexus as it is currently measured and understood.

Despite this compelling theoretical and intuitive rationale linking HSR, proximity, and innovation via concepts like agglomeration and knowledge spillovers, translating this broad logic into specific, empirically verifiable pathways presents significant complexity. The potential influence of HSR could operate through numerous channels – impacting how individuals interact, how firms behave and organise, how factors of production move, and how markets function. Furthermore, the effects are likely shaped by the structure of the HSR network itself and moderated by diverse local conditions (Vickerman, 2018). Given this inherent complexity, achieving a clear, synthesised understanding of the specific mechanisms driving the observed HSR-Innovation relationship is challenging. Whilst individual studies may investigate certain aspects, a comprehensive overview mapping the range of proposed mechanisms and assessing the aggregate empirical focus across the field appears necessary. Without such a synthesis, it remains difficult to ascertain the relative importance of different potential pathways, identify areas where evidence is well-established versus under-researched, or pinpoint potential blind spots in the current research landscape – such as the degree to which less structured social interactions, known to be relevant for innovation broadly (Granovetter, 1973; Merton & Barber, 2004), are accounted for within HSR studies. Therefore, a systematic review is warranted to structure the existing knowledge and clarify the current state of understanding regarding the mechanisms linking HSR and innovation.

To address this need, this paper employs a Systematic Literature Review (SLR) methodology to comprehensively identify, evaluate, and synthesise existing research investigating the relationship between HSR and innovation. Specifically, this review aims to:

1. Map the range of mechanisms proposed or studied in the literature that link HSR to innovation outcomes and present a summary of these key thematic findings.
2. Assess the nature and focus of the empirical evidence supporting identified mechanisms, noting areas that have received investigative attention and those that have not.
3. Identify potential gaps or imbalances in the current understanding based on the synthesised literature, with a particular focus on the role of informal interactions.

By systematically collating and organising the existing knowledge, this review seeks to provide an overview of the proposed HSR-innovation pathways and the state of their empirical investigation, thereby establishing a foundation for future, targeted research. The remainder of this paper details the SLR methodology (Section 2), presents a summary of the key findings from the literature (Section 3), discusses these findings and their implications (Section 4), and offers concluding remarks and future research directions (Section 5).

2 Methodology

This study employed a systematic literature review (SLR) methodology to identify, evaluate, and synthesise the existing research on the relationship between HSR and innovation. The review focused on identifying the mechanisms linking HSR and innovation and exploring the role of knowledge worker mobility and unplanned interactions within this context. The SLR was conducted following the principles of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2009), adapted to the specific context of this research. Specifically, we adhered to PRISMA guidelines for conducting a

systematic search, defining explicit eligibility criteria, and performing data extraction and synthesis.

2.1 Eligibility criteria

To ensure a focused and relevant body of literature, we established the following inclusion and exclusion criteria, which are detailed in Table 1.

Table 1: SLR inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
Publication Type	Peer-reviewed journal articles, conference papers, and book chapters. Some grey literature (reports, theses, working papers) was also considered.	Editorials, commentaries, and book reviews.
Language	English	Any language other than English
Publication Date Range	No date restriction was applied. While the focus was on recent research, foundational older works were considered relevant for establishing the theoretical basis of the study.	
Geographic Scope	Studies from any geographic context were included, with particular interest in countries with established HSR systems (e.g., China, Japan, Europe) and countries considering HSR development (e.g., Australia).	
Subject Matter	Studies that explicitly examined the relationship between HSR and innovation, broadly defined. Studies focusing solely on technical aspects of HSR without addressing economic or innovation impacts were excluded. Studies were required to investigate at least one mechanism by which HSR might influence innovation or economic growth more generally.	Studies that did not address the relationship between HSR (or analogous high-speed transportation infrastructure) and innovation.
Methodology	Studies using quantitative, qualitative, or mixed methods. Priority was given to studies using rigorous quantitative methods attempting to establish causal relationships (e.g., difference-in-differences, spatial econometrics).	Purely descriptive studies without a clear analytical framework.
Outcomes	Studies that considered at least one of the following outcomes: patents, new firm formation, knowledge flows, labour market effects, regional development, or other relevant indicators of innovation.	Studies that did not measure or analyse any innovation-related outcomes.

2.2 Information sources and search strategy

We conducted a comprehensive search of the following electronic databases:

- Science Direct
- Scopus
- Web of Science
- Google Scholar
- TRID (Transport Research International Documentation)
- ProQuest One Academic
- JSTOR
- Oxford Academic
- Springer

Searches were conducted in February and March 2025.

An iterative, multi-stage search strategy was employed. Initial broad searches used general terms related to HSR, mobility, and innovation. These searches yielded a large number of

results, many of which were not directly relevant. Therefore, we progressively refined the search terms, using more specific keywords (e.g., "knowledge spillovers"), combining terms with the Boolean operator 'AND', and employing field restrictions (e.g., searching within titles and abstracts) to improve precision. We also used proximity operators (e.g., NEAR/n in Web of Science) and truncation (e.g., "patent*") to capture variations of terms. The search terms were refined until the number of search results was manageable (n<400), while still broad enough.

In addition to the database searches, we employed 'snowballing' techniques, checking the reference lists of key articles to identify additional relevant studies (backward citation chasing) and using the databases to identify articles that cited key foundational works (forward citation chasing). Keywords identified in these articles were then used in the crafting of subsequent systematic search terms to ensure similar papers were also identified.

2.3 Study selection process

The study selection involved a multi-stage screening process, visually detailed in the flowchart (Figure 1). After initial record identification from databases and snowballing (Section 2.2) and the removal of duplicates, titles and abstracts were reviewed against the basic eligibility criteria (Table 1). At this first screening stage, clearly irrelevant records (e.g., wrong topic, non-English, incorrect acronym interpretation) or those lacking sufficient abstract information were excluded.

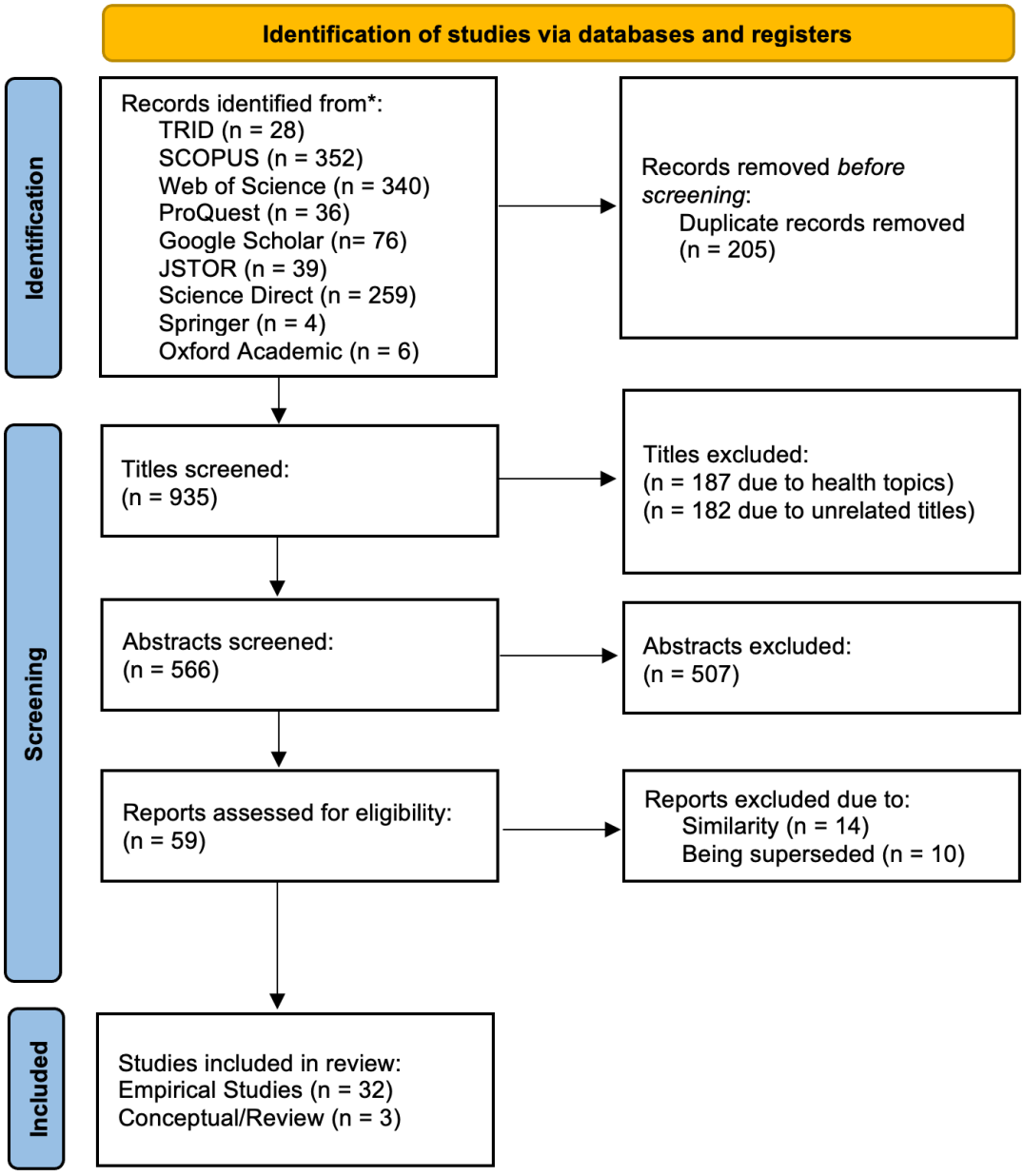
Remaining abstracts then underwent a more detailed assessment for substantive relevance to the review's focus on HSR-innovation mechanisms. This stage saw a significant reduction in papers, as a large volume of literature that was initially captured by keyword searches did not meet the specific requirements for synthesising the causal pathways linking HSR, knowledge workers, and innovation. The key reasons for exclusion, based on abstract content, were grouped into the following categories:

- **No Link to HSR or Analogous Infrastructure:** Many papers discussed knowledge worker mobility, collaboration, or innovation in a general sense but had no connection to transportation infrastructure, a core component of this review. For example, a study on collaboration patterns within a single tech company's office would be excluded.
- **No Focus on Knowledge Workers or the Knowledge Economy:** A substantial number of HSR-related papers focused on impacts outside the scope of this project, such as general passenger travel, tourism, or effects on sectors not directly tied to knowledge-intensive innovation. A paper titled "The Impact of HSR on Tourism in Coastal Regions" or a study on "HSR and Construction Sector Employment" would fall into this category.
- **No Relation to Innovation, Serendipity, or Knowledge Exchange:** Some studies linked HSR to knowledge workers but did not discuss the innovation or knowledge flow outcomes central to this review. An abstract describing "Commuting Time Savings for Professional Workers on the New HSR Line," for instance, would be excluded as its focus is on direct travel benefits rather than the subsequent impacts on innovation.
- **Overly Narrow Scope Lacking Generalisable Insights:** A portion of the literature examined highly localised or specific economic impacts without attempting to connect these to broader, generalisable mechanisms. For example, a study quantifying the real estate value uplift in a single development adjacent to a station, without a link to innovation processes, would be excluded.
- **Purely Methodological Contributions:** A small but distinct category of papers used the HSR rollout as a convenient dataset to demonstrate a new econometric or spatial modelling technique. In these cases, the paper's primary contribution was methodological, with little to no substantive findings or discussion on the socio-economic impacts of HSR itself.

These stringent criteria were necessary to isolate the literature that explicitly engaged with the causal pathways linking HSR infrastructure to broader regional innovation outcomes. Consideration was also given during screening to prioritise studies relevant to knowledge-intensive sectors and, where possible, to include diverse geographical contexts, acknowledging the literature's strong focus on China.

Finally, shortlisted articles were retrieved and assessed. Studies found to be redundant, often due to significant overlap with more recent or comprehensive papers already selected, were excluded. This iterative screening process resulted in the final corpus of 35 key studies (32 empirical and 3 conceptual/review), which were then taken forward for data extraction and synthesis.

Figure 1: Systematic literature review PRISMA framework flowchart



2.4 Data extraction

Data were extracted using a standardised data extraction form. The following data were extracted from each included study:

Author(s) and Year of Publication

- Article Title
- Journal
- Country or Region Studied
- Core research question/objective
- Underlying theories/concepts
- Research Design/Techniques
- Specific data used
- Main results related to HSR-innovation
- Identified or inferred mechanisms
- Factors influencing the HSR-innovation link
- Acknowledged or identified limitations
- Main Contribution
- Authors' assigned keywords.

2.5 Data analysis and synthesis

Data extracted from these 35 studies were analysed using a combination of content analysis, thematic analysis, and tabular analysis. We identified recurring themes and patterns across the studies related to the mechanisms linking HSR and innovation and the contextual factors influencing the relationship. The findings were synthesised narratively, highlighting areas of agreement, disagreement, and gaps in the literature. The tabular analysis was used to compare and contrast the key findings related to mechanisms across the included studies.

3 Results

The systematic literature review process resulted in a final corpus of 35 key research outputs, comprising 32 empirical studies and 3 conceptual/review papers. A geographical distribution analysis of the 32 empirical studies was conducted to substantiate the claim of a strong regional focus within the literature. This analysis confirmed that existing research is overwhelmingly concentrated on the Chinese HSR network, which was the primary subject of 23 studies. The remaining empirical work examined HSR systems in Europe (a combined total of 3 studies focusing on Germany, France, and Spain), Japan (2 studies), and the United States (2 studies). A single study took a global empirical perspective, and one context-specific Canadian study on technology adoption was included for its theoretical relevance to interaction mechanisms. This geographical imbalance is discussed further in Section 4.3.

Thematic analysis and synthesis of these 35 research outputs revealed several recurring and interconnected categories of mechanisms through which HSR is understood to influence innovation. While a detailed, multi-component framework was developed during the initial synthesis, for the purposes of this conference paper, these mechanisms are presented as broad thematic pathways. These include:

- **Connectivity enhancements and accessibility gains:** A foundational theme across nearly all studies was the direct effect of HSR in reducing travel times and increasing inter-city accessibility. This was often quantified through measures like weighted average travel time or market potential, forming the basis for subsequent impacts.
- **Facilitation of human interaction and knowledge exchange:** A significant body of literature links improved accessibility via HSR to enhanced opportunities for human interaction. The evidence strongly points towards the facilitation of formal, direct knowledge exchange, such as increased inter-city academic co-authorship, patent collaborations between firms in connected cities, and improved management of multi-locational businesses.
- **Inducement of structural economic and organisational reorganisation:** Beyond direct interaction, the review identified numerous studies detailing how HSR acts as a catalyst for broader structural adjustments. These include the reallocation of capital (e.g., attracting fixed asset investment), the spatial sorting of talent, firms, and

industries (e.g., concentration of service industries), and alterations in firm strategy and internal organisation in response to reduced communication and travel costs.

- **Mediation by network characteristics and spatial dynamics:** The literature also emphasises that the impact of HSR is not uniform but is significantly mediated by the HSR network's topology, a city's positionality (centrality) within that network, and complex spatial dynamics such as spillover effects, concentration tendencies, and siphoning effects.
- **Moderation by local contextual factors:** Finally, the translation of HSR's potential into actual innovation outcomes was consistently shown to be highly moderated by pre-existing local conditions. These include geographic factors (e.g., city size, core-periphery status), industrial structure, institutional quality, and the presence of complementary government policies.

These thematic pathways, derived from the synthesis of the 35 reviewed studies, are further illustrated in Table A1. This table presents representative research examples for each theme, detailing the HSR-induced mechanism, the broader outcome investigated, the key outcome indicators used, and the overarching thematic pathway to which each study contributes.

As evidenced in Table A1, the reviewed literature covers a range of HSR-induced mechanisms and innovation outcomes. Studies frequently highlight enhanced connectivity as a primary trigger (e.g., Ahlfeldt & Feddersen, 2017), leading to facilitated formal collaborations (e.g., Hanley et al., 2022) and significant structural economic changes (e.g., Diao, 2018). The table also illustrates the mediating role of network dynamics and the moderating influence of local contexts. However, it is also apparent from the thematic focus of the studies that formal interaction channels are more extensively explored than informal ones, an aspect that will be examined further in the Discussion (Section 4).

4 Discussion

The systematic literature review presented in Section 3 summarised the key thematic pathways through which HSR is understood to influence innovation. Building on these findings, this section digs deeper into their implications. It interprets the dominant themes in the HSR-innovation literature, examines a prominent research gap concerning informal interaction mechanisms, and considers the broader consequences for policy and future research directions.

4.1 Interpreting the landscape of HSR-innovation mechanisms

The emphasis on connectivity enhancements as a foundational HSR impact underscores HSR's role in strengthening formal knowledge exchange channels, such as academic and inter-firm collaborations, likely supporting existing strong ties or activating formerly established weak ties. This suggests that HSR is perceived and utilised as a tool for planned and structured interactions. Beyond these direct interaction effects, the literature points to HSR as an enabler of significant structural economic shifts, including capital reallocation, the spatial sorting of talent and firms, and market integration. These indirect structural adjustments appear to be key components of HSR's overall impact, reshaping the economic landscape within which innovation occurs. Furthermore, the review highlights the decisive roles of HSR network centrality and the spatial decay of benefits, alongside the substantial moderating influence of pre-existing local contexts (such as city size, industrial structure, and institutional quality) in shaping the ultimate innovation outcomes. This complex, contingent nature means that HSR investment alone is unlikely to be a panacea for stimulating innovation without considering these mediating and moderating factors.

4.2 Theoretical tensions: agglomeration economies vs. knowledge spillovers

Beyond the specific mechanisms identified, the reviewed literature also reflects a broader theoretical tension within economic geography concerning the primary drivers of urban and regional development: agglomeration economies versus knowledge spillovers. While often

used interchangeably, these concepts represent different levels of analysis. Agglomeration economies typically refer to the benefits firms derive from co-location, such as access to a shared labour pool, specialised suppliers, and a large customer base (Marshall, 1890). In HSR research, studies emphasising this perspective tend to use macro-level economic indicators like GDP, firm productivity (TFP), or new firm formation as their primary outcomes (e.g., Ahlfeldt & Feddersen, 2017; Zou & Chen, 2024). These studies implicitly treat knowledge exchange as one of several 'black box' benefits of proximity, with the primary unit of analysis being the firm or the region and the driving force being economic mass and reduced transaction costs. This perspective also accounts for potential negative outcomes, such as the 'siphoning' or 'shadow' effect, where improved connectivity allows dominant core cities to draw resources and talent away from peripheral areas, leading to increased spatial inequality (e.g., Yu & Jin, 2023).

In contrast, literature focusing on knowledge spillovers as a mechanism looks at the transmission of ideas and knowledge that is not fully compensated through market transactions (Jaffe et al., 1993). Studies from this perspective, as seen in our review, are more likely to use direct measures of knowledge creation and diffusion, such as patent citations, co-authorship networks, and technology transfer agreements as their key outcome indicators (e.g., Dong et al., 2020; Long & Yi, 2024). Here, the primary driver of innovation is not merely co-location, but the facilitated interaction that enables the flow of valuable, often tacit, knowledge.

This systematic review reveals that the HSR literature draws from both perspectives without always explicitly reconciling them. HSR is seen as both a catalyst for increasing economic mass and market potential (supporting the agglomeration view) and as a conduit for facilitating the face-to-face interactions necessary for high-value knowledge spillovers. The differing conclusions in the literature—whether HSR leads to concentration (an agglomeration effect) or more balanced regional knowledge sharing (a spillover effect)—can partly be explained by which of these theoretical lenses and corresponding methodologies a study adopts. Recognising this tension is important for interpreting HSR's complex role; it is likely that both forces are at play, and their relative importance may vary depending on the specific industry, policy context, and the type of innovation being measured.

4.3 The prominent gap: informal interactions, weak ties, and serendipity

Beyond the documented pathways primarily involving formal interactions and structural reorganisations, an important insight from this review is the lack of research attention on the mechanisms through which HSR might foster innovation via informal interactions, the activation of informal weak ties, or serendipitous encounters. This is somewhat surprising, given the well-established theoretical prominence of such pathways for accessing novel information, bridging diverse knowledge domains, and sparking the creativity necessary for significant innovation (Granovetter, 1973; Kauffman, 2000; Merton & Barber, 2004). While HSR demonstrably reduces the cost of travel for planned meetings, its potential to increase the unplanned interactions between diverse individuals or to facilitate the maintenance of a broader, geographically dispersed network of weak ties has not been systematically investigated. This oversight may lead to an underestimation of HSR’s full innovation potential or a misunderstanding of the nuanced ways it could contribute. For instance, the train journey itself, or the increased footfall in and around HSR stations, could present opportunities for such encounters, but these remain largely conjectural in the HSR literature. The current focus on measurable outcomes like patents and formal collaborations may inadvertently sideline these less tangible but potentially major innovation drivers.

4.4 Implications of geographical concentration in research

The review confirmed the predominant focus of existing empirical research on the Chinese HSR network, as detailed in Section 3. While China's recent, rapid, and extensive HSR rollout provides a unique 'natural laboratory' for studying its impacts, this geographical concentration severely limits the generalisability of the current body of evidence. It is prudent to clarify that

this research imbalance does not necessarily imply that the HSR-innovation connection is weak or non-existent in other HSR-intensive regions like Europe or Japan. Rather, it signifies a critical blind spot in the literature. The specific institutional, economic, and cultural contexts of different regions undoubtedly shape how HSR mechanisms operate. For instance, the top-down, state-led economic planning in China may create different conditions for firm relocation and industry specialisation compared to the more market-driven dynamics in Europe. Therefore, the lack of research in these other contexts means we currently have a poor understanding of whether the same mechanisms are at play, or if different pathways are more dominant. Consequently, caution is warranted when attempting to transfer lessons or policy implications, underscoring the urgent need for more contextually diverse research.

4.5 Policy considerations

The high-level findings and identified gaps suggest several considerations for policymakers aiming to leverage HSR for innovation. Firstly, the evidence implies that simply providing HSR infrastructure is insufficient; complementary policies are likely needed to translate connectivity into innovation. This might include initiatives that support talent mobility, foster local absorptive capacity, or encourage inter-regional networking. Secondly, the significant gap concerning informal interactions suggests that policymakers and planners might consider how HSR and associated urban developments (e.g., station precincts) could be designed or programmed to foster environments conducive to a wider range of social and professional interactions, beyond just facilitating efficient point-to-point travel for formal purposes. Finally, the importance of context means that policies must be tailored to local conditions rather than adopting a one-size-fits-all approach.

5 Conclusion and future research directions

This paper presented a systematic literature review identifying key mechanisms linking HSR and innovation. The summarised findings (Section 3) revealed several dominant thematic pathways, whilst the discussion (Section 4) highlighted the significance of these mechanisms, the critical research gap concerning informal interactions, and the implications of geographical concentration in current research.

Building on these observations, several key directions for future research are proposed:

1. **Investigating informal and serendipitous mechanisms:** There is a critical need for research to empirically explore how HSR may facilitate informal social interactions, the development or activation of weak ties, and serendipitous encounters that can lead to innovation. This requires methodological innovation, potentially employing qualitative approaches (e.g., interviews, ethnography), interaction diaries, or advanced network analysis to capture these more elusive dynamics, both at destinations and potentially during the HSR journey itself.
2. **Differentiating interaction and knowledge types:** Future studies should aim to move beyond treating 'interaction' monolithically. Research could differentiate HSR's impact on strong versus weak ties, formal versus informal interactions, and the exchange of tacit versus codified knowledge, thereby providing a more nuanced understanding of knowledge flow processes.
3. **Modelling complexity and dynamics:** The interplay of HSR connectivity, interaction, structural changes, network effects, and contextual moderators is inherently complex and dynamic. Future research could employ statistical techniques suited for moderated mediation analysis or computational models like Agent-Based Modelling (ABM) or temporal network analysis to explore these interdependencies and potential feedback loops over time, even without a universally accepted detailed framework.
4. **Broadening geographical and comparative contexts:** To enhance the generalisability of findings, comparative studies across diverse institutional and economic settings (beyond China) are essential. This research should test the applicability of identified mechanisms in different contexts and could also compare

HSR's impact on interaction patterns and innovation with that of alternative transport modes.

5. **Disaggregating innovation outcomes:** Innovation is not a homogenous outcome. Future work could explore whether different HSR-induced mechanisms (e.g., those supporting strong-tie reinforcement versus weak-tie bridging) differentially affect various types of innovation, such as radical versus incremental, technological versus service, or conventional versus unconventional innovations (Berkes & Gaetani, 2021).

In conclusion, while this review has shed light on the primary mechanisms documented in the HSR-innovation literature, it also underscores the journey that remains in fully understanding this complex relationship, particularly the under-explored informal dimensions. Continued mechanism-focused research, adopting diverse methodologies and geographical contexts, is vital for guiding effective policy interventions.

Data availability statement

Data supporting this systematic literature review are openly available. The comprehensive search strategy is provided in a supplementary data file, which can be accessed at: https://drive.google.com/drive/folders/1ZWoUtPYA_FuRz1YtxvmHrxDSJ-JrMaGS

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Appendix A

Table A1: Overview of key studies and thematic mechanism pathways linking HSR and innovation

Citations	Mechanism (HSR-induced)	Broader outcome	Key outcome indicator(s) used	Thematic pathway
Ahlfeldt and Feddersen (2017)[1]	Connectivity (Market Potent.)	Economic Productivity	GDP	Connectivity Enhancement
Hanley et al. (2022); Yang and Ma (2023)	F2F Ease / Reduced Interaction Cost	Collaborative Innovation	Collaborated Patents, Citations	Human Interaction / Knowl. Exch. – Formal/Strong Ties
Dong et al. (2020)		Academic Collaboration	Co-authorship, Pubs Qty/Qlty	
Long and Yi (2024)		Knowledge Diffusion	Patent Citations	
Bhatt and Kato (2021); Miwa et al. (2022); Zhang et al. (2020)	Improved Access / Knowledge Spillovers / Interaction	Innovation / Knowledge Productivity	Patents	
Li et al. (2024)	Network Effect	Inter-city Technology Transfer	Patent Trade	
Russell et al. (2024)	Informal Interaction Potent.	Social/Tacit Knowledge Exchange	Conceptual Knowl. Flow	Human Interaction / Knowl. Exch. – Informal/Weak Ties/Serendipity (Conceptual/Theoretical)
Diao (2018)	Connectivity	Capital Attraction	FAI	Structural Reorganisation – Factor Mobility
Wang et al. (2024)		Talent Attraction/Mobility	Urban Innov. Index; Patents	
Liu et al. (2023)		Factor Outflow (Periphery)	New Firms (-); Capital/Labor Outflow	
Chang and Zheng (2022)		Sectoral Firm Sorting	New Firms (by sector)	
Chen and Silva (2015)	Accessibility	Firm & Population Attraction	Firms; Pop.; GDP; Employment	
Charnoz et al. (2018)	Comm. Cost ↓	Firm Functional Specialisation	Job/Skill Allocation	Structural Reorganisation – Firm Strategy/Organisation
Chen et al. (2023)		Affiliate Network Expansion	Affiliate No./Distance	
Kuang et al. (2021)	Connectivity	Firm Performance Increase	Financial Performance Metrics	

Citations	Mechanism (HSR-induced)	Broader outcome	Key outcome indicator(s) used	Thematic pathway
Zou and Chen (2024)	Market Access ↑	Firm Productivity (Comp/Scale)	TFP	Structural Reorganisation – Market/Industry Shifts
Chen and Guo (2023)	Connectivity	Technological Specialisation	Tech. Diversity Index (-)	
Gao and Zheng (2020)		Firm Innovation (Companion Test)	Firm Innovation Survey Data	
He et al. (2025)	Network Effect	Service Industry Development	Sectoral Output	
Li et al. (2023)	Operation	Economic Resilience	Econ. Resilience Index	
An et al. (2022)	Network Structure	Spatial Hierarchy Reinforcement	Connectivity; Centrality	Network/Spatial Dynamics (Mediators)
Yu and Jin (2023)		Siphoning from Non-core Cities	Service Sector Output (-)	
Zhu and Yue (2024)		Regional Balance/Status (Small Cities)	Coop. Patents (LCIS)	
Tian et al. (2023)	Network Position	Agglomeration Economies Boost	Network Position	
Yi et al. (2025)	Connectivity (Station Prox.)	Localised Entrepreneurship	New Firm Registrations ('Pass-thru')	
Shi et al. (2025)	Network Effect	Industrial Upgrading (Borrowed Size/Power)	Sectoral Output Shift	
Tierney (2012)	HSR Impact (Conceptual)	Knowledge Economy Growth	Conceptual (Policy, Urban Form)	Contextual Contingencies (Moderators - Conceptual/Illustrative)
Vickerman (2018)	Transformation (Conceptual)	Economic Transformation	Conceptual (Complementary Policy)	

Notes: [1]Enhanced connectivity/accessibility is a foundational premise in nearly all reviewed studies investigating HSR impacts e.g., (Diao, 2018; Komikado et al., 2021; Long & Yi, 2024). Ahlfeldt and Feddersen (2017) is highlighted here for its specific focus on quantifying this effect via Market Potential.

Contextual & Theoretical Papers (Not listed in table for specific Mechanism -> Indicator mapping): Gertler (1995): Provides important non-HSR context on the importance of physical, organisational, and cultural proximity for tacit knowledge transfer in technology adoption. Cross et al. (2010): Offers non-HSR insights into the role of informal organisational networks in knowledge flow and innovation. Berkes and Gaetani (2021): Explores how urban density (non-HSR context) links to diverse informal interactions and unconventional innovation, providing background for the weak ties and moderation themes.

Abbreviations: FAI=Fixed Asset Investment; TFP=Total Factor Productivity; LCIS=Low-Carbon Innovation Synergy; F2F=Face-to-Face; Comm=Communication; Org=Organisation; Econ=Economies; Knowl=Knowledge; Tech=Technology; Coop=Cooperative; Pubs=Publications; Emp=Employment; Pop=Population; (-)=Negative effect found.