Research Policy 55 (2026) 105542

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

Connectivity infrastructure and innovation: The effects of headquarters versus subsidiary management

Catherine Magelssen [a], Luis Ballesteros [b,*], Casidhe Troyer [c]

[a] University of South Carolina, 1014 Greene Street Columbia, SC 29208, United States
[b] Questrom School of Business, Boston University, 595 Commonwealth Avenue, Boston, MA 02215, United States
[c] London Business School, Sussex Place, Regent's Park, London, NW1 4SA, United Kingdom

ARTICLE INFO

Keywords:
Innovation performance
Multinational enterprises (MNEs)
R&D subsidiaries
Knowledge transfer
ICT infrastructure
Headquarters
Organizational structure

ABSTRACT

Improvements in connectivity infrastructure can stimulate innovation by reducing information frictions across locations, yet firms benefit unevenly, and the organizational sources of this heterogeneity remain insufficiently understood. Drawing on information processing theory, this study examines how the locus of managerial authority within multinational enterprises (MNEs)—specifically, whether R&D subsidiaries are managed by headquarters or by another subsidiary—influences the change in innovation from improved connectivity. We use a novel longitudinal dataset covering 1004 R&D subsidiaries from 78 MNEs and exploit the staggered global rollout of broadband as a quasi-exogenous shock to connectivity. Triple difference analyses using matched samples indicate that broadband increases subsidiary innovation on average, but the effects are driven by R&D subsidiaries managed by other subsidiaries. These subsidiaries experience substantially larger post-broadband increases in innovation productivity, knowledge flows from, and co-inventions with their managing entity than headquarters-managed subsidiaries. Additional analyses indicate that the gap widens when headquarters face greater information complexity, associated with larger MNE size, more extensive international operations, and broader roles, suggesting that headquarters' heavier information load constrains its ability to leverage improved connectivity. Consistent with information processing under constraints, we find suggestive evidence that headquarters prioritize their most important and technologically proximate subsidiaries. In contrast, subsidiary-managed units achieve innovation gains more broadly. Overall, the findings show that the innovation benefits of connectivity infrastructure hinge on organizational structure, highlighting the pivotal role of subsidiaries in managing innovation and the conditions that can impede or enhance these effects, advancing understanding of both connectivity-enabled innovation and MNE management.

1. Introduction

Improvements in connectivity infrastructure such as new flights, better roads, and faster telecommunications can stimulate innovation by facilitating information transfer across locations (Agrawal et al., 2017; Koh et al., 2025). Greater connectivity enhances innovation by enabling collaboration and knowledge flows between sites (Bahar et al., 2023; Catalini et al., 2020; Forman and van Zeebroeck, 2019, 2012) and strengthening managers' ability to monitor and support distant R&D (Bernstein et al., 2016; Glaeser et al., 2023). These effects are especially crucial for multinational enterprises (MNEs), the primary engines of global innovation, which must manage R&D across diverse geographic and technological contexts while contending with substantial information frictions (Branstetter and Maskus, 2022).

However, considerable firm-level heterogeneity in the benefits of connectivity infrastructure remains unexplained (Campante and Yanagizawa-Drott, 2018; Wu et al., 2021) despite trillions of dollars invested in digital and physical connectivity each year (Donaldson, 2018; OECD/ITF, 2025; PwC, 2025; World Bank, 2024). Existing research has thus far shown that the benefits of connectivity infrastructure depend on *external* contingencies such as local innovation resources and the cultural, geographic, or technological distance between locations (Bahar et al., 2023; Catalini et al., 2020; Forman and van Zeebroeck, 2019), as well as on firm or R&D operation size (Bahar et al., 2023). Far less attention, however, has been given to how the impact of connectivity on innovation depends on firms' *internal*

* Corresponding author.
E-mail addresses: catherine.magelssen@moore.sc.edu (C. Magelssen), luis@bu.edu (L. Ballesteros), ctroyer@london.edu (C. Troyer).

https://doi.org/10.1016/j.respol.2026.105542
Received 3 May 2025; Received in revised form 19 April 2026; Accepted 1 June 2026
Available online 6 June 2026

management structures, which are integral to innovation. Information processing theory (IPT) emphasizes that reporting structures shape the access, flow, and processing of information within firms (Galbraith, 1973; Tushman and Nadler, 1978). Accordingly, the gains from improved connectivity may differ depending on where authority over R&D subsidiaries resides within MNEs. Because organizational structures are relatively “sticky,” often taking many years or even decades to change (Bloom et al., 2012; Bresnahan et al., 2002; Cuervo-Cazurra et al., 2019), some firms may be structurally better positioned than others to capture the innovation benefits of improved connectivity. To date, studies have not systematically examined how internal management structures condition the effects of improved connectivity infrastructure.

This study investigates how systemic structural differences in authority over R&D within MNEs, specifically whether R&D is managed by headquarters (HQ) or by managing subsidiaries (MS), influences the innovation outcomes of improved connectivity infrastructure. HQ occupies a distinct position as the central informational hub of the corporate network (Egelhoff, 1991). However, to reduce information frictions with geographically dispersed R&D subsidiaries, MNEs often grant MS formal authority to manage other R&D subsidiaries, rather than having HQ oversee all R&D (Schotter et al., 2017). MS's proximity to R&D subsidiaries and regions of expertise can improve monitoring and access to knowledge (Gumpert et al., 2022). Like HQ, MS select and fund projects, share knowledge, monitor, and coordinate innovation activities (Aghion and Tirole, 1994; Roth and Morrison, 1992; see Fig. 1), thereby alleviating HQ's information-processing burden.[1] Consequently, the locus of authority, HQ or MS, may shape how improved connectivity translates into innovation performance.

On the one hand, HQ's central position gives it broad access across entities, regions, and activities to firm-wide knowledge and resources that often surpass those of MS (Egelhoff, 1982). Improved connectivity with an R&D subsidiary may amplify these advantages by enabling HQ to exchange richer, more timely information and to deploy its superior knowledge more effectively with the R&D subsidiaries it manages (Huber, 1990), ultimately improving their innovation outcomes. Moreover, prior research suggests that MS reduce geographic frictions that hinder innovation (Gumpert et al., 2022). If connectivity infrastructure substitutes for proximity by reducing information frictions, then MS may realize smaller marginal gains than HQ and the relative advantage that they derive from their geographic position may diminish. Under this logic, HQ-managed subsidiaries will experience greater increases in innovation from improved connectivity than those managed by MS.

On the other hand, HQ's central position may constrain its ability to fully exploit the opportunity for more efficient and richer information exchange (Galbraith, 1973; March and Simon, 1958). HQ faces inherently higher information-processing demands than MS because its parental role within the MNE group requires the integration of information from a wide range of operations (Egelhoff, 1982; Galbraith, 1977). The more diverse the set of tasks overseen by managing entities, the greater the informational complexity, i.e., the variety, volume, and interdependence of information that must be processed (Daft and Lengel, 1986; West, 2000). Although HQ may increase headcount to assist with information processing, decision making is ultimately concentrated in a small number of key central actors (i.e. senior managers), and their bounded rationality creates inherent bottlenecks that persist (March and Simon, 1958; Henderson and Fredrickson, 1996). A substantial stream of research has demonstrated that there are limits to HQ information processing ability (Bouquet and Birkinshaw, 2008; Gumpert et al., 2022) and adjusting HQ scale to address information complexity leads to bureaucracy and ineffective management. Thus, improved connectivity may exacerbate HQ's burden, leading to overload and diminishing innovation returns if processing demands outpace capacity (Galbraith, 1973; Henderson and Fredrickson, 1996). In contrast, MS tend to have narrower responsibilities than HQ, facing fewer information-processing demands and less complexity (Egelhoff, 1982; Tushman and Nadler, 1978). As a result, MS may be better positioned to leverage their knowledge and expertise with improved connectivity to support R&D subsidiary innovation, yielding relatively greater marginal benefits for MS-managed subsidiaries than for those managed by HQ.

Existing research offers no definitive prediction regarding which effect, if any, dominates. Additionally, multiple mechanisms may operate simultaneously. Therefore, we abductively investigate how HQ and MS management influence the effects of new connectivity infrastructure on R&D subsidiary innovation. This research goal faces three key empirical challenges. First, innovation management within firms is notoriously difficult to observe (Aghion et al., 2014). Prior studies have relied on proxies such as patent assignments and surveys, each with limitations. Patent assignments do not indicate when R&D subsidiaries are managed by other subsidiaries and involve legal confounders.[2] Surveys are typically cross-sectional and raise endogeneity concerns. Second, the assignment of managerial responsibility is likely endogenous to innovation performance. MNEs may systematically match R&D subsidiaries with managing entities that can provide better resources. Third, improvements in connectivity infrastructure may be endogenous to either the assignment of managerial responsibility or innovation performance.

We address these challenges as follows. First, we compile a rich longitudinal dataset from transfer pricing reports, identifying managing entity-R&D subsidiary relationships across 78 MNEs and their managed 1004 R&D subsidiaries worldwide. We later test the sensitivity of our results to tax avoidance in Section 4.1.7. Second, we exploit the staggered introduction of broadband infrastructure at the country level as a new connectivity infrastructure that dramatically eased information flows between locations. We implement staggered triple difference-in-differences (DDD) analyses that account for underlying differences in innovation between HQ- and MS-managed subsidiaries and use matched samples. Broadband represented a major leap in connectivity, enabling data transfers up to 20 times faster than dial-up connections and supporting real-time, two-way communication and video conferencing (OECD, 2015). Following prior research (Forman and van Zeebroeck, 2019, 2012), we conceptualize bilateral broadband access as a two-sided ease in information flows within managing entity–R&D subsidiary dyads. Similar to railroads, highways, or nonstop flights, broadband significantly reduced information frictions between locations (Akerman et al., 2022); however, as a communication connectivity infrastructure, it enabled real-time information exchange and lowered the need for in-person visits. Because of its potential for substantial productivity gains at low implementation costs, its adoption was primarily driven by exogenous infrastructure availability rather than firm strategy (Akerman et al., 2015; Bertschek et al., 2013; Ericsson et al., 2013).

We begin by establishing a pre-broadband baseline comparing HQ- and MS-managed R&D subsidiary innovation output (measured by the quantity of filed successful patent applications invented by the R&D subsidiary). To reduce potential selection bias, we match HQ- and MS-managed subsidiaries on factors identified in prior research, including subsidiary role, R&D expenditures, regional expertise, geographic and cultural distances between the managing entity and R&D subsidiary, host country, and industry.

[1] Managing subsidiaries are separate from the R&D subsidiary they oversee and are often referred to as regional headquarters, secondary headquarters, or intermediate supervisory units (Birkinshaw et al., 2006; Gillmore et al., 2023; Zhou, 2015).

[2] The legal assignment of patents is conceptually distinct from managing R&D. MNEs strategically allocate patent assignment based on factors such as legal requirements for local representation in patent defense, eligibility for tax incentives (e.g., patent boxes), and the advantages of centralizing intellectual property protection within a single entity.

Fig. 1. Example of R&D subsidiary management in a representative MNE from the sample (*within the same MNE*). Notes. Fig. 1 displays examples of subsidiary- and headquarters-managed R&D subsidiaries from a representative MNE in our sample. The MNE is headquartered in the U.S. The Swedish subsidiary manages the R&D activities of subsidiaries in Argentina, Finland, and Estonia. Headquarters manages the R&D activities of subsidiaries in Brazil, the UK, and France. As managing entities, the Swedish subsidiary and headquarters have the right to make strategic decisions on R&D projects, including selecting, funding, directing, and monitoring their R&D subsidiaries' activities. They also compensate the R&D subsidiaries for their R&D activities and hold economic ownership rights to any innovations created by the R&D subsidiaries that they manage.

We then estimate the effect of broadband on innovation. Since connectivity requires bilateral access (Forman and van Zeebroeck, 2019, 2012), we construct a dyadic broadband introduction measure based on its rollout in both the managing entity and R&D subsidiary locations. We later assess whether the effects persist under unilateral access (either subsidiary-only or managing-entity-only access). Using an intention-to-treat staggered difference-in-differences (DD) design, we compare pre- and post-broadband changes in innovation output between treated (connected) and control (unconnected) subsidiaries.

To assess whether the effects differ by managing entity type, we estimate a staggered DDD model, holding the management structure constant.[3] This involves: 1) calculating the change in innovation output for HQ-managed R&D subsidiaries before and after broadband introduction and comparing it to the change in innovation for HQ-managed subsidiaries that have not yet had broadband introduced at that point in time; 2) performing the same calculation for MS-managed subsidiaries; and, 3) subtracting the MS-managed subsidiary difference from the HQ-managed difference and assessing its statistical significance. We further estimate the DDD on a propensity score matched sample to address selection concerns.

Two central findings emerge. First, before broadband, HQ-managed R&D subsidiaries were more innovative on average than comparable MS-managed ones. Second, broadband introduction is associated with an overall average increase in R&D subsidiary innovation output, but this effect is concentrated among MS-managed subsidiaries. After broadband introduction, MS-managed R&D subsidiaries experienced a 24.7% increase in the number of patents produced, which is 25.2% greater than the change for HQ-managed subsidiaries, while the post-broadband change in innovation output for HQ-managed subsidiaries was statistically indistinguishable from zero (p-value > 0.10).

Supplementary analyses indicate that the effects arise only under bilateral broadband access; no significant effects appear under unilateral access. The impact also grows with geographic distance and is robust to controls for fixed assets. Moreover, we do not find evidence that external knowledge flows drive the effect. Together, these patterns are consistent with our findings being driven by the easing of information flow between managing entities and R&D subsidiaries and suggest that local externalities or technological upgrading do not explain our results.

We also perform within-country analyses on U.S. R&D subsidiaries that have U.S. managing entities using broadband rollout at the U.S. zip-code–level data, allowing a finer-grained measure of access. The results are consistent with our main findings, indicating they are not driven by country-level aggregation. Additional robustness checks using alternative innovation measures (patent quality, market value), placebo years, alternative broadband thresholds, and staggered heterogeneous treatment corrections all confirm the main findings. Thus, we find robust evidence that improved connectivity between managing entities and subsidiaries is associated with greater increases in innovation for MS-managed R&D than HQ-managed.

IPT suggests that this result may be a function of the relative fit between information-processing demands and capacity (Galbraith, 1973; Tushman and Nadler, 1978). HQ's central structural position exposes it to broader and more complex information flows, potentially constraining its ability to improve the management of its R&D subsidiaries (Egelhoff, 1991; Galbraith, 1977; March and Simon, 1958). We conduct additional analyses to examine the plausibility of this explanation.

First, drawing on IPT research, we examine four complementary channels through which connectivity with the managing entity can enhance innovation: knowledge-sharing, collaboration, monitoring, and R&D spending. Prior work shows that reducing information frictions between locations increases knowledge sharing (e.g., Agrawal et al., 2017) and supports sustained interaction and joint project implementation across locations, thereby fostering collaboration (Bahar et al., 2023; Catalini et al., 2020; Forman and van Zeebroeck, 2012; Koh et al., 2025). Improved connectivity also reduces information asymmetries, which improves monitoring and, in turn, innovation productivity (Bernstein et al., 2016; Glaeser et al., 2023). Furthermore, reductions in information friction enables better access to funding, making it easier for R&D subsidiaries to propose new projects and for managing entities to select projects to fund (Choudhury, 2017).

We find that MS-managed subsidiaries experience a 16.0% larger post-broadband increase in the R&D subsidiary's number of backward citations to the managing entity's prior art (i.e. knowledge flows), compared to HQ-managed subsidiaries. They also exhibit an 18.7% larger increase in co-inventions with their managing entity. Although we lack a direct measure of monitoring, prior research links higher-quality monitoring to greater innovation productivity and predicts stronger monitoring benefits for entities with higher spans of control, i.e., larger number of managed units (Aghion et al., 2013; Garicano, 2000).

[3] A natural concern is that connectivity infrastructure might alter management structures (Aghion et al., 2014; Dessein, 2002). However, reassigning managerial authority is costly and typically takes years to implement (Bloom et al., 2012; Bresnahan et al., 2002). In our data, only 79 subsidiaries (155 subsidiary-year observations) changed their managing entities during or after broadband introduction. We exclude these observations, effectively holding the management structure constant and alleviating this concern. The results remain robust when these observations are included. Since the number of changes is small and shifts in managing entity represent a distinct research question, we do not analyze them separately.

Consistent with this, MS-managed R&D subsidiaries show a 25.2% larger post-broadband increase in the number of patents per R&D dollar (i.e., innovation productivity) than HQ-managed R&D subsidiaries, with the strongest effect among managing entities overseeing more subsidiaries than the median. We find no systematic differences in R&D funding, suggesting that the relative gains in innovation arise from productivity improvements rather than increased spending. Overall, these findings indicate that MS-managed R&D subsidiaries benefited more from reduced information frictions than their HQ-managed counterparts through larger increases in knowledge flows and collaboration with their managing entities, along with suggestive evidence of improved monitoring.

We next investigate whether the difference between HQ- and MS-managed R&D subsidiaries arises from HQ's information-processing demands. Consistent with this theoretical reasoning, the difference is larger when HQ faces greater information complexity, specifically, in larger MNEs with more expansive international operations and when the managing entity holds broader roles. In line with research showing that entities under high processing demands concentrate on areas closer to their expertise (Lo et al., 2022) or strategically important areas (Bouquet and Birkinshaw, 2008), we find that the HQ–MS difference is insignificant when the R&D subsidiary is technologically close but larger when the R&D subsidiary is technologically distant. Moreover, for R&D subsidiaries located in regions of technological expertise or with broader mandates, post-broadband innovation changes do not differ significantly between HQ- and MS-managed units. This pattern suggests that HQ prioritizes its most important R&D subsidiaries, whereas MS-managed subsidiaries achieve broader post-broadband improvements in innovation. Finally, while both HQ- and MS-managed subsidiaries show smaller effects when culturally distant from the managing entity, the difference between high and low cultural distance is not statistically significant.

We investigate a series of alternative explanation and robustness tests, including investigating whether the results are driven by MNE tax avoidance, subsidiary roles, regulatory quality, investment profile, political risk, and market growth. The results remain robust to these alternative explanations.

This study contributes to research on connectivity infrastructure and innovation, offering fresh insight by providing evidence that the structure of management influences why some units benefit more from new connectivity infrastructure than others. Existing research has primarily focused on the mechanisms through which connectivity increases innovation—knowledge sharing, collaboration, monitoring, and R&D funding (Agrawal and Goldfarb, 2008; Catalini et al., 2020; Ding et al., 2010; Forman and van Zeebroeck, 2019, 2012; Koh et al., 2025)—and external contingencies that moderate these effects (Agrawal et al., 2017; Bahar et al., 2023). While recent studies have shown that connectivity infrastructure improves the management of geographically distant R&D (Bernstein et al., 2016; Glaeser et al., 2023), it thus far generally treats the managing entities as homogeneous, overlooking how their structural positions influence innovation outcomes.

A central implication of the findings is that the managing entity matters for realizing the innovation benefits of connectivity. MS-managed R&D subsidiaries experience substantially larger post-broadband increases in innovation productivity, knowledge flows, and collaboration with their managing entity relative to HQ-managed. The results provide suggestive evidence that these differences arise from variation in information-processing constraints. When HQ faces greater informational complexity, its ability to capitalize on improved connectivity diminishes, whereas MS, typically subject to narrower information processing demands, are better able to leverage connectivity to increase knowledge sharing and co-inventions with the subsidiaries they manage, ultimately yielding larger post-broadband increases in innovation. As emerging infrastructures—such as low-earth-orbit satellite networks, AI-powered communication systems, non-terrestrial network integration, and edge computing—continue to transform real-time global information exchange, our findings underscore that firms' internal structures play a critical role in realizing their full innovative potential.

We also advance research on MNE innovation management (e.g., Berry, 2015; Gillmore et al., 2023; Knott and Turner, 2019; Nell and Ambos, 2013; Teodorescu et al., 2022) by providing the first large-scale empirical comparison of HQ- and MS-managed R&D subsidiary innovation output. A critical yet understudied decision for MNEs is whether to place R&D subsidiaries under the control of HQ or MS. While existing research has provided valuable insights into the benefits of delegating control over R&D subsidiaries to MS primarily through theory or qualitative case studies (Gillmore et al., 2023; Lunnan and Zhao, 2014), it has yet to empirically examine the implications of MS versus HQ management for R&D subsidiary innovation. Research has emphasized MS's proximity-based advantages (Birkinshaw et al., 2006; Lunnan and Zhao, 2014), raising the question of whether the benefits of MS management may erode as advances in connectivity infrastructure increasingly reduce information frictions across locations. Our results highlight that the benefits of MS management not only persist but also grow as advances in connectivity improve the ability of MS to collaborate, share knowledge with, and improve monitoring of their R&D subsidiaries. Taken together, the findings indicate that MS's value extends beyond mitigating distance, challenge the longstanding presumption of HQ primacy, and suggest that connectivity may be shifting the relative advantages of MS versus HQ in managing innovation.

2. Setting and data

2.1. Introduction of new connectivity infrastructure: Broadband internet

The global rollout of broadband infrastructure provides a natural setting for this study. Broadband, defined as high-speed internet with download speeds of at least 256 Kbit/s, radically eased inter-unit information flows by enabling simultaneous two-way data transfers, real-time video conferencing, and rapid, high-quality information exchange (Ericsson et al., 2013; Ezell et al., 2009; OECD, 2015).[4] Distinct from physical transport, broadband virtualizes information exchange. It allows rich, real-time interaction without co-location or costly travel time, thereby facilitating the exchange of complex and tacit knowledge between managing entities and R&D subsidiaries (Akerman et al., 2015; Bertschek et al., 2015).

Before broadband, firms relied on slower, more costly alternatives (Ericsson et al., 2013). Principally, alternatives such as dial-up internet offered a maximum speed of 56 Kbit/s, which made data-intensive communication, such as video conferencing, impractical (Ezell et al., 2009). Wide area networks (WANs) could connect offices to mainframes but were too expensive to lease for most firms (Majumdar, 2019). Both WANs and private intranets depended on a country's communication infrastructure because the private installation of communications infrastructure, such as broadband, across geographical distances was prohibitively costly for firms (De Wit, 2022; Majumdar, 2019). While MNEs often have sophisticated internal systems, many modern collaboration tools—such as cloud-based R&D platforms, video conferencing, shared design systems, and AI-assisted workflows—require broadband connectivity infrastructure at both ends to function. Thus, regional broadband access directly determines whether such tools can operate across locations. Other alternatives for information exchange included telephone (with conference calls), messenger services, traditional mail, and in-person visits.

Broadband infrastructure installation began in the early 2000s, generally in urban and industrial centers where MNEs are typically located. Governments drove the installation of broadband infrastructure

[4] Video conferencing was slow to gain widespread adoption after the introduction of broadband and is therefore more likely to be a factor towards the end of our sample (Tucker, 2008).

due to its socioeconomic impacts (OECD, 2015). The European Commission, for example, aimed for full broadband coverage in all EU countries by 2013 (OECD, 2015). By 2011, broadband had been introduced in 85% of the countries in our sample. The staggered introduction of this infrastructure across countries provides useful quasi-experimental variation, helping to mitigate, albeit not fully eliminate, concerns about time-varying institutional factors that could influence subsidiary innovation.

A defining feature of broadband is its dyadic nature: benefits arise only when both endpoints are connected. Thus, bilateral rather than unilateral access drives information flows (Forman and van Zeebroeck, 2019). Aligned with prior research establishing broadband infrastructure as plausibly exogenous to firms (e.g., Akerman et al., 2015),[5] we conceptualize broadband availability as an externally driven reduction in bilateral information frictions, conditional on both nodes in a managing-entity–subsidiary dyad having access. Given that broadband offered sizable productivity improvements at relatively low adoption costs, firms' adoption largely reflected the timing of external infrastructure rollout (Akerman et al., 2015; Bertschek et al., 2013; Ericsson et al., 2013).

We obtain broadband data from the World Bank's World Development Indicators, which reports broadband penetration as a percentage of fixed broadband subscriptions in the population, including businesses and residences. Following specialized studies, we set a 5% market penetration rate as the threshold for broadband introduction and test different thresholds in robustness checks to ensure consistency (Ezell et al., 2009; Mack-Smith, 2013). Research indicates that, even at low penetration rates, the availability of communication infrastructure can significantly influence productivity (Roller and Waverman, 2001). Since bilateral access drives information flow (Forman and van Zeebroeck, 2019), we code *Post-Broadband Introduction* as a binary indicator set to one starting the year after broadband penetration reaches the threshold in the countries of the R&D subsidiary and the managing entity. The mean and median time a country in our sample reaches this threshold is two years.

2.2. Innovation management data from transfer pricing reports

We construct a panel on innovation management using the transfer pricing reports from 102 MNEs and their 1004 managed R&D from 1997 to 2011. The transfer pricing reports provide detailed, audited information on intra-firm transactions and management structures. We obtained access through a confidentiality agreement with a consulting firm that conducts economic analyses for transfer pricing compliance and works with both firms and governments in audits and tax cases. The data we use come from mandatory transfer pricing documentation submitted to tax authorities, not from consulting advice. The dataset contains the data from all 102 MNEs that the consulting firm had information in accordance with company agreements for provision under the confidentiality agreement at the time of data collection. Strict confidentiality was maintained throughout data handling and coding; only aggregate statistics are reported to not identify any firm in the sample.

Given that public and commercial databases do not contain data on which entities oversee R&D subsidiaries within the firm (which helps explain the scarcity of empirical research on MS-based R&D management), this data provides a unique opportunity to investigate our research question. We merge the organizational managing entity-R&D subsidiary data from these reports with USPTO patent data, an independently verified measure of innovation, and with the World Bank's broadband introduction data to create a novel, rich dataset for understanding the relationship between connectivity infrastructure, R&D management, and innovation. Section 4.1.7 examines whether tax avoidance affects the results.

International and domestic regulations mandate that MNEs document the intra-firm transactions and activities of each entity, including R&D management responsibilities, in transfer pricing reports (OECD, 2017). Employee roles are verified through interviews, company documents, intra-firm contracts, communications, and on-site inspections, and records are auditable. The intra-company contracts included in the reports are ongoing (they remain in force as long as the relevant activities continue) and are changed when roles, responsibilities, or ownership rights change. Because the reports cover at least three years of data (e.g., the current year and preceding two years) (EY, 2013), any modifications to the managing entity-R&D subsidiary relationships (e.g., a change in managing entity) and the corresponding changed contracts are recorded in the reports, allowing us to observe organizational changes over time.

The reports must comply with domestic and international tax regulations (e.g., IRS Treas. Reg. §1.482, n.d.; OECD, 2017; BEPS Action 13) and are reviewed by auditors and tax authorities, sometimes through joint audits involving the jurisdictions of both the R&D subsidiary and the managing entity. Because governments tax income earned within their borders, they monitor whether MNE entities within their jurisdiction are properly compensated for their activities. Transfer pricing reports serve to verify that intra-firm transactions are conducted at arm's length and that profits are aligned with the underlying economic activity, ensuring tax compliance and transparency in the allocation of income, expenses, and risks across jurisdictions (OECD, 2017). Tax authorities use these reports to assess whether managing entities and R&D subsidiaries are appropriately compensated and impose substantial penalties for misreporting and noncompliance (EY, 2013). In practice, these reports are legal documents that form part of intracompany transaction audits and litigation (IRS Treas. Reg. §1.482, n.d.; OECD, 2017).

While firms may engage in strategic tax behavior, such behavior typically targets pricing decisions (i.e., the valuation of intellectual property or the allocation of profits across subsidiaries) rather than the reporting of organizational structure. This is because while there may be ambiguity around what is the fair price for a novel innovation that lacks any comparable asset price, organizational structure is verifiable through contracts, records, communications, and testimony. Auditors routinely validate reported roles through site visits and employee interviews. During government audits and tax disputes, employees can be subpoenaed to testify in court about their roles and whether they made strategic decisions such as selecting projects and controlling R&D. Misrepresentation can result in substantial penalties, reputational damage, or even criminal liability.

Changes in managing entities are infrequent, typically taking years to implement, and impose substantial adjustment costs as they provoke employee resistance, are constrained by internal power structures, and attract governmental scrutiny that may trigger audits concerning potential tax liabilities (Bloom et al., 2012; Bresnahan et al., 2002; Cuervo-Cazurra et al., 2019; Magelssen, 2020; OECD, 2017). Consequently, this further limits the scope for strategic misreporting and reduces the likelihood that our results are driven by opportunistic behavior around broadband introduction events. Our analysis relies exclusively on

[5] Exogeneity in our study is supported by three key factors. First, we employ a rich fixed effects structure of subsidiary, year, and HQ-managed-year fixed effects and we further test robustness to MNE-year fixed effects and country-year fixed effects. Second, as shown in Appendix Table D.13, placebo tests reveal no significant pre-trends: subsidiaries in regions about to receive broadband were not already on divergent innovation trajectories. Third, our unilateral-access falsification (Table 5) shows that increases in innovation arise only when both the managing entity and the R&D subsidiary have broadband access. No effect is observed under one-sided access. This bilateral pattern, corroborated by the U.S. zip-code replication (Appendix Table D.5), helps rule out confounding influences such as local economic shocks or regional spillovers by isolating the treatment to intra-firm information flows. While we do not claim random assignment, the combination of these design choices, placebo and falsification tests, and extensive robustness checks supports a plausibly causal interpretation of broadband as an exogeneous shock to information flows.

organizational information identifying the R&D subsidiaries and the entities that oversee them, rather than pricing data that may be more easily distorted.

We read each transfer pricing report to identify the entities that managed the R&D activities of subsidiaries across time. The reports document and identify the entities with formal control rights over innovation activities—those that approve and fund projects, direct execution, and own any resulting IP—supported by intra-company contracts (IRS Treas. Reg. §1.482, n.d.; OECD, 2017). Our focus on managing entity-R&D subsidiary relationship means that our study is conditional on the R&D subsidiary being managed by another unit. Therefore, our starting sample of 1004 subsidiaries excludes R&D subsidiaries that have formal authority over their own activities.[6]

We create indicators for the two types of units that can control subsidiaries, HQ and/or MS. We code an R&D subsidiary B as managed by subsidiary A (or HQ A) at time t if the report documented that subsidiary B was under the direction or control of subsidiary A or contracted to perform R&D on behalf of subsidiary A (see Appendix A for an example excerpt of a contract). *Headquarters-Managed* equals 1 if HQ manages the R&D subsidiary, and 0 otherwise. Appendix B provides a redacted sample from a representative transfer pricing report, where subsidiary A is the managing entity and subsidiary B is the R&D subsidiary.

In our sample, the 1004 R&D subsidiaries assigned to a managing entity have 4395 subsidiary-year observations. Of these subsidiaries, 53.2% are managed by HQ and 69.8% by an MS. The sum exceeds 100% as some subsidiaries perform projects for multiple managing entities, with 256 of these managed by both HQ and MS. A total of 677 subsidiaries is under a single managing entity, with 50.7% managed by HQ and 49.3% by MS. When both HQ and MS manage an R&D subsidiary, we are unable to differentiate the total patents attributable to HQ- versus MS-managed R&D projects. Therefore, we match R&D subsidiaries managed exclusively by either HQ or MS to better isolate the effects of HQ versus MS management. We perform additional within-subsidiary analyses for dependent variables that we can track to each managing entity: specifically, knowledge flows from each managing entity and co-inventions with the managing entity in Section 4.2.

A total of 96 R&D subsidiaries experienced a change in their managing entity during the sample window, with 79 of these occurring in or after the year of broadband introduction. We retain the R&D subsidiary in the sample as long as its management remains unchanged. We exclude 155 subsidiary-year observations for the years during and after the management change to ensure that these changes do not affect the results. By excluding changes in management structure, our analysis minimizes the possibility that our results are biased by changes in structure driven by broadband availability or other shocks. The time between broadband introduction and the change in management ranges from zero to eight years, with a median and mean of four years. Most changes occurred around the 2008 financial crisis. Seven subsidiaries were dropped from the sample due to the timing of their changes, reducing the sample to 4240 subsidiary-year observations across 997 subsidiaries.

We also exclude four subsidiaries (16 subsidiary-year observations) that license technologies from another MNE entity to avoid conflating intra-firm management effects with licensing relationships. Consistent with prior research (e.g., Zhou, 2015), 47 subsidiaries (215 subsidiary-year observations) with pure tax haven management relationships—where managing entities are located in tax havens without operations—are also excluded. The final sample includes 4009 subsidiary-year observations for 946 managed R&D subsidiaries from 70 MNEs.

2.3. Innovation data

We measure R&D subsidiary innovation using patent inventor location.[7] Patents are a widely recognized and externally validated indicator of technological novelty commonly used in studies of firm innovation (Griliches, 1990; Lerner and Seru, 2017). Patent data, including inventor locations, assignees, forward and backward citations, and technological classes, are sourced from the United States Patent and Trademark Office (USPTO). Using data from a single patent authority is standard practice due to cross-office inconsistencies in coverage and reporting (Berry, 2014).

While USPTO data does not capture all innovative activity, several considerations make them a reliable and meaningful indicator of international innovation within MNEs. First, all MNEs in our sample maintain at least one U.S. location and firms active in the U.S. have strong incentives to file with the USPTO regardless of where an invention originates. Second, the USPTO provides extensive international inventor coverage: more than half of its patents list at least one non-U.S.-based inventor (Branstetter et al., 2014). Third, USPTO data offer the most comprehensive and consistent inventor-level coverage over our sample period (1997–2011). During this period, the USPTO required complete inventor address disclosure, whereas other patent offices either did not systematically collect these data, required only one inventor address per filing, or applied inconsistent reporting standards across jurisdictions and years. These inconsistencies risk introducing selection bias and measurement error if used to compare cross-site organizational configurations and innovation, which is particularly problematic for our design. As discussed in Sections 3.3 and 4.6, we conduct robustness tests by estimating the models on separate samples of R&D subsidiaries in and outside the U.S., finding consistent results.

To construct the innovation panel, we search the USPTO database for all granted patent applications assigned to each MNE or any subsidiary within the MNE group.[8] Our search includes the full legal entity name and variations of the root name, incorporating suffixes such as “Inc.,” “Corporation,” “A.G.,” and “SAS.” In cases of ambiguity regarding the corresponding MNE or subsidiary, we verify the assignee address to ensure it corresponds to one of the MNE's known addresses. Our dataset contains 50,934 patents.

We match all the entities of the MNEs in our data to their invented patents based on the inventor's city, state, country, and year of filing, given that the filing date is closer to the invention date than the grant date (Lerner and Seru, 2017). For instances with multiple MNE entities in the same city, we match patents based on the overlap in the assignee and MNE entity names. If MNE entities have similar root names, we match based on the technological focus of the entity. For example, if two pharmaceutical subsidiaries conduct R&D on drugs, a patent for an oncological drug is linked to the subsidiary focused on oncological research.

Our dataset includes 29,028 patents with a single inventor, 10,711 patents with multiple inventors from the same MNE entity location, and 11,195 patents with inventors from multiple MNE-entity locations,

[6] While all R&D subsidiaries in our study do not hold formal authority to make strategic decisions (i.e. they are non-autonomous units), we are unable to observe variations in the degree of real authority that subsidiaries exercise (Aghion and Tirole, 1997) and believe investigating such variations can be an insightful avenue for future research.

[7] We code subsidiary innovation using inventor locations, not patent legal assignees. This distinction is crucial. While firms may reassign patent legal ownership for tax or legal reasons, inventor addresses are recorded at the time of filing the patent as a required part of the patent process and reflect the actual locus of inventive activity. This allows us to capture where innovation occurs and avoids distortions stemming from patent legal assignments.

[8] We use the algorithms from https://www.leydesdorff.net/indicators/ to download the patent data.

which we code to each inventing subsidiary.[9]

2.4. Dependent variable

The main dependent variable is *Innovation Output*, measured as the natural log of one plus the total number of successful patent applications filed by the R&D subsidiary's inventors each year. We apply a one-year lead to our dependent variables. Combined with our post-broadband indicator, which is coded as one in the year following broadband adoption, this specification captures outcomes two years after broadband infrastructure reaches the introduction threshold. We later assess the sensitivity to a three-year lead (see Appendix D). In robustness tests, we use two alternative measures. *Innovation Quality* is the total number of forward citations (excluding examiner citations) received from other firms within five years of the subsidiary's granted patent application year. Forward citations are highly correlated with an innovation's underlying value and importance (Hall et al., 2005; Lanjouw and Schankerman, 2004). To address the mechanical decline in citations towards the end of the patent database (Lerner and Seru, 2017), we limit the analysis of innovation quality to patents filed by 2009, ensuring each patent has the same five-year window to receive citations. *Innovation Market Value* captures the anticipated commercial value of the innovation and is the MNE market-adjusted returns (in millions of 1982 dollars) within three days following a patent's issue date for patents invented by the subsidiary in that year (Kogan et al., 2017). We obtained this measure from the Kogan database, which covers 61.1% of all patents in our sample.[10] We use the natural log of one plus both the innovation quality and market value measures.

2.5. Data facts, representativeness, and propensity score matching

The 102 MNEs in our starting sample primarily operate in manufacturing, with some in retail and service sectors. Approximately 78% are headquartered in North America, 19% in Europe, and the remainder in Asia. Given our focus, we limit the sample to 78 MNEs with at least one subsidiary-invented patent.[11] To assess representativeness, we compared our sample to multiple benchmarks. First, we compare against the 2000 largest MNEs worldwide in Orbis (based on *Forbes Global 2000* rankings for 2011). After excluding the typically non-innovative sectors that are not in our sample—agriculture, mining, banking, and public administration—our firms do not differ significantly in size ($p = 0.19$) or R&D intensity ($p = 0.13$ for firms that report R&D expenditures) relative to MNEs ranked 1150–2000. Thus, our sample represents relatively large MNEs, though not the very largest companies globally.

Second, we compare against the Fortune 1000 firms (Cho and Pucik, 2005). We find no statistical differences in total assets ($p = 0.87$) or revenues ($p = 0.44$). Third, we compare against Berry's (2014) sample of firms, which represents one of the best datasets on MNE innovation over our sample period. This dataset contains information on the patenting of the foreign subsidiaries of U.S. MNEs from the Bureau of Economic Analysis, which we view as an important dimension in assessing the generalizability of the MNEs in our sample. We find no significant differences in MNE size ($p = 0.17$), in the proportion of foreign subsidiaries performing R&D (16.9% vs. 18.2%), or in average annual patents per MNE ($p = 0.29$).

2.5.1. Broadband introduction and R&D subsidiary innovation by managing entity type

Table 1 details the distribution of R&D subsidiaries by country location and managing entity type. There are 53 countries represented in our data. About 11.6% of HQ-managed subsidiaries and 13.5% of MS-managed subsidiaries are in the U.K. In comparison, 19.6% of HQ-managed and 22.2% of MS-managed subsidiaries are based in the U.S. Broadband infrastructure was introduced in countries between 2000 and 2015, with a median country introduction year of 2004.

Table 2 compares the mean values of key variables for R&D subsidiaries managed by HQ only, MS only, or both. In terms of innovation output, the table shows that before the introduction of broadband, HQ- and MS-managed subsidiaries produced similar quantities of patents. However, HQ-managed subsidiaries slightly outperform MS-managed subsidiaries in innovation quality, suggesting a larger impact of their innovations. In contrast, MS-managed subsidiaries have higher mean innovation market values, which suggests greater expected commercial success or market reception. Following the introduction of broadband, MS-managed subsidiaries exhibit larger average innovation output, quality, and market value compared to those managed by HQ.

2.5.2. Factors associated with HQ versus MS-management and propensity score matching

The assignment of R&D subsidiaries to HQ or MS is non-random and may be influenced by several factors, raising concerns about selection bias. Existing research suggests HQ may be more likely to manage R&D subsidiaries that are strategically important (such as those performing more operational roles, or those that are organic rather than acquired) and those that are geographically, technologically, or culturally more similar to HQ (Birkinshaw et al., 2006; Bouquet and Birkinshaw, 2008; Zhou, 2015). In contrast, MS tend to manage subsidiaries that are acquired, geographically or culturally proximate, and operating in weak institutional environments, particularly within large and diversified firms (Birkinshaw et al., 2006; Gumpert et al., 2022; Zhou, 2015). These systematic differences between HQ- and MS-managed subsidiaries risk confounding comparisons and could otherwise lead to misleading inferences.

To help alleviate this concern, we use propensity score matching (PSM), one of the most commonly employed techniques for observable characteristics across comparison groups (e.g., Dambra and Gustafson, 2021; Faccio and O'Brien, 2021; Lin et al., 2021). The PSM allows us to match HQ- and MS-managed subsidiaries on factors that may jointly influence management structure and innovation outcomes. We implement nearest-neighbor matching without replacement using two matching vectors.

For the baseline OLS analysis, we estimate the propensity of an R&D subsidiary being managed by HQ versus MS using a logit model. Because country, industry, and subsidiary fixed effects absorb substantial variation, we match on key pre-treatment variables and fixed effects, then test for balance across additional covariates. The matching algorithm includes geographical and cultural distance and language similarity between the managing entity and the R&D subsidiary, and the average pre-broadband value of MNE size, diversification, stock compensation, host-country-industry technological advantage, host-country-industry market concentration, and industry and host-country fixed effects. Measures of innovation outcomes are excluded from the matching algorithm in this first analysis to understand the correlational differences in subsidiary innovation by managing entity types. Section 4.6 discusses the robustness tests incorporating different variables in our matching process. Appendix C provides detailed descriptions of the variables used to construct the matching vectors.

When both HQ and MS manage an R&D subsidiary, we are unable to differentiate the total patents attributable to HQ- versus MS-managed R&D projects. To isolate the effects of each management type, we

[9] We code the variable this way because the focus of this study is on the effect of broadband on the focal R&D subsidiary's innovation. We perform a robustness test with each patent weighted by the number of co-inventing entities and find consistent results (see Section 4.6).

[10] See Kogan et al. (2017) for details on the conditions under which market values are not estimated.

[11] Of note, this study focuses on the management of R&D activities, rather than the reasons MNEs choose specific R&D locations. Thus, the analysis is conditional on the MNE assigning R&D activities to the subsidiary.

Table 1
Distribution of R&D subsidiaries.

	Proportion of Total				Proportion of Total		
	Headquarters-Managed	Subsidiary-Managed	Broadband Introduction Year		Headquarters-Managed	Subsidiary-Managed	Broadband Introduction Year
Argentina	0.00	0.51	2007	Luxembourg	0.00	0.03	2004
Australia	2.05	1.84	2004	Malaysia	0.46	0.38	2009
Austria	0.36	0.99	2002	Mexico	1.50	1.36	2008
Belgium	1.68	2.59	2002	Netherlands	1.82	2.86	2002
Brazil	1.36	1.02	2008	New Zealand	0.64	0.85	2005
Canada	3.37	2.73	2001	Norway	1.50	0.82	2003
Chile	0.82	0.51	2006	Peru	0.14	0.20	2013
China	5.09	1.50	2008	Philippines	0.00	0.24	.
Colombia	0.59	0.44	2010	Poland	1.36	1.64	2006
Croatia	0.32	0.17	2006	Portugal	0.73	0.92	2004
Czech Republic	0.46	0.78	2005	Romania	0.14	0.17	2007
Denmark	1.09	0.99	2002	Russian Federation	0.50	1.06	2008
Ecuador	0.00	0.14	2012	Singapore	1.00	1.60	2002
Egypt	0.00	0.10	.	Slovakia	0.00	0.07	2006
Estonia	0.36	0.38	2003	Slovenia	0.00	0.20	2004
Finland	1.68	1.23	2002	South Africa	0.59	0.85	2015
France	6.55	4.40	2003	South Korea	2.77	2.05	2000
Germany	3.96	6.34	2003	Spain	0.55	1.74	2003
Greece	1.36	1.47	2007	Sweden	2.50	2.22	2001
Hong Kong	3.87	2.83	2000	Switzerland	1.68	2.25	2002
Hungary	0.64	0.95	2005	Taiwan	2.50	0.95	.
India	3.59	0.95	.	Thailand	0.36	0.58	2011
Indonesia	0.00	0.10	.	Turkey	0.50	0.68	2007
Ireland	1.41	1.26	2005	United Kingdom	11.64	13.53	2003
Israel	0.96	0.75	2003	United States of America	19.55	22.15	2002
Italy	2.32	3.24	2004	Venezuela	0.14	0.03	2010
Japan	3.55	2.35	2002	Total	100.00	100.00	

Table 2
R&D subsidiaries by managing entity type.

Variable	Number of Observations	All	Headquarters-Managed	Subsidiary-Managed	Headquarters-Managed Only	Headquarters and Subsidiary- Managed	Subsidiary-Managed Only
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Broadband Introduction Year	4009	2005	2005	2005	2005	2005	2005
Panel A: Pre-Broadband							
Innovation Output	1570	0.282	0.233	0.270	0.320	0.168	0.341
Innovation Quality	1413	0.298	0.305	0.253	0.452	0.203	0.289
Innovation Market Value	1482	0.513	0.381	0.518	0.496	0.299	0.681
Panel B: Post-Broadband							
Innovation Output	2439	0.483	0.303	0.568	0.274	0.335	0.702
Innovation Quality	1856	0.525	0.382	0.584	0.393	0.369	0.720
Innovation Market Value	2112	0.760	0.416	0.937	0.361	0.477	1.239
Panel C: Full Sample							
Innovation Output	4009	0.404	0.276	0.446	0.290	0.262	0.561
Innovation Quality	3269	0.427	0.350	0.432	0.414	0.289	0.528
Innovation Market Value	3594	0.659	0.402	0.754	0.408	0.396	1.002

Notes. This table contains the respective sample mean values of Broadband Introduction Year, Innovation Output, Quality, and Market Value. Broadband Introduction Year represents the mean year that broadband is introduced both in the R&D subsidiary and managing entity locations. The full sample is composed of subsidiaries performing R&D activities that are managed by headquarters or another subsidiary. Pre-broadband represents the sample of R&D subsidiaries before broadband is introduced in both the R&D subsidiary and its managing entity country locations. Post-broadband represents the sample of R&D subsidiaries after broadband is introduced in both the R&D subsidiary and its managing entity country locations. Innovation Output is the total number of patents produced by a subsidiary in year t + 1. Innovation Quality is the number of forward citations received over the five-year period after patent grant date. Innovation Market Value is the total market-adjusted MNE returns (millions of dollars) on the three-day window following the patent issue date for the patents invented by the focal R&D subsidiary in that year, deflated to 1982 using the CPI. Innovation Output, Quality, and Market Value reflect the natural logarithm values of innovation outcomes plus one. The full sample is used for Innovation Output. The sample years are restricted to 1997–2009 for Innovation Quality to reduce problems with right censoring of forward citations. Innovation Market Value has a smaller number of observations due to missing patent market values in the database (see Kogan et al. (2017) for missing data circumstances).

therefore focus on R&D subsidiaries managed exclusively by either HQ or MS.

Appendix Table D.1 reports baseline OLS balancing tests. Column 7 presents *t*-tests comparing unmatched and matched samples for each variable. The first row shows mean differences between HQ- and MS-managed R&D subsidiaries in the unmatched sample, identifying factors significantly associated with HQ management (versus MS management). We find that, relative to MS-managed, HQ-managed R&D subsidiaries are located farther from the managing entity ($p < 0.001$), more likely to share its official language ($p < 0.001$), face marginally lower host-country versus home-country effective tax rates ($p < 0.10$), and operate in faster-growing economies ($p < 0.05$), with lower investment profiles ($p < 0.001$), and lower political stability ($p < 0.05$). They also tend to belong to smaller firms ($p < 0.001$), have marginally higher stock compensation ($p < 0.10$), have marginally less R&D expenses ($p < 0.10$), and are more likely to be greenfield rather than acquired R&D subsidiaries ($p < 0.001$). These patterns are broadly consistent with established findings in the international management and innovation literature, with two notable exceptions: investment profile and political stability. Whereas Zhou (2015) shows that MS are more likely to manage manufacturing operations in institutionally weak environments—based on an aggregate institutional quality measure—we find that HQs are more likely to oversee R&D units located in contexts characterized by weak investment profiles and low political stability. This divergence may reflect differences in the strategic importance of innovation relative to more routinized manufacturing. In environments where uncertainty and institutional weakness are more acute, HQs may prefer to retain tighter control over R&D activities to mitigate risk and safeguard knowledge assets.

The second row of Appendix Table D.1 reports differences for the PSM matched sample. The t-tests show that matching substantially reduces observable differences between HQ- and MS-managed R&D subsidiaries, with only the acquisition variable remaining significant at the 5% level—a factor absorbed by subsidiary fixed effects in the main analyses.

We also implement PSM for the DD and DDD specifications to address systematic differences between HQ- and MS-managed R&D subsidiaries that may affect post-broadband innovation. Building on the OLS matching algorithm described above, we incorporate additional pre-broadband characteristics capturing the innovativeness of both the R&D subsidiary and its managing entity: the subsidiary's mean pre-broadband innovation output, market value, R&D expenditures, knowledge flows from the managing entity, as well as the managing entity's innovation output and R&D spending. Aligned with the OLS algorithm above, including host-country fixed effects in the matching procedure helps account for baseline cross-country differences in connectivity infrastructure and the type of broadband technology (e.g., DSL vs. fiber).

Appendix Table D.2 presents the balancing tests for the DD and DDD estimations, which are broadly consistent with Appendix Table D.1. Overall, the matching effectively minimizes differences between HQ- and MS-managed R&D subsidiaries, providing a more balanced basis for the subsequent analyses. We also present the primary analysis results using the (unmatched) full sample.

Appendix Table D.3 reports descriptive statistics for the full and matched samples.[12] On average, R&D subsidiaries produce 1.37 patents per year, although output is highly skewed by a few prolific subsidiaries (SD = 7.44). After matching, the average falls to 0.36 patents per year (SD = 1.12), indicating that the matching procedure effectively reduces outliers and yields a more balanced sample. Innovation quality averages 4.37 in the full sample and declines to 0.87 after matching. Similarly, the average patent market value decreases from \$43.88 million to \$2.06 million, reflecting the removal of extreme values. The average distance between managing entities and their R&D subsidiaries is 4837 miles, with distances ranging from 9.56 to 19,147 miles and remains relatively consistent after matching at 5095 miles.

[12] We report aggregated statistics rather than firm-specific minimum or maximum values to maintain confidentiality.

3. Analysis

3.1. Baseline pre-broadband analysis: Type of managing entity and R&D subsidiary innovation

We start by examining the baseline association between the type of managing entity and R&D subsidiary innovation output. Using OLS models with panel random effects, we estimate results for both the pre-broadband full sample and the PSM-matched sample as follows[13]:

$$Y_{it+1} = \beta_0 + \beta_1 HQ_{it} + \beta_2 X_{it} + \delta_t + \gamma_t + \mu_i + \varepsilon_{it+1} \tag{1}$$

where Y_{it+1} is the innovation outcome of subsidiary i in year $t+1$, HQ_{it} is a binary variable for HQ-managed, X_{it} is a vector of R&D subsidiary-, host-country-industry-, and MNE-level controls (including a binary indicator for whether the subsidiary was acquired), δ_t represents subsidiary-role fixed effects (e.g., distribution, manufacturing, services),[14] γ_t denotes year-fixed effects, and μ_i indicates industry fixed effects. Standard errors are clustered at the R&D subsidiary level.

Because local skills and expertise may influence R&D subsidiary innovation, we control for the host-country industry regional technological advantage. We also control for the R&D subsidiary's host-country industry market concentration index; MNE size, diversification, and stock compensation; and subsidiary role. We include the subsidiary's R&D expenditure in our mechanism tests. Additionally, we employ a set of supplementary variables for the matched sample and other analyses. Details on these variables, their sources, and their construction are provided in Appendix C.

Table 3 presents the results. In the full sample, we do not find a significant association between HQ managed and the patents produced by R&D subsidiaries ($p > 0.10$). However, in the PSM sample (i.e., after accounting for potential confounders that influence the likelihood of HQ versus MS management), HQ-managed subsidiaries exhibit significantly higher innovation output. Taking the exponentiated value, HQ-managed subsidiaries are associated with 22.6% more patents per year than comparable MS-managed subsidiaries ($p < 0.05$). After controlling for subsidiary R&D expenditures (Column 4), HQ-managed subsidiaries also show higher innovation productivity than MS-managed subsidiaries ($p < 0.05$).

3.2. Broadband introduction and R&D subsidiary innovation

We next examine whether broadband introduction is associated with changes in R&D subsidiary innovation and whether those changes differ between HQ- and MS-managed subsidiaries. Starting with the raw data, Fig. 2 presents binscatter plots comparing innovation output for HQ- and MS-managed subsidiaries across levels of broadband penetration. The plots show that as broadband penetration increases, MS-managed R&D subsidiaries produce more patents, whereas innovation output for HQ-managed subsidiaries remains relatively stable.[15]

We formally test these relationships using difference-in-differences (DD) and triple difference-in-differences (DDD) models. The DD model estimates changes in innovation output for R&D subsidiaries following broadband introduction (treatment group) relative to those that have not yet had broadband introduced at that time (control group). The DDD

[13] The Breusch and Pagan Lagrangian multiplier test for random effects was significant ($p < 0.001$), thereby indicating the presence of random effects and rejecting a pooled OLS model. Because HQ-managed, the independent variable of interest, is constant in our sample, we are unable to employ R&D subsidiary fixed effects in the OLS analysis.

[14] Role fixed effects are absorbed by subsidiary fixed effects in the DD and DDD analyses.

[15] Once we employ the DDD regression analysis that incorporates year and subsidiary fixed effects, the coefficient for HQ-managed is statistically indistinguishable from zero (see Table 4, Columns 2 and 3).

Table 3
Random effects OLS results for headquarters-managed vs subsidiary-managed innovation pre-broadband.

	Full Sample		Matched Sample	
	Innovation Quantity	Innovation Productivity	Innovation Quantity	Innovation Productivity
Dependent Variable = ln (Number of Patents +1) $_{t+1}$	(1)	(2)	(3)	(4)
Headquarters-Managed	0.087	0.093	0.204	0.204
	(0.062) [0.157]	(0.063) [0.139]	(0.085) [0.017]	(0.085) [0.017]
Control Variables	Yes	Yes	Yes	Yes
Subsidiary Controls	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Role FE	Yes	Yes	Yes	Yes
Number of Observations	1466	1424	457	457
Number of Clusters	569	561	190	190
R-Squared	0.246	0.255	0.298	0.297

Notes. This table presents the random effects OLS estimates of Headquarters-Managed and innovation output and productivity. Innovation Output represents the natural log of one plus the total number of patents invented by the R&D subsidiary in year t + 1. Innovation Productivity controls for R&D expenditures in estimating the number of patents produced. The full sample pre-broadband contains the observations prior to broadband introduction. The Matched Sample Pre-Broadband contains the pre-broadband PSM matched sample of R&D subsidiaries managed by headquarters to those managed by subsidiaries with one managing relationship only. All models are estimated with robust standard errors clustered at the subsidiary level. Standard errors are in parentheses and *p*-values are in brackets.

model extends this framework to assess whether the broadband effect differs between HQ- and MS-managed R&D subsidiaries. We discuss the exponentiated coefficients for a straightforward interpretation.

3.2.1. The effect of broadband on R&D subsidiary innovation

We estimate the following specification using the DD model:

$$Y_{it+1} = \beta_0 + \beta_1 Post\ Broadband_{ct} + \beta_2 X_{it} + \alpha_i + \gamma_t + \varepsilon_{it+1} \tag{2}$$

Here, Y_{it+1} represents the dependent variable of interest for subsidiary i in year $t+1$. Given that the dependent variable is measured at $t+1$ and the post-broadband measure is defined one year after broadband introduction, our analyses capture R&D subsidiary innovation two years after broadband reaches the threshold. *Post-Broadband*$_{ct}$ is a binary indicator for post-broadband introduction (as defined in Section 2.1), and X_{it} represents subsidiary-, host-country-industry-, and MNE- level controls. Subsidiary (α_i) and year (γ_t) fixed effects are included, and standard errors are clustered at the subsidiary level.

Table 4 presents the results. Column 1 reports estimates for the full sample, Columns 2–3 for HQ-managed subsidiaries, and Columns 4–5 for MS-managed subsidiaries for Eq. (2). Across the full sample, broadband introduction is associated with a 9.1% increase in the number of patents produced (Column 1, $p < 0.001$) compared to those that did not have broadband introduced at that time. This effect is concentrated among MS-managed subsidiaries: Columns 2–3 do not provide evidence of a significant change for HQ-managed subsidiaries ($p = 0.746$, Column 3), whereas Columns 4–5 indicate a substantial positive effect for MS-managed subsidiaries. In the most stringent specification (Column 5), MS-managed subsidiaries are associated with an average increase of 21.0% in patents after broadband introduction ($p < 0.001$) relative to MS-managed without broadband.

3.2.2. The effect of broadband on R&D subsidiary innovation by type of managing entity

We next test whether the impact of broadband on innovation differs between HQ- and MS-managed subsidiaries using a DDD model, specified as follows:

$$\begin{aligned} Y_{it+1} = {} & \beta_0 + \beta_1 (HeadquartersManaged_{it} \times PostBroadband_{ct}) + \\ & \beta_2 PostBroadband_{ct} + \beta_3 X_{it} + \alpha_i + \eta_{it} + \gamma_t + \varepsilon_{it+1} \end{aligned} \tag{3}$$

Eq. (3) extends the DD specification by interacting $HeadquartersManaged_{it}$ with the post-broadband indicator. As in Eq. (2), Y_{it+1} is the innovation outcome of subsidiary i in year $t+1$, X_{it} includes subsidiary-, host-country–industry-, and MNE-level controls, and α_i and γ_t denote subsidiary and year fixed effects, respectively. We also include HQ-managed-year fixed effects (η_{it}) to isolate the triple-differences (Pischke, 2005).

The coefficient β_2 captures the change in innovation outcomes for MS-managed R&D subsidiaries in countries with broadband introduction relative to MS-managed R&D subsidiaries without broadband at that time. The main term of interest in the DDD analysis is $HeadquartersManaged_{it} \times PostBroadband_{ct}$. Essentially, its coefficient β_1 represents the differential effect for HQ-managed subsidiaries relative to MS-managed subsidiaries by accounting for existing differences between HQ- and MS-managed subsidiaries in areas where it has not yet been introduced.

The results in Table 4, Columns 6–9, indicate that the effect of broadband infrastructure on innovation output depends on the type of managing entity. Column 7 reports a negative and statistically significant coefficient for the $HeadquartersManaged_{it} \times PostBroadband_{ct}$ interaction, indicating that HQ-managed R&D subsidiaries exhibit a smaller post-broadband change in the number of patents produced than MS-managed subsidiaries. Since the positive post-broadband coefficient for MS-managed subsidiaries is economically significant, we infer that the DDD coefficient can be interpreted as a 18.2% smaller post-broadband increase among HQ-managed subsidiaries than MS-managed subsidiaries ($p < 0.001$). This reflects a smaller relative increase in innovation rather than an absolute decline in HQ-managed output.

The difference becomes more pronounced in the matched sample. In Column 9, our most stringent specification, HQ-managed subsidiaries exhibit a 25.2% smaller post-broadband increase in patents relative to MS-managed subsidiaries ($p < 0.001$), underscoring a robust and economically significant divergence once pre-broadband characteristics are balanced.

3.3. Within-country differences in broadband introduction

Our analyses thus far have focused on country-level broadband availability. Yet broadband access may vary substantially within countries (Akerman et al., 2015; Prieger, 2003). For instance, the greater patent increase observed among MS-managed subsidiaries might be due to HQ-managed subsidiaries operating in regions without local broadband access, even after national rollout, potentially biasing our results.

To address this concern, we collect broadband data at the U.S. zip-code level from the Federal Communications Commission (FCC), which tracks the number of broadband providers per zip code during our sample period.[16] The United States hosts the largest share of R&D subsidiaries in our dataset and with these data we can assess whether the results hold on a more granular level.[17]

We define a binary *Post-Broadband Introduction* variable equal to one

[16] Data was collected from https://www.fcc.gov/form-477-data-zip-codes-number-high-speed-service-providers.

[17] To alleviate the concern that U.S. data disproportionately influences the findings, we also conduct analyses excluding U.S. R&D subsidiaries (see Section 4.6).

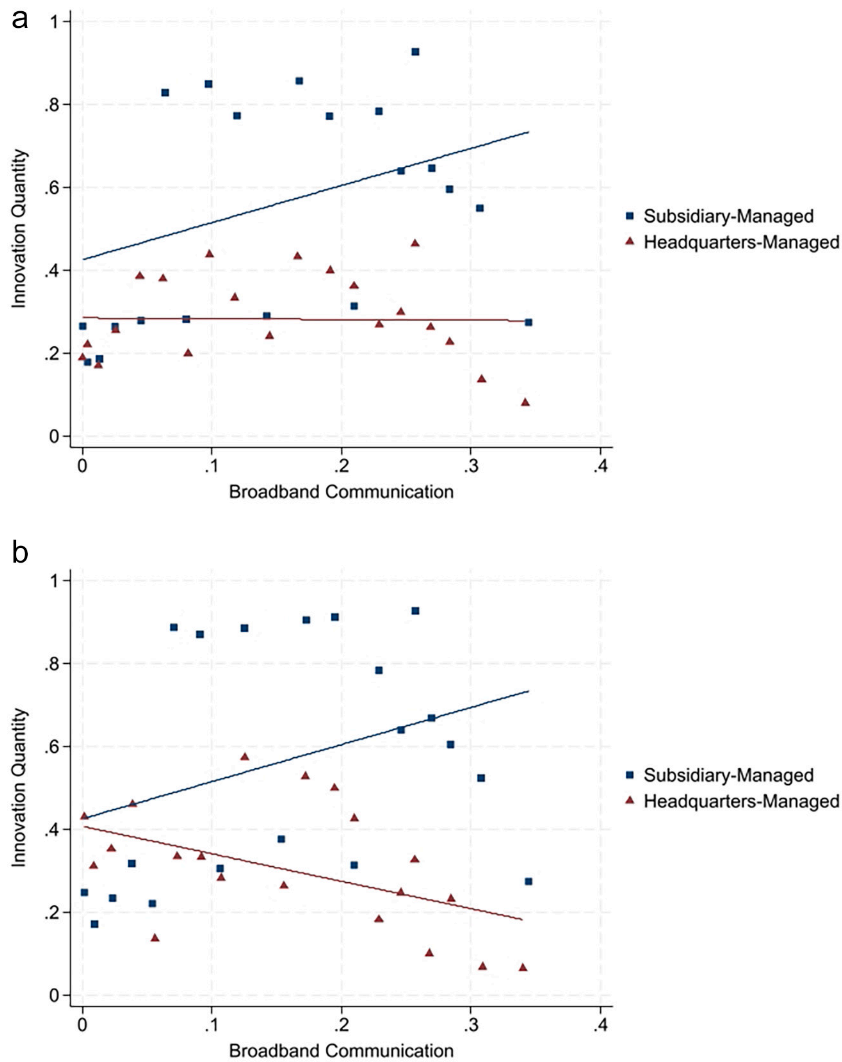

Fig. 2. Binscatter plots for innovation output and broadband penetration by managing entity. Notes. These figures plot innovation output across the broadband penetration rate in the R&D subsidiary's location by R&D subsidiary management relationship (subsidiary versus headquarters) for 1997–2011 for the full sample (graph on the left) and the sample of R&D subsidiaries that are managed by only one MNE entity (graph on the right). Innovation output is the natural log of one plus the number of successful patents filed in year t + 1 by the R&D subsidiary. To account for both the R&D subsidiary and the managing entity needing broadband access, each R&D subsidiary's country broadband value equals zero until the first year that its managing entity has at least a 5% broadband penetration rate, at which point broadband in the graphs equal the R&D subsidiary's host-country broadband penetration rate.

for the years following the entry of at least one broadband provider in the zip codes where the R&D subsidiary and its managing entity are located, and zero otherwise. The PSM matching is adjusted so that both the R&D subsidiary and its managing entity are U.S.-based.[18] Appendix Table D.4 reports the balancing tests for this matched sample.

Appendix Table D.5 presents the results. The DD model (Column 1) indicates that broadband introduction is associated with a 40.8% increase in the number of patents produced by R&D subsidiaries ($p < 0.05$). The DDD estimates (Columns 2–3) confirm a significant difference by managing entity type: in the fully specified model (Column 3), HQ-managed subsidiaries experience a 43.6% smaller post-broadband change in the number of patents than MS-managed subsidiaries ($p < 0.05$). These results reinforce our main findings, suggesting that the observed differences are not attributable to within-country variation in access.

[18] Using the baseline DDD PSM matched sample results in a disproportionate number of HQ-managed R&D subsidiaries compared with MS-managed, however, it yields consistent results with Table 4.

3.4. Assessing broadband as a dyadic connectivity infrastructure

We now focus on the dyadic nature of connectivity. The prior analysis tested whether broadband operates through connectivity between managing entities and their R&D subsidiaries. In this section, we test the effects of unilateral access. This distinction is important because broadband could also directly increase subsidiary innovation. For instance, broadband may enable faster testing, laboratory automation, or greater access to local knowledge and information networks.

To investigate whether direct effects drive the results, we construct a binary indicator for *R&D Subsidiary Post-Broadband Introduction,* equal to one for the years after broadband penetration reaches the threshold in the R&D subsidiary's host-country. We then re-estimate the DDD specification in Eq. (3), excluding observations where the managing entity has broadband access. As shown in Table 5 (Columns 1–2), the coefficients are economically small and statistically insignificant (McShane et al., 2019), which together suggest that broadband's direct effect on subsidiaries alone does not account for the findings. We repeat the analysis using a *Managing Entity Post-Broadband Introduction* indicator, defined analogously for the managing entity's host country, and

Table 4
The effect of broadband on R&D subsidiary innovation by type of managing entity.

	Difference-in-Differences Analysis					Triple Difference-in-Differences Analysis			
	All R&D Subsidiaries	HQ-Managed R&D Subsidiaries		MS-Managed R&D Subsidiaries		Full Sample		Matched Sample	
Dependent Variable = ln (Number of Patents +1)$_{t+1}$	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Post-Broadband Introduction	0.087	0.007	0.012	0.170	0.191	0.180	0.203	0.189	0.221
	(0.027)	(0.035)	(0.037)	(0.040)	(0.042)	(0.039)	(0.042)	(0.060)	(0.064)
	[0.001]	[0.852]	[0.746]	[0.000]	[0.000]	[0.000]	[0.000]	[0.002]	[0.001]
Headquarters-Managed* Post-Broadband Introduction						−0.178	−0.201	−0.248	−0.290
						(0.049)	(0.054)	(0.086)	(0.088)
						[0.000]	[0.000]	[0.004]	[0.001]
Control Variables	No	No	Yes	No	Yes	No	Yes	No	Yes
Subsidiary Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Headquarters-Managed-Year Fixed Effects	No	No	No	No	No	Yes	Yes	Yes	Yes
Number of Observations	4009	2199	2086	1938	1785	4009	3764	1013	981
Number of Clusters	946	510	496	480	454	946	914	258	258
R-squared	0.052	0.035	0.033	0.104	0.114	0.066	0.070	0.070	0.088

Notes. This table presents the difference-in-differences estimates of broadband introduction and innovation output for the full sample in Column 1, the sample of headquarters-managed R&D subsidiaries in Columns 2–3, and the sample of subsidiary-managed R&D subsidiaries in Columns 4–5. Columns 6–7 and 8–9 contain the triple difference estimates of the effect of broadband introduction on the innovation of R&D subsidiaries managed by headquarters vis-à-vis those managed by other subsidiaries for the full sample and the PSM matched sample, respectively. The PSM matched sample uses a vector of mean pre-treatment variables that can affect innovation outcomes. Changes in sample size are due to missing control data. Post-broadband introduction is a binary indicator for whether the broadband penetration rate has reached or surpassed 5% market penetration rate for both the R&D subsidiary-country and the managing-entity country. Headquarters-Managed*Post-broadband Introduction reflects the interaction term of the binary indicator for headquarters-managed R&D subsidiary with the binary indicator for post-broadband introduction. The main effect for the binary indicator for headquarters-managed R&D subsidiary is absorbed by subsidiary fixed effects. Innovation Output represents the natural log of one plus the total number of patents invented by the R&D subsidiary in year t + 1. All models are estimated using fixed effects OLS with robust standard errors clustered at the subsidiary level. Standard errors are in parentheses and p-values are in brackets.

exclude observations where the R&D subsidiary has broadband access. Again, we find economically small coefficients with no statistically significant effect, suggesting that broadband access by the managing entity alone does not increase subsidiary innovation. Significant increases emerge only when both the managing entity and the R&D subsidiary have broadband access (Table 5), consistent with broadband operating as a dyadic connectivity infrastructure. Additional support for this connectivity infrastructure facilitating information exchange between the managing entity and R&D subsidiary comes from the knowledge flow and co-inventions channels tested in Sections 3.5.1 and 3.5.2.

Second, we test whether broadband acts as a shock to remoteness, which would imply stronger effects at greater geographical distances between subsidiaries and their managing entities (Glaeser et al., 2023; Gumpert et al., 2022).

Using data from the GeoDist database on the geographical distance between the countries of the R&D subsidiaries and their managing entities, we split the sample into observations above or below the median distance. As shown in Appendix Table D.6, MS-managed subsidiaries located farther from their managing entities experienced a 29.8% post-broadband increase in patents ($p < 0.05$), compared to a 23.9% increase for closer subsidiaries ($p < 0.05$). While this pattern aligns with research suggesting that information frictions increase with distance (Akerman et al., 2022; Gumpert et al., 2022), the difference between the coefficients is not statistically significant.

Taken together, these results suggest that while distance does not significantly moderate broadband's effect, joint broadband access for both the managing entity and the R&D subsidiary is a necessary condition for realizing these innovation benefits.

3.5. Exploring the channels through which connectivity increases innovation

We now examine four key channels through which eased information flows from improved connectivity may affect R&D subsidiary innovation and assess whether these channels differ for HQ versus MS-managed subsidiaries: knowledge sharing, collaboration, monitoring, and access to funding. Enhanced connectivity may strengthen knowledge flows by allowing managing entities to access, interpret, and transmit more timely and relevant information to their R&D subsidiaries (Agrawal et al., 2017; Bahar et al., 2023; Forman and van Zeebroeck, 2019). It may also facilitate collaboration among geographically dispersed actors by reducing information asymmetries and enabling more continuous interaction (Forman and van Zeebroeck, 2012; Koh et al., 2025). Improved information flows between managers and R&D units may further enhance innovation by increasing the effectiveness of monitoring (e.g., Bernstein et al., 2016; Glaeser et al., 2023). Finally, recent work suggests that an overlooked channel through which information exchange increases innovation in IPT is R&D funding: by reducing information asymmetries, R&D units are more likely to have projects approved and funded (Choudhury, 2017). Accordingly, our analyses focus on two dimensions directly linked to information exchange and two additional related outcomes reflecting monitoring and R&D funding.

3.5.1. Knowledge flows from the managing entity

A primary channel through which connectivity infrastructure may foster innovation is by enabling geographically separated units to exchange knowledge more easily (e.g., Agrawal et al., 2017; Bahar et al., 2023; Forman and van Zeebroeck, 2019). Access to relevant knowledge is central to innovation (Yoon et al., 2024), yet geographic distance poses well-documented barriers to the transfer of tacit knowledge, which depends on observation, demonstration, and iterative exchanges that convey context and meaning (Polanyi, 1966; Szulanski, 1996; Teece, 1977). Within MNEs, managing entities serve as knowledge integrators: they accumulate specialized, often tacit, expertise and disseminate it to R&D subsidiaries to support innovation (Berry, 2015; Ciabuschi et al., 2011; Lunnan and Zhao, 2014).

Connectivity infrastructure can alleviate the limitations imposed by distance by enabling more frequent and higher-quality interactions, thereby complementing in-person communication (Gaspar and Glaeser, 1998). As connectivity infrastructure advances, knowledge transfers that require rich interpersonal exchanges become more feasible across distance (Forman and van Zeebroeck, 2019). Broadband, in particular,

Table 5
Unilateral broadband access only R&D subsidiary or only managing entity has broadband access.

	R&D Subsidiary has Broadband Access, Managing Entity Does Not Have Broadband Access		Managing Entity has Broadband Access, R&D Subsidiary Does Not Have Broadband Access	
	Full Sample	Matched Sample	Full Sample	Matched Sample
Dependent Variable = ln (Number of Patents +1) $_{t+1}$	(1)	(2)	(3)	(4)
R&D Subsidiary Post-Broadband Introduction	0.021 (0.029) [0.477]	0.089 (0.096) [0.355]		
Headquarters-Managed*R&D Subsidiary Post-Broadband Introduction	0.004 (0.038) [0.921]	0.114 (0.163) [0.486]		
Managing Entity Post-Broadband Introduction			0.030 (0.109) [0.782]	−0.028 (0.135) [0.834]
Headquarters-Managed* Managing Entity Post-Broadband Introduction			−0.038 (0.125) [0.762]	−0.055 (0.166) [0.739]
Control Variables	Yes	Yes	Yes	Yes
Subsidiary Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Headquarters-Managed-Year Fixed Effects	Yes	Yes	Yes	Yes
Number of Observations	1436	210	1287	322
Number of Clusters	549	115	524	146
R-squared	0.071	0.426	0.042	0.355

Notes. In Columns 1 and 2, R&D Subsidiary Post-Broadband Introduction is a binary indicator for whether the broadband penetration rate has reached or surpassed 5% market penetration rate for the R&D subsidiary host country, and the sample excludes observations where the managing entity has had broadband introduced in its location. In Columns 3–4, Managing Entity Post-Broadband Introduction is a binary indicator for whether the broadband penetration rate has reached or surpassed 5% market penetration rate for the managing entity-country, and the sample excludes observations where the R&D subsidiary has had broadband introduced in its location. The dependent variable is Innovation Output calculated as the natural log of one plus the total number of patent applications filed by the R&D subsidiary in year t + 1. Headquarters-Managed*R&D subsidiary (Managing Entity) Post-Broadband Introduction reflects the interaction term of the binary indicator for headquarters-managed R&D subsidiary with the binary indicator for R&D Subsidiary (Managing Entity) Post-Broadband Introduction. The main effect for the binary indicator for headquarters-managed R&D subsidiary is absorbed by subsidiary fixed effects. All models are estimated using fixed effects OLS with robust standard errors clustered at the subsidiary level. Standard errors are in parentheses and p-values are in brackets. All tests are two-tailed.

reduces information frictions by supporting real-time visualization, remote demonstration, and rapid communication (Ericsson et al., 2013; Ezell et al., 2009; OECD, 2015). These capabilities improve the ability of managing entities to identify relevant knowledge, communicate it across distance, and support subsidiaries in absorbing and applying it in innovation.

If improved knowledge flows explain our main results, we should observe larger post-broadband increases in knowledge transfers from MS to their R&D subsidiaries than from HQ to theirs. We test this by re-estimating the staggered DDD model from Eq. (3) using *Knowledge Flows from the Managing Entity* as the dependent variable. Knowledge flows are measured as the natural log of one plus the annual number of backward citations (excluding examiner citations) to the managing entity's prior art not previously cited by the R&D subsidiary in the past five years at $t + 1$, a common proxy for knowledge transfer and communication between parties (Singh, 2005; Sorenson et al., 2006).

Table 6, Column 3, shows that MS-managed subsidiaries have a 10.6% increase in the number of backward citations to MS ($p < 0.05$). HQ-managed subsidiaries are associated with a 16.0% smaller post-broadband increase in backward citations to their managing entity (i.e. knowledge flows) relative to MS-managed subsidiaries ($p < 0.05$). This commonly used proxy for communication suggests that MS more effectively leverage connectivity to transfer relevant knowledge than HQ, providing a plausible mechanism for the stronger innovation effects observed.

3.5.2. Collaboration with managing entity

Collaboration across organizational units requires several interrelated information-processing activities: identifying where knowledge resides, developing mutual knowledge and shared interpretive frameworks, transferring complex information, and coordinating interdependent tasks (Catalini et al., 2020; Cramton, 2001; Forman and van Zeebroeck, 2012). Because collaboration entails interdependence, shared problem solving substantially increases units' information needs and the information-processing capacity required to meet them (Tushman and Nadler, 1978). However, geographic dispersion hampers the transfer of information necessary for effective collaboration (Cramton, 2001).[19] It increases coordination costs, slows decision making, and creates information asymmetries that fuel disagreements (Cuijpers et al., 2011).

Connectivity infrastructure alleviates many of these problems by enabling more frequent and higher-quality interactions across locations, which reduces coordination costs and strengthens inter-unit linkages that support joint problem solving and mutual learning (Forman and van Zeebroeck, 2012). Rich information channels, in particular, allow rapid feedback and multiple cues that help collaborators converge on shared interpretations (Daft and Lengel, 1986), while shared digital platforms built on connectivity infrastructure allow dispersed collaborators to access common data repositories and other jointly used resources (Malhotra et al., 2007). Empirical studies provide evidence that improved connectivity increases collaboration among geographically dispersed actors by enabling real-time coordination and more frequent information exchanges (Bahar et al., 2023; Forman and van Zeebroeck, 2012; Koh et al., 2025).

If collaboration is a channel underlying our main results, MS-managed subsidiaries should exhibit larger increases in joint innovation with managing entities than HQ-managed. We explore this prediction by re-estimating Eq. (3) using *Co-inventions with the Managing Entity*, operationalized as the number of R&D subsidiary patents in year t + 1 that list co-inventors from the managing entity location as the dependent variable (Bahar et al., 2023). Table 6, Column 6, shows that HQ-managed subsidiaries are associated with a 18.7% smaller post-broadband change in the number of managing entity co-invented patents relative to MS-managed subsidiaries ($p < 0.001$). This pattern indicates that MS are more effective than HQ in leveraging broadband to collaborate with their R&D subsidiaries.

3.5.3. R&D funding

Connectivity may also enhance innovation by increasing the number of R&D projects proposed and funded (Choudhury, 2017). Funding decisions rely on subsidiaries' ability to convey project value and managing entities' ability to evaluate it (Seru, 2014). Connectivity infrastructure

[19] Cramton (2001) identifies six recurring information problems in distributed collaboration: lack of contextual information, uneven distribution of information, differences in information salience, differences in speed of access, misinterpretation of silence, and uncertainty about technical problems. These problems impede mutual knowledge—an understanding of what others know and how they interpret information—which is considered a prerequisite for effective collaboration (Cramton, 2001). Mutual knowledge enables collaborators to tailor communication with an awareness of others' perspectives rather than relying on their own, potentially misaligned interpretations (Cramton, 2001).

Table 6
Exploring the channels through which managing entity and R&D subsidiary connectivity increases innovation.

	Mechanism 1:			Mechanism 2:			Mechanism 3:			Mechanism 4:		
	Knowledge Flows from Managing Entity			Co-inventions with Managing Entity			R&D Funding			Innovation Productivity	Span of Control: Low	High
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Post-Broadband Introduction	0.008	0.091	0.101	0.003	0.109	0.115	0.336	0.315	0.294	0.221	0.116	0.285
	(0.037)	(0.047)	(0.051)	(0.032)	(0.048)	(0.051)	(0.125)	(0.201)	(0.222)	(0.064)	(0.087)	(0.096)
	[0.838]	[0.056]	[0.047]	[0.915]	[0.024]	[0.025]	[0.008]	[0.119]	[0.186]	[0.001]	[0.184]	[0.003]
Headquarters-Managed* Post-Broadband Introduction		−0.167	−0.174		−0.206	−0.207		0.059	0.064	−0.290	−0.164	−0.378
		(0.073)	(0.080)		(0.059)	(0.062)		(0.243)	(0.260)	(0.088)	(0.107)	(0.136)
		[0.023]	[0.030]		[0.001]	[0.001]		[0.807]	[0.806]	[0.001]	[0.126]	[0.006]
Subsidiary R&D	No	No	No	No	No	No	No	No	No	Yes	Yes	Yes
Control Variables	No	No	Yes	No	No	Yes	No	No	Yes	Yes	Yes	Yes
Subsidiary Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Headquarters-Managed-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	1013	1013	981	1013	1013	981	571	571	563	981	490	491
Number of Clusters	258	258	258	258	258	258	196	196	196	258	135	123
R-squared	0.013	0.043	0.050	0.014	0.062	0.067	0.052	0.130	0.147	0.088	0.148	0.129
Split Sample Comparison												
Post-Broadband Introduction F-Statistic												3.80
p-value												[0.053]
Headquarters-Managed* Post-Broadband Introduction F-statistic												3.99
p-value												[0.048]

Notes. Estimated on the PSM matched sample. This table contains the DD and DDD estimates of the effect of broadband introduction on knowledge flows from managing entity (Columns 1–3), Co-inventions with managing entity (Columns 4–6), R&D funding (Columns 7–9), and innovation output (Columns 10–12). The regressions for Columns 10–12 include R&D expenditures to estimate innovation productivity. The sample is split based on the median value of Span of Control (Columns 11 and 12). Knowledge Flows from Managing Entity is the proportion of R&D subsidiary citations in year t + 1 to prior art invented by the managing entity that the R&D subsidiary had not previously cited in the past five years. Co-inventions with Managing Entity is the natural log plus one of the total number of patents in year t + 1 with inventors from both the R&D subsidiary and managing entity locations. R&D Funding is the natural log of subsidiary R&D expenditures in year t + 1. The sample size is reduced in columns 7–9 due to missing observations because the dependent variable is predicting the R&D expenditures, rather than using lagged R&D expenditures used in other analyses. Innovation output is calculated as the natural log of one plus the total number of patent applications filed by the R&D subsidiary in year t + 1. Post-Broadband Introduction is a binary indicator for whether the broadband penetration rate has reached or surpassed 5% market penetration rate for both the R&D subsidiary-country and the managing entity-country. The main effect for the binary indicator for headquarters-managed R&D is absorbed by subsidiary fixed effects. All models are estimated using fixed effects OLS with robust standard errors clustered at the subsidiary level. Standard errors are in parentheses and *p*-values are in brackets.

facilitates project proposal and evaluation, easing information asymmetries that might otherwise constrain managing entities' willingness to approve or fund new initiatives (Seru, 2014). If information asymmetries are greater between MS and their subsidiaries than between HQ and theirs, improved connectivity may lead to relatively larger funding increases for MS-managed R&D.

To explore this possibility, we re-estimate the baseline DDD model (Eq. (3)) using the natural log of R&D expenditures in year t + 1 as the dependent variable. Table 6, Column 9 shows no significant difference in post-broadband R&D expenditure changes between HQ- and MS-managed subsidiaries. Funding therefore does not appear to explain the larger post-broadband increase in innovation observed among MS-managed R&D subsidiaries.

This result also suggests that it is unlikely that our results are driven by the possibility that broadband induces a shift from patenting to trade secrecy due to increased information security concerns (e.g., Glaeser, 2018; Glaeser et al., 2020). Any substitution between trade secrecy and patenting would likely be accompanied by changes in funding (Glaeser and Lang, 2024), which we do not observe.

3.5.4. *Monitoring*

A fourth potential channel is enhanced monitoring. Effective monitoring is crucial for successful innovation, but it is information-intensive and relies on frequent, high-quality exchanges to assess progress, provide guidance, and adjust project trajectories (De Meyer and Mizushima, 1989; Manso, 2011). Connectivity infrastructure makes effective monitoring more feasible by lowering the cost of such information interactions between managing entities and R&D subsidiaries (e.g., Bernstein et al., 2016; Glaeser et al., 2023). Better information flows allow managers to synthesize diverse viewpoints, correct errors, and offer timely feedback resulting in more efficient use of parties' time and efforts (Tushman and Nadler, 1978). Regular interaction also strengthens relational and contextual understanding, supporting more accurate project and performance assessments (Manso, 2011). Improved monitoring thus enhances innovation productivity by reducing agency problems, mitigating shirking, and supporting better project coordination and execution (Bernstein et al., 2016; Glaeser et al., 2023).

If monitoring is a key channel for our results, MS-managed R&D subsidiaries should exhibit greater increases in innovation productivity than HQ-managed subsidiaries. Prior research also suggests that connectivity infrastructure enables managing entities to monitor a larger number of subsidiaries, referred to in the literature as 'span of control' (Bloom et al., 2014; Garicano, 2000; Rajan and Wulf, 2006). Thus, if broadband improves monitoring, its impact on innovation productivity should be strongest for managing entities with broader spans of control.

To explore this mechanism, we follow prior studies and estimate innovation productivity, a common proxy for monitoring effectiveness, by including the log of R&D expenditure in the DDD specification (e.g., Aghion et al., 2013; Ahuja and Katila, 2001) and by splitting the sample at the median span of control. Table 6 shows that MS-managed R&D subsidiaries experience a 24.7% post-broadband increase in the number of patents per R&D expense (i.e., innovation productivity) ($p < 0.001$), while HQ-managed subsidiaries exhibit a 25.2% smaller change ($p < 0.001$). Moreover, the effect of broadband is greater for MS with larger spans of control, consistent with connectivity enabling more effective monitoring for MS.

One potential explanation for the results is that HQs may use connectivity to impose tighter control, which could dampen R&D subsidiary creativity and motivation to innovate (Aghion and Tirole, 1997). Excessive monitoring may crowd out intrinsic motivation, reduce tolerance for failure, and stifle creativity (Allen et al., 2015; Amabile, 1988; Holmstrom, 1989). Because HQs are closer to shareholders and regularly report to the board of directors, they may face stronger pressure than MS to yield MNE fiscal performance (Balsmeier et al., 2017), and may be more prone to such "negative monitoring." If so, based on prior research indicating that managing entities are more likely to exert control when they have a smaller number of subsidiaries they manage, i.e. a smaller span of control (Aghion et al., 2014), the adverse effect should be strongest when HQs manage fewer subsidiaries. However, Table 6, Columns 11–12, shows the opposite pattern—HQ-managed subsidiaries perform worse when HQs have larger spans of control. A potential hypothesis is that the constraint lies not in over-monitoring but in limited managerial capacity to use connectivity effectively for oversight.

Overall, these tests show that, post-broadband, MS-managed subsidiaries experience significantly larger increases in knowledge flows, co-inventions, and innovation productivity than HQ-managed subsidiaries, indicating that MS units benefited more from reduced information frictions. We find no evidence that differences in R&D funding drive the observed effects and find suggestive evidence from the span-of-control analysis that headquarters may face greater information-processing demands.

3.6. Exploring heterogeneity

We next investigate whether the difference between HQ- and MS-managed R&D subsidiaries stems from HQ's greater information-processing demands. The matched sample design accounts for MNE-level (e.g., MNE size, diversification), managing-entity level (e.g. R&D expenditures, innovativeness), dyad-level (e.g., geographical, technological, and cultural distance), subsidiary-level (e.g., R&D expenditures and role), and contextual factors (e.g., country, industry, host-country-industry revealed technological advantage and market concentration). Therefore, the interpretation of these split-sample analyses is the differential effect when both MS and HQ fall into the same category (e.g., high) of the split-sample dimension. By virtue of their structural positions, HQ and MS may still face distinct information processing demands within the same MNE and thus respond differently to similar conditions (Galbraith, 1973; Henderson and Fredrickson, 1996; March and Simon, 1958).

Information complexity refers to the diversity, interdependence, and volume of information that must be processed (Daft and Lengel, 1986). HQ, due to its corporate role, typically assumes broader, more complex responsibilities than MS, overseeing diverse strategic, operational, and financial information across the MNE group (Nell and Ambos, 2013; Schotter et al., 2017). Prior IPT research suggests that headquarters face greater informational complexity than MS when the MNE is large, geographically dispersed, and diversified (Egelhoff, 1991; Schotter et al., 2017). Even with enhanced connectivity, this scope can create cognitive bottlenecks that limit HQ's ability to process subsidiary-level signals and translate them into timely innovation support. Accordingly, we conduct split-sample analyses using MNE size, diversification, and geographic dispersion—a standard proxy for HQ's information complexity operationalized as the total number of countries in which the MNE operates (see, e.g., Schotter et al., 2017).

If HQ is more constrained in its information processing, we would also expect it to prioritize information exchange from strategically important or technologically proximate R&D subsidiaries. Prior research shows that when information-processing demands exceed capacity, managing entities concentrate on units closer to their expertise or of greater strategic importance (Lo et al., 2022; Bouquet and Birkinshaw, 2008). Subsidiaries with greater organizational "weight," that is, those that are larger or have more strategic roles, tend to attract more managerial attention (Bouquet and Birkinshaw, 2008). We therefore also investigate split sample analyses for technological distance and R&D subsidiary strategic importance (based on R&D expenditures, host-country industry technological advantage, and role).

As reported in Table 7, when managing entities operate in smaller MNEs, with less geographic dispersion, or have narrower roles (conditions of lower complexity – see, e.g., Egelhoff, 1982), the post-broadband performance gap between HQ- and MS-managed subsidiaries becomes statistically insignificant. The results suggest that information complexity underlies the observed divergence: the gap widens in more complex MNEs, consistent with HQ's information burden from the MNE group constraining its information processing capacity. Interestingly, we do not find significant differences for highly diversified firms, implying that diversification structures may help alleviate HQ's informational burden.

Consistent with research on information processing under constraints, we find suggestive evidence that headquarters prioritizes its most important and technologically proximate R&D subsidiaries. Table 7 shows that when R&D subsidiaries are technologically distant from their managing entity, MS-managed subsidiaries experience significantly larger post-broadband increases in innovation than those managed by HQ. For HQ-managed subsidiaries, this pattern is consistent with findings that under high information-processing demands, managers focus on domains closer to their expertise and overlook more distant areas (Lo et al., 2022).

For strategically important R&D subsidiaries—i.e., those that are large, hold more mandates, or are located in regions of expertise—post-broadband innovation increases do not differ significantly between HQ- and MS-managed units, consistent with the idea that managing entities focus their limited information-processing resources on units offering the greatest potential knowledge-sourcing benefits. We find no evidence that R&D subsidiaries with R&D expenditures above the median increased their innovation post-broadband, suggesting that both MS and HQ may have already concentrated their limited pre-broadband information-processing capacity on these strategically important units (e.g. by using flights and other alternative means to visit the most important R&D units). These subsidiaries likely already attract managerial attention (Bouquet and Birkinshaw, 2008), leaving limited room for further gains. In contrast, smaller MS-managed subsidiaries exhibit the largest post-broadband increases in innovation, indicating that connectivity disproportionately benefits less prominent units. This pattern suggests that HQ prioritizes processing information for its most important R&D subsidiaries, whereas MS—regardless of small size or mandate breadth—achieve broader post-broadband improvements in innovation.

Taken together, these findings suggest that although connectivity infrastructure eases information flows, HQ's relatively greater informational complexity from the MNE group may constrain its ability to convert additional information into innovation outcomes. MS, by contrast, are able to leverage connectivity more effectively in supporting R&D subsidiary innovation.

4. Alternative explanations, specification tests, and robustness

4.1. Alternative explanations

4.1.1. Innovation quality and market value

The observed differential effects could be due to MS-managed subsidiaries merely boosting the number of patents produced without enhancing innovation quality or market value. To assess this, we re-estimate the baseline DD and DDD models using innovation quality and market value as alternative dependent variables. As shown in Table 8, the results are consistent with those for innovation output. Broadband introduction is associated with a 50.6% ($p < 0.01$) increase

Table 7
Exploring heterogeneity in post-broadband changes in HQ and MS-managed R&D subsidiary innovation.

	Managing Entity Role		MNE Size		MNE Complexity		MNE Complexity		Managing Entity-R&D Subsidiary Technological Distance		Subsidiary R&D		Subsidiary Role		Host-Country Industry Revealed Technological Advantage	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Dependent Variable = ln (Number of Patents +1)$_{t+1}$	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Post-Broadband Introduction	0.239	0.292	0.104	0.319	0.022	0.395	0.149	0.232	0.058	0.274	0.244	0.157	0.198	0.235	0.160	0.285
	(0.108)	(0.105)	(0.060)	(0.104)	(0.044)	(0.098)	(0.091)	(0.107)	(0.075)	(0.087)	(0.096)	(0.108)	(0.081)	(0.097)	(0.100)	(0.116)
	[0.028]	[0.006]	[0.086]	[0.003]	[0.613]	[0.000]	[0.105]	[0.032]	[0.441]	[0.002]	[0.012]	[0.149]	[0.016]	[0.017]	[0.113]	[0.015]
Headquarters-Managed* Post-Broadband Introduction	−0.210	−0.425	−0.107	−0.488	−0.108	−0.373	−0.263	−0.173	−0.100	−0.480	−0.325	−0.240	−0.238	−0.258	−0.260	−0.199
	(0.123)	(0.138)	(0.074)	(0.160)	(0.087)	(0.114)	(0.121)	(0.154)	(0.084)	(0.168)	(0.123)	(0.184)	(0.109)	(0.140)	(0.118)	(0.168)
	[0.090]	[0.002]	[0.152]	[0.003]	[0.214]	[0.001]	[0.031]	[0.263]	[0.235]	[0.005]	[0.010]	[0.195]	[0.030]	[0.067]	[0.030]	[0.238]
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Subsidiary Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Headquarters-Managed-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Observations	463	518	492	489	480	501	490	491	489	492	484	497	448	533	494	487
Number of Clusters	116	155	148	131	149	155	157	149	146	112	122	136	137	155	136	145
R-squared	0.130	0.120	0.140	0.121	0.148	0.142	0.134	0.138	0.105	0.160	0.123	0.096	0.113	0.132	0.129	0.100
Split Sample Comparison																
Post-Broadband F-Statistic		0.260		4.280		14.520		0.610		6.170		0.650		0.140		1.180
p-value		[0.612]		[0.041]		[0.000]		[0.438]		[0.015]		[0.422]		[0.706]		[0.280]
Headquarters-Managed* Post-Broadband F-statistic		2.420		5.630		5.400		0.340		5.130		0.210		0.020		0.130
p-value		[0.122]		[0.019]		[0.022]		[0.561]		[0.026]		[0.645]		[0.889]		[0.720]

Notes. Estimated on the PSM matched sample. This table contains the DDD estimates of the effect of broadband introduction on innovation output. The sample is split based on the median value of the respective variables in the column heads. Since subsidiary R&D expenditures and technological distance from its managing entity might change due to broadband, the sample is split based on the pre-treatment mean values for these variables. The dependent variable innovation output calculated as the natural log of one plus the total number of patent applications filed by the R&D subsidiary in year t + 1. Post-Broadband Introduction is a binary indicator for the years after the broadband penetration rate has surpassed 5% market penetration rate for both the R&D subsidiary-country and the managing entity country. The main effect for the binary indicator for headquarters-managed R&D is absorbed by subsidiary fixed effects. All models are estimated using fixed effects OLS with robust standard errors clustered at the subsidiary level. Standard errors are in parentheses and p-values are in brackets.

Table 8
Alternative measures of innovation output: innovation quality and innovation market value.

	Innovation Quality					Innovation Market Value				
	Full Sample			Matched Sample		Full Sample			Matched Sample	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Post-Broadband Introduction	0.136	0.237	0.284	0.449	0.506	0.197	0.384	0.437	0.244	0.318
	(0.048)	(0.080)	(0.087)	(0.167)	(0.179)	(0.063)	(0.100)	(0.108)	(0.143)	(0.155)
	[0.005]	[0.003]	[0.001]	[0.008]	[0.005]	[0.002]	[0.000]	[0.000]	[0.089]	[0.041]
Headquarters-Managed* Post-Broadband Introduction		−0.177	−0.230	−0.396	−0.458		−0.345	−0.415	−0.404	−0.478
		(0.099)	(0.108)	(0.187)	(0.199)		(0.121)	(0.131)	(0.218)	(0.203)
		[0.075]	[0.034]	[0.035]	[0.022]		[0.005]	[0.002]	[0.066]	[0.020]
Control Variables	No	No	Yes	No	Yes	No	No	Yes	No	Yes
Subsidiary Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Headquarters-Managed-Year Fixed Effects	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Number of Observations	3269	3269	3079	876	854	3594	3594	3366	917	885
Number of Clusters	897	897	866	257	257	911	911	879	251	251
R-squared	0.017	0.023	0.026	0.080	0.091	0.032	0.044	0.048	0.064	0.088

Notes. This table presents the difference-in-differences estimates of the introduction of broadband and innovation outcomes in columns 1 and 6. The remaining columns contain the triple difference estimates of the effect of broadband introduction on the innovation of R&D subsidiaries managed by headquarters vis-à-vis those managed by other subsidiaries. The PSM matched sample uses a vector of mean pre-treatment variables that can affect innovation outcomes. The sample years are restricted to 1997–2009 for Innovation Quality in order to reduce problems with right censoring of forward citations. Innovation Market Value has a smaller number of observations due to missing patent market values in the database (see Kogan et al. (2017) for missing data circumstances). Other changes in sample size are due to missing control data. Post-broadband introduction is a binary indicator for whether the broadband penetration rate has reached or surpassed 5% market penetration rate for both the R&D subsidiary-country and the managing-entity country. Headquarters-Managed*Post-broadband Introduction reflects the interaction term of the binary indicator for headquarters-managed R&D subsidiary with the binary indicator for post-broadband introduction. The main effect for the binary indicator for headquarters-managed R&D subsidiary is absorbed by subsidiary fixed effects. Innovation Quality is the natural log of one plus the total number of forward citations (excluding examiner and self-citations) received by the R&D subsidiary in five years for the patents filed in the current year. Innovation Market Value is the natural log of one plus the total market-adjusted MNE returns (millions of dollars) on the three-day window following the patent issue date for the patents invented by the focal R&D subsidiary in that year, deflated to 1982 using the CPI. All models are estimated using fixed effects OLS with robust standard errors clustered at the subsidiary level. Standard errors are in parentheses and p-values are in brackets.

in innovation quality (Column 5) and a 31.8% ($p < 0.05$) increase in innovation market value (Column 10) for MS-managed R&D subsidiaries. HQ-managed subsidiaries exhibit a 45.8% ($p < 0.05$) percent smaller change in innovation quality and a 47.8% ($p < 0.05$) percent smaller change in innovation market value compared to MS-managed subsidiaries, indicating that post-broadband, MS-managed R&D subsidiaries increased both the quality and economic impact of innovation more than HQ-managed.

4.1.2. Cultural distance

An alternative explanation is that MS may be better equipped to interpret information from culturally distant R&D subsidiaries, even after we match MS to HQ subsidiaries of equal cultural distance. If so, the broadband effect should be stronger when subsidiaries are culturally distant. Split-sample analyses using the median cultural distance suggest, however, that cultural barriers dampen the overall benefits of connectivity infrastructure. As shown in Appendix Table D.7, coefficient magnitudes are smaller for both HQ- and MS-managed subsidiaries when cultural distance is high. This suggests that high cultural distance reduces innovation performance for both HQ- and MS-managed subsidiaries relative to low cultural distance, though the differences between the high and low coefficients are not statistically significant.

4.1.3. Local market competition

Another factor is local market competition. High market competition creates dynamic, information-rich environments where firms must adapt quickly to local customer needs, rivals, and technologies. Relative to HQ, MS may be more attuned to local market conditions and able to process and act on this local market information more efficiently once connectivity improves than HQ. However, several factors suggest this is not driving our results. First, R&D subsidiaries are matched on host-country–industry market concentration. Second, this variable is included as a control in all regressions. Split-sample analyses by high and low concentration confirm that the performance gap between HQ- and MS-managed subsidiaries remains stable (see Appendix Table D.7), indicating that local market concentration does not explain the observed effects.

4.1.4. Local innovation effects

Another alternative explanation is that broadband may increase subsidiary innovation by improving access to local knowledge and expertise, independent of managing entity involvement. Several factors indicate that this mechanism does not drive our results. First, the matched sample design pairs HQ- and MS-managed subsidiaries within the same country and industry, and all models control for time-varying country–industry regional technological advantage, accounting for changes in local knowledge conditions. Second, we code the broadband treatment based on dyadic access because information exchange requires two-way connectivity between the managing entity and the R&D subsidiary. In contrast, local externalities, such as improved labor markets or regional knowledge access, would manifest under subsidiary-only broadband access. However, as shown in our unilateral-access analysis (see Section 3.4), innovation output does not increase when only the subsidiary or only the managing entity has broadband access, indicating that local spillovers are unlikely to explain the results. Third, we examine changes in external knowledge flows, measured as the total number of backward citations to non-MNE patents (excluding examiner citations). If R&D subsidiaries were drawing more heavily on local knowledge, this measure should increase; yet, as shown in Appendix Table D.8, we find no evidence supporting this channel. This result also aligns with notion that large firms rely more on their own internal knowledge than external knowledge (Agrawal et al., 2017).

4.1.5. Investments in fixed assets

Another possibility is that broadband introduction coincides with MS-managed R&D subsidiary investments in fixed assets that independently raise innovation productivity. To test this, we re-estimate our models including the natural log of subsidiary fixed assets as a control. As reported in Appendix Table D.9, the results remain robust, suggesting that asset investments do not account for the findings.

4.1.6. Environmental context: Host-country economic, regulatory, and political factors

Despite the within-country matched-sample design, systematic differences in host-country environments might still bias results. Economic, regulatory, or political factors may influence R&D intensity, site selection, or personnel mobility. We therefore include controls for GDP growth, intellectual property rights index, bureaucratic quality, investment profile, rule of law, and political stability (see Appendix C for definitions and data sources). We find consistent results across all models (see Appendix Table D.9), indicating that contextual heterogeneity does not explain the results.

4.1.7. Tax avoidance

Since our data come from transfer pricing reports, we assess the potential influence of tax avoidance behavior. Although patent data comes independently from the USPTO, firms might misreport management structures for tax purposes. To address this concern, we conduct robustness tests controlling for (1) the standard firm-level measure of tax avoidance (Dyreng et al., 2019), (2) a binary indicator equal to one if the host country has a patent box regime, (3) the host-country–industry effective tax rate, and (4) the difference between host- and home-country-industry effective tax rates. As shown in Appendix Table D.10, the results remain robust across all specifications, indicating that the observed effects are not driven by tax avoidance.

4.2. Within-MNE and within-subsidiary differences in HQ and MS management

We assume broadband access closely corresponds to its adoption due to its low implementation costs and potential for substantial productivity gains. Nonetheless, unobserved MNE-level heterogeneity could influence the likelihood of broadband adoption after its introduction. To evaluate the risk of this heterogeneity biasing the results and other unobservable factors such as MNE home country, we conduct within-MNE analyses incorporating MNE × year fixed effects. As shown in Appendix Table D.11, the results remain consistent, indicating that firm-level unobserved heterogeneity does not bias our findings.

A related concern is that unobserved differences between HQ- and MS-managed subsidiaries may remain even after matching. For example, MS-managed R&D subsidiaries may also receive resources or oversight from HQ, potentially inflating the estimated effects of MS management. To address this, we analyze R&D subsidiaries jointly managed by both HQ and MS and trace knowledge flows from and co-inventions with each managing entity separately. This within-subsidiary design accounts for dual management and mitigates bias from subsidiary-specific unobservables. As reported in Appendix Table D.12, after broadband introduction, subsidiaries managed by both HQ and MS have significantly smaller changes in knowledge flows from, and co-inventions with, HQ relative to MS. This pattern supports the view that broadband differentially affects knowledge transfer and collaboration across managing entity types and alleviates concerns that unobserved subsidiary characteristics drive the results.

4.3. DDD specification tests

4.3.1. Verifying parallel trends and placebo tests

We begin by examining the assumption of parallel trends for DDD analyses. This assumption requires that, absent the treatment (broadband introduction), the difference between the treatment and control groups would have remained constant over time. Unlike standard DD models, the DDD estimator does not require two parallel trends for causal interpretation. Instead, the bias from two biased DD estimators cancels out (i.e., it is differenced out) if it is consistent across both estimators (Olden and Møen, 2022). Therefore, the parallel trend assumption in our case applies only to the interaction term that compares changes in HQ- to MS-managed subsidiaries.

We visually assess the parallel trends assumption by splitting the HQ-Managed×Post-Broadband Introduction interaction term into four-year periods relative to broadband introduction and plot the estimated coefficients with 95% confidence intervals (Fig. 3). Because the sample excludes observations with changes in management structure, the results can be interpreted as the relative four-year average change in innovation output for R&D subsidiaries under continued HQ management compared to MS management. The analysis shows no significant pre-trends, confirming adherence to the DDD parallel trend assumption, with a notable upward shift after broadband introduction.

As an additional robustness check, we conduct placebo tests using one-, two-, and three-year leads of the post-broadband variable and its interaction with HQ-managed. The placebo results, reported in Appendix Table D.13 for innovation output, quality, and market value, provide evidence that the results are not likely driven by spurious time effects.

4.3.2. Staggered difference-in-differences heterogeneous and dynamic effects tests

Recent research on staggered difference-in-differences highlights potential biases that can emerge if treatment timings and effects are heterogeneous (Baker et al., 2022; Callaway and Sant'Anna, 2021). This is because two-way fixed effects compute the weighted average from: 1) comparing treated with untreated units, and 2) comparing treated with pre-treated units. The second comparison can produce negative weights even when true treatment effects are positive (De Chaisemartin and d'Haultfoeuille, 2020; Goodman-Bacon, 2021). This concern is relevant to our long panel, where early and late treatments may differ and treatment effects may vary with technological advancements. Moreover, treatment effects may evolve as exposure increases, for instance, as complementary technologies emerge, infrastructure improves, and users advance along learning curves.

Testing for such biases in our case is complex due to the DDD design involving an unbalanced panel with a time-constant interaction term, which most current methods have yet to fully address. Our strategy involves a combination of two procedures. First, to examine whether heterogeneous effects vary by treatment timing, we implement the Wooldridge (2021) procedure and construct binary indicators for each "cohort" of R&D subsidiaries treated in a given period. This flexible approach allows estimation of cohort-specific effects while addressing biases in DDD models with unbalanced panel data. Due to limited observations and following Wooldridge's (2021) recommendation, we combine the first and last three years of our sample period into two respective cohorts, treating all other years as individual cohorts. Running each year as a separate cohort yields consistent coefficient signs but larger standard errors. In Appendix Table D.14, we find that the estimated broadband and HQ-management effects are stable across cohorts and display no temporal trend, indicating that our results are not driven by heterogeneous treatment timing.

Second, we use the estimator from (de Chaisemartin et al., 2024) which is robust to both heterogeneous and dynamic treatment effects. This approach generates dynamic effect estimates by comparing outcome changes between units that switched to treatment ℓ years before and those yet to be treated. It also computes the average heterogeneity-robust effects as a weighted sum of instantaneous and dynamic effects by HQ-managed and MS-managed R&D subsidiaries. As shown in Appendix Table D.15, consistent with the main results in Columns 2–5 of Table 4, the average total heterogeneity-robust effect for MS-managed subsidiaries is positive and significant (coefficient $=$ 0.244, $p < 0.05$). In contrast, for HQ-managed subsidiaries, it is negative and non-significant ($p > 0.10$). Examining effects across each ℓ year since treatment, we find that dynamic effects are non-significant ($p =$ 0.252 for HQ-managed and $p = 0.166$ for MS-managed). Additionally, placebo tests indicate that the three years before treatment do not significantly differ from zero ($p = 0.27$ for HQ-managed and $p = 0.98$ for MS-managed), aligning with the earlier placebo tests in Section 4.3.1.

Together, these results suggest that our findings are not driven by

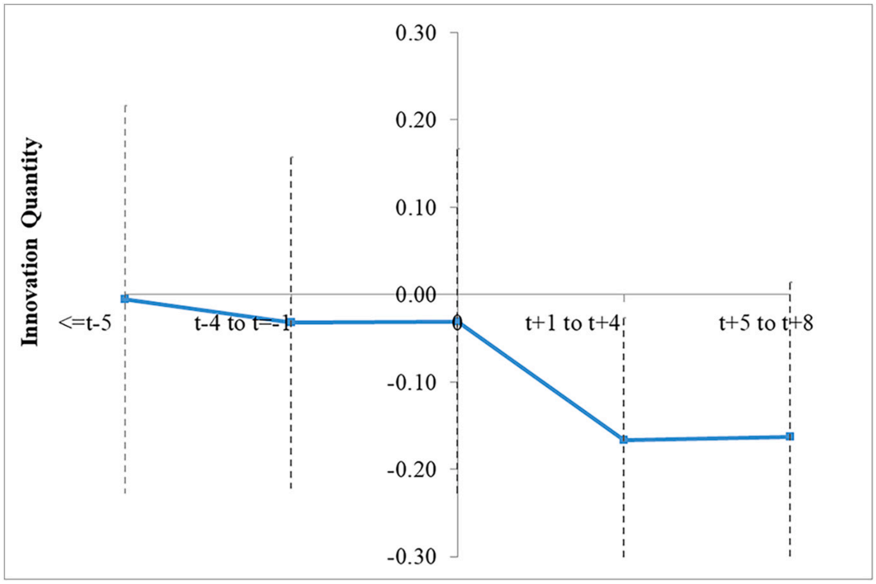

Fig. 3. Triple differences pre-treatment trend for innovation output. Notes. The graph is based on the baseline specification in Table 4, with the Headquarters-managed × Post-Broadband Introduction split into multiple periods as indicated. Each point on the graph represents the coefficient estimate for the Headquarters-managed × Post-Broadband Introduction binary indicators. The dashed lines represent the 95% confidence interval. The wider confidence intervals relative to those in Table 4 reflect the reduced degrees of freedom resulting from splitting the interaction term into separate period-specific indicators.

heterogeneous or dynamic treatment effects and that the estimated broadband impacts are robust across treatment cohorts and time horizons.

4.4. *Different thresholds for broadband introduction*

We test alternative broadband penetration thresholds of 3.0%, 7.0%, and 9.0% in both the R&D subsidiary's and managing entity's countries. At the 3.0% threshold, we do not find evidence that broadband is associated with changes in R&D subsidiary innovation output. However, once penetration reaches 5.0%, broadband consistently and significantly is associated with increased innovation in MS-managed R&D subsidiaries, with similar results to Table 4 at higher thresholds (see Appendix Table D.16).

4.5. *Specification check: Inverse hyberbolic sine transformation and fixed effects Poisson*

We assess the robustness of the results using alternative model specifications. Following prior work, our main analyses employ the shifted logarithmic transformation, $\ln(1 + y)$, which is suited to highly skewed, non-negative outcomes with zeros (De Bruyn and Freed, 2025; Wang et al., 2024). However, this transformation can limit interpretability of effect sizes. To verify consistency, we re-estimate all models using the inverse hyperbolic sine (IHS) transformation (Burbidge et al., 1988; Glaeser and Lang, 2024) and fixed-effects Poisson pseudo maximum likelihood regression (Cohn et al., 2022), useful alternatives for nonnegative, right-skewed dependent variables such as innovation counts.

While Poisson estimators assume conditional mean–variance equality, we cluster robust standard errors at the subsidiary level to address heteroskedasticity. We employ Poisson primarily to assess coefficient consistency rather than for precise inference. The results in Appendix Table D.17 are consistent with the main specification: MS-managed subsidiaries experience significantly larger post-broadband increases in innovation output, and the HQ–MS difference remains both directionally and statistically robust. Overall, our results hold under both the IHS and fixed-effects Poisson specifications.

4.6. *Additional robustness*

We conduct several additional robustness tests. First, because the matching algorithm includes many variables, including matching based on country, we test alternative matched samples with fewer matching variables and fixed effects, which results in more matches, and find consistent results. Second, we extend the timing structure by using innovation output at $t + 3$ to capture a longer lead time for R&D projects to yield patents. As shown in Appendix Table D.18, the results remain robust: MS-managed subsidiaries continue to exhibit significantly larger post-broadband increases in innovation than HQ-managed subsidiaries, consistent with the stable effects observed in Fig. 3. Third, we test the sensitivity of our results to the number of co-inventors by weighting each patent by the number of co-inventing entities and find consistent results (see Appendix D.19). Third, to test for country-specific influence, we exclude one-by-one major contributors to the sample: China, France, Germany, India, Taiwan, the United Kingdom, and the United States, and find that the results are unaffected (Appendix Table D.20). Finally, because regional headquarters may perform functions similar to corporate HQs, we reclassify the 34 cases involving regional HQs as corporate HQs and observe no change in the main results.

5. Discussion and conclusion

This study contributes to the literature on connectivity infrastructure by identifying a key mechanism underlying the heterogeneous effects of connectivity on innovation (Campante and Yanagizawa-Drott, 2018; Schreyer, 2000; Wu et al., 2021). We show that the impact of improved connectivity infrastructure on innovation depends critically on an MNE's internal management structure, specifically whether an R&D subsidiary is managed by HQ or MS. Although improved connectivity reduces information transmission costs, HQ's broader and more complex informational demands limit its ability to convert increased information flows into innovation.

We find evidence that differences in informational complexity faced by managing entities underlie the divergence between HQ and MS management. When coordination demands on HQ are limited, as in smaller or less complex MNEs, its performance converges with that of MS. Conversely, in more complex settings, the HQ–MS gap widens, consistent with the view that HQ's broad organizational responsibilities create information-processing bottlenecks that limit its ability to capitalize on improved information flows. HQ-managed subsidiaries exhibit relatively larger post-broadband increases in innovation when they are strategically important, have greater organizational weight, or are technologically closer to HQ—contexts in which managers are more likely to allocate attention when information-processing demands outstrip capacity.

We also contribute to the literature on MNE innovation management (e.g., Berry, 2015; Gillmore et al., 2023; Knott and Turner, 2019) by providing the first large-scale empirical comparison of innovation outcomes under HQ versus MS management. The findings inform the debate on whether the field should reconsider the headquarter-centric view (Nell and Ambos, 2013; Teodorescu et al., 2022). Connectivity advances disproportionately enhance MS effectiveness in managing R&D relative to HQ, reflected in relatively larger improvements in knowledge sharing, collaboration, and monitoring. Contrary to the conventional view that MS advantages over HQ derive primarily from mitigating frictions because of their geographic proximity to R&D subsidiaries (Gumpert et al., 2022), the analysis robustly indicates that, holding proximity constant, MS-managed subsidiaries achieve greater post-broadband increases in innovation than HQ-managed counterparts. Taken together, the findings indicate that MS's value extends beyond mitigating distance, challenging assumptions of HQ primacy and raising the possibility that improvements in connectivity may shift innovative advantage towards more specialized managerial structures.

Finally, we extend research on the (de)centralization of R&D management by offering a more functional characterization of internal authority structures (Asakawa, 2001; Eklund, 2022; West, 2000). Prior work often frames management as a dichotomy between HQ and autonomous subsidiaries, overlooking the prevalence and strategic role of MS (Nell et al., 2017). This disconnect between theory and practice partly reflects empirical challenges in documenting internal innovation management structures. Using detailed longitudinal data linking R&D subsidiaries to their managing entities, we show that MS constitutes a distinct organizational form with meaningful implications for innovation. The large post-broadband increases under MS management underscore the theoretical and managerial importance of vertical subsidiary-to-subsidiary authority structures.

This study has several limitations that inform promising avenues for future research. First, we rely on USPTO data because it is the most consistent source for identifying inventor locations and tracing intrafirm collaboration during our study period, but it restricts the sample to US-patented inventions. As datasets improve, expanding to global patent datasets would strengthen generalizability and cross-country comparability. Second, the analysis does not investigate the full structure of inventor networks. Incorporating network-level measures (e.g., centrality, density, or tie-formation) could provide additional insight on the impact of connectivity. Third, our approach may not fully capture the direct effects of broadband on innovation independent of management structure. Finer-grained multi-level data could help disentangle these effects. Finally, although we hold management structures constant, firms may adapt in response to improved connectivity over time (Bloom et al., 2014). For example, connectivity infrastructure may enable MS more than HQ to enhance recruitment, training, automation, or innovation practices. Future research could examine how connectivity shapes subsidiary human capital, skill composition, and internal innovation routines.

The findings also have important managerial implications. In increasingly dynamic and uncertain environments, organizational design plays a critical role in determining whether firms can capitalize on connectivity-enabled opportunities. MS can equip the MNE with greater agility, enabling the firm to identify, integrate, and diffuse opportunities more effectively across subsidiaries, in the face of emerging infrastructure. This underscores how firms' choices regarding HQ- and MS-management of R&D subsidiaries carry meaningful consequences for innovation performance from infrastructural improvements.

In conclusion, this study provides systematic evidence that the innovation returns to connectivity infrastructure depend on firms' internal management structures. Although improved connectivity enhances information-processing capacity across the organization, MS-managed subsidiaries experience substantially larger increases in innovation than those managed by HQ. We provide robust empirical evidence on the channels and conditions under which MS-managed R&D subsidiaries achieve greater post-broadband increases in innovation than those managed by HQ. In doing so, the study addresses an important gap in understanding whether and when connectivity infrastructure increases innovation and highlights the role of internal management structures. The findings offer actionable guidance for firms managing geographically dispersed R&D and underscore the growing strategic importance of MS in capturing the opportunities enabled by connectivity infrastructure.

CRediT authorship contribution statement

Catherine Magelssen: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Luis Ballesteros:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Casidhe Troyer:** Writing – review & editing, Writing – original draft, Investigation, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used ChatGPT in order to copy edit the manuscript and for developing the visual image for the graphical abstract. After using this tool/service, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the published article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We are grateful to Heather Berry, Ritta Katila, Tim Simcoe, Keyvan Vakili, and Minyuan Zhao for their valuable comments on our drafts. We thank the participants for seminars and brown bag series at Boston University, Olin Business School, London Business School, and the University of South Carolina. We also thank participants at the Wharton Corporate Strategy and Innovation Conference, the Ghoshal Conference, Academy of Management Conference, Strategic Management Society Conference, and the Academy of International Business Conference for their helpful feedback. We acknowledge the financial support of London Business School, which made this research possible. All remaining errors are our own.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.respol.2026.105542.

Data availability statement

The data underlying this article derive from data obtained a confidentiality agreement, which prohibits sharing or publicly disclosing the raw data. Non-confidential information on variable construction and estimation procedures is provided in the manuscript and appendices.

Additional details may be available from the corresponding author subject to legal and confidentiality constraints.

References

Aghion, P., Tirole, J., 1994. The Management of Innovation. Q. J. Econ. 109, 1185–1209. https://doi.org/10.2307/2118360.

Aghion, P., Tirole, J., 1997. Formal and real authority in organizations. J. Polit. Econ. 105, 1–29. https://doi.org/10.1086/262063.

Aghion, P., Van Reenen, J., Zingales, L., 2013. Innovation and institutional ownership. Am. Econ. Rev. 103, 277–304. https://doi.org/10.1257/aer.103.1.277.

Aghion, P., Bloom, N., Van Reenen, J., 2014. Incomplete contracts and the internal organization of firms. J. Law Econ. Organ. 30, 37–63. https://doi.org/10.1093/jleo/ewt003.

Agrawal, A., Goldfarb, A., 2008. Restructuring research: communication costs and the democratization of university innovation. Am. Econ. Rev. 98, 1578–1590. https://doi.org/10.1257/aer.98.4.1578.

Agrawal, A., Galasso, A., Oettl, A., 2017. Roads and innovation. Rev. Econ. Stat. 99, 417–434. https://doi.org/10.1162/REST_A_00619.

Ahuja, G., Katila, R., 2001. Technological acquisitions and the innovation performance of acquiring firms: a longitudinal study. Strateg. Manag. J. 22, 197–220. https://doi.org/10.1002/smj.157.

Akerman, A., Gaarder, I., Mogstad, M., Shakespeare, W., 2015. The skill complementarity of broadband internet. Q. J. Econ. 130, 1781–1824. https://doi.org/10.1093/qje/qjv028.

Akerman, A., Leuven, E., Mogstad, M., 2022. Information frictions, internet, and the relationship between distance and trade. Am. Econ. J. Appl. Econ. 14, 133–163. https://doi.org/10.1257/app.20190589.

Allen, M.R., Adomdza, G.K., Meyer, M.H., 2015. Managing for innovation: managerial control and employee level outcomes. J. Bus. Res. 68, 371–379. https://doi.org/10.1016/j.jbusres.2014.06.021.

Amabile, T.M., 1988. A model of creativity and innovation in organizations. Res. Organ. Behav. 10, 123–167.

Asakawa, K., 2001. Organizational tension in international R&D management: the case of Japanese firms. Res. Policy 30, 735–757. https://doi.org/10.1016/S0048-7333(00)00103-7.

Bahar, D., Choudhury, P., Kim, D.Y., Koo, W.W., 2023. Innovation on wings: nonstop flights and firm innovation in the global context. Manag. Sci. 69, 6202–6223. https://doi.org/10.1287/mnsc.2023.4682.

Baker, A.C., Larcker, D.F., Wang, C.C.Y., 2022. How much should we trust staggered difference-in-differences estimates? J. Financ. Econ. 144, 370–395. https://doi.org/10.1016/j.jfineco.2022.01.004.

Balsmeier, B., Fleming, L., Manso, G., 2017. Independent boards and innovation. J. Financ. Econ. 123, 536–557. https://doi.org/10.1016/j.jfineco.2016.12.005.

Bernstein, S., Giroud, X., Townsend, R.R., 2016. The impact of venture capital monitoring. J. Finance 71, 1591–1622. https://doi.org/10.1111/jofi.12370.

Berry, H., 2014. Global integration and innovation: multicountry knowledge generation within MNCs. Strateg. Manag. J. 35, 869–890. https://doi.org/10.1002/smj.2140.

Berry, H., 2015. Knowledge inheritance in global industries: the impact of parent firm knowledge on the performance of foreign subsidiaries. Acad. Manage. J. 58, 1438–1458. https://doi.org/10.5465/amj.2013.0724.

Bertschek, I., Cerquera, D., Klein, G.J., 2013. More bits - more bucks? Measuring the impact of broadband internet on firm performance. Inf. Econ. Policy 25, 190–203. https://doi.org/10.1016/j.infoecopol.2012.11.002.

Bertschek, I., Briglauer, W., Hüschelrath, K., Kauf, B., Niebel, T., 2015. The economic impacts of broadband internet: a survey. Rev. Netw. Econ. 14, 201–227. https://doi.org/10.1515/RNE-2016-0032.

Birkinshaw, J., Braunerhjelm, P., Holm, U., Terjesen, S., 2006. Why do some multinational corporations relocate their headquarters overseas? Strateg. Manag. J. 27, 681–700.

Bloom, N., Sadun, R., Van Reenen, J., 2012. Americans do IT better: US multinationals and the productivity miracle. Am. Econ. Rev. 102, 167–201. https://doi.org/10.1257/aer.102.1.167.

Bloom, N., Garicano, L., Sadun, R., Van Reenen, J., 2014. The distinct effects of information technology and communication technology on firm organization. Manag. Sci. 60, 2859–2885. https://doi.org/10.1287/mnsc.2014.2013.

Bouquet, C., Birkinshaw, J., 2008. Weight versus voice: how foreign subsidiaries gain attention from corporate headquarters. Acad. Manage. J. 51, 577–601. https://doi.org/10.5465/amj.2008.32626039.

Branstetter, L., Maskus, K.E., 2022. Global knowledge flows, absorptive capacity and capability acquisition: old ideas, recent evidence and new approaches. In: Trade in Knowledge Intellectual Property, Trade and Development in a Transformed Global Economy. Cambridge University Press, pp. 405–430. https://doi.org/10.1017/9781108780919.017.

Branstetter, L., Li, G., Veloso, F., 2014. The rise of international coinvention. In: NBER Chapters, in: The Changing Frontier: Rethinking Science and Innovation Policy. National Bureau of Economic Research, Inc, pp. 135–168.

Bresnahan, T.F., Brynjolfsson, E., Hitt, L.M., 2002. Information technology, workplace organization, and the demand for skilled labor: firm-level evidence. Q. J. Econ. 117, 339–376. https://doi.org/10.1162/003355302753399526.

Burbidge, J., Magee, L., Robb, A.L., 1988. Alternative transformations to handle extreme values of the dependent variable. J. Am. Stat. Assoc. 83, 123–127. https://doi.org/10.1080/01621459.1988.10478575.

Callaway, B., Sant'Anna, P.H.C., 2021. Difference-in-differences with multiple time periods. J. Econom. 225, 200–230. https://doi.org/10.1016/j.jeconom.2020.12.001.

Campante, F., Yanagizawa-Drott, D., 2018. Long-range growth: economic development in the global network of air links. Q. J. Econ. 133, 1395–1458. https://doi.org/10.1093/qje/qjx050.

Catalini, C., Fons-Rosen, C., Gaulé, P., 2020. How do travel costs shape collaboration? Manag. Sci. 66, 3340–3360. https://doi.org/10.1287/mnsc.2019.3381.

de Chaisemartin, C., Ciccia, D., D'Haultfœuille, X., Knau, F., Malézieux, M., SOW, D., 2024. Event-Study Estimators and Variance Estimators Computed by the did_multiplegt_dyn Command. Available at SSRN.

Cho, H., Pucik, V., 2005. Relationship between innovativeness, quality, growth, profitability, and market value. Strateg. Manag. J. 26, 555–575. https://doi.org/10.1002/smj.461.

Choudhury, P., 2017. Innovation outcomes in a distributed organization: intrafirm mobility and access to resources. Organ. Sci. 28, 339–354. https://doi.org/10.1287/orsc.2017.1121.

Ciabuschi, F., Dellestrand, H., Martín, O.M., 2011. Internal embeddedness, headquarters involvement, and innovation importance in multinational enterprises. J. Manag. Stud. 48, 1612–1639. https://doi.org/10.1111/j.1467-6486.2011.01014.x.

Cohn, J.B., Liu, Z., Wardlaw, M.I., 2022. Count (and count-like) data in finance. J. Financ. Econ. 146, 529–551. https://doi.org/10.1016/j.jfineco.2022.08.004.

Cramton, C.D., 2001. The mutual knowledge problem and its consequences for dispersed collaboration. Organ. Sci. 12, 346–371. https://doi.org/10.1287/orsc.12.3.346.10098.

Cuervo-Cazurra, A., Mudambi, R., Pedersen, T., 2019. Subsidiary power: loaned or owned? The lenses of agency theory and resource dependence theory. Glob. Strategy J. 9, 491–501. https://doi.org/10.1002/gsj.1362.

Cuijpers, M., Guenter, H., Hussinger, K., 2011. Costs and benefits of inter-departmental innovation collaboration. Res. Policy 40, 565–575. https://doi.org/10.1016/j.respol.2010.12.004.

Daft, R.L., Lengel, R.H., 1986. Organizational information requirements, media richness and structural design. Manag. Sci. 32, 554–571. https://doi.org/10.1287/mnsc.32.5.554.

Dambra, M., Gustafson, M., 2021. Do the burdens to being public affect the investment and innovation of newly public firms? Manag. Sci. 67, 594–616. https://doi.org/10.1287/mnsc.2019.3436.

De Bruyn, G., Freed, P.G., 2025. Workforce sleep and corporate innovation. Res. Policy 54, 105191. https://doi.org/10.1016/j.respol.2025.105191.

De Chaisemartin, C., d'Haultfoeuille, X., 2020. Two-way fixed effects estimators with heterogeneous treatment effects. Am. Econ. Rev. 110, 2964–2996. https://doi.org/10.1257/aer.20181169.

De Meyer, A., Mizushima, A., 1989. Global R&D management. R D Manag. 19, 135–146. https://doi.org/10.1111/j.1467-9310.1989.tb00634.x.

De Wit, K., 2022. How broadband infrastructure gets built [WWW Document], URL. https://www.pewtrusts.org/en/research-and-analysis/fact-sheets/2022/07/how-broadband-infrastructure-gets-built. (Accessed 5 May 2023).

Dessein, W., 2002. Authority and communication in organizations. Rev. Econ. Stud. 69, 811–838. https://doi.org/10.1111/1467-937X.00227.

Ding, W.W., Levin, S.G., Stephan, P.E., Winkler, A.E., 2010. The impact of information technology on academic scientists' productivity and collaboration patterns. Manag. Sci. 56, 1439–1461. https://doi.org/10.1287/mnsc.1100.1195.

Donaldson, D., 2018. Railroads of the raj: estimating the impact of transportation infrastructure. Am. Econ. Rev. 108, 899–934.

Dyreng, S.D., Hanlon, M., Maydew, E.L., 2019. When does tax avoidance result in tax uncertainty? Account. Rev. 94, 179–203. https://doi.org/10.2308/ACCR-52198.

Egelhoff, W.G., 1982. Strategy and structure in multinational corporations: an information-processing approach. Adm. Sci. Q. 435–458. https://doi.org/10.2307/2392321.

Egelhoff, W.G., 1991. Information-processing theory and the multinational enterprise. J. Int. Bus. Stud. 22, 341–368. https://doi.org/10.1057/palgrave.jibs.8490306.

Eklund, J.C., 2022. The knowledge-incentive tradeoff: understanding the relationship between research and development decentralization and innovation. Strateg. Manag. J. 43, 2478–2509. https://doi.org/10.1002/smj.3416.

Ericsson, Little, Arthur D., Chalmers University of Technology, 2013. Socioeconomic Effects of Broadband Speed. Available at: https://www.ericsson.com/res/thecompany/docs/corporate-responsibility/2013/ericsson-broadband-final-071013.pdf.

EY, 2013. Navigating the Choppy Waters of International Tax 2013 Global Transfer Pricing Survey.

Ezell, S.J., Atkinson, R.D., Castro, D., Ou, G., 2009. The Need for Speed: The Importance of Next-Generation Broadband Networks, The Information Technology and Innovation Foundation. Elsevier BV. https://doi.org/10.2139/ssrn.1354032.

Faccio, M., O'Brien, W.J., 2021. Business groups and employment. Manag. Sci. 67, 3468–3491. https://doi.org/10.1287/mnsc.2020.3616.

Forman, C., van Zeebroeck, N., 2012. From wires to partners: how the internet has fostered R & D collaborations within firms. Manag. Sci. 58, 1549–1568. https://doi.org/10.1287/mnsc.1110.1505.

Forman, C., van Zeebroeck, N., 2019. Digital technology adoption and knowledge flows within firms: can the internet overcome geographic and technological distance? Res. Policy 48, 103697. https://doi.org/10.1016/j.respol.2018.10.021.

Galbraith, J., 1973. Designing Complex Organizations. Addison-Wesley, Reading, Mass.

Galbraith, J., 1977. Organization Design, Organization Design. Addison-Wesley, Reading, Massachusetts.

Garicano, L., 2000. Hierarchies and the organization of knowledge in production. J. Polit. Econ. 108, 874–904. https://doi.org/10.1086/317671.

Gaspar, J., Glaeser, E.L., 1998. Information technology and the future of cities. J. Urban Econ. 43, 136–156. https://doi.org/10.1006/juec.1996.2031.
Gillmore, E., Andersson, U., Dellestrand, H., 2023. Between a rock and a hard place: the consequences of complex headquarters configurations for subsidiary R&D activities. Glob. Strategy J. 13, 217–247. https://doi.org/10.1002/gsj.1431.
Glaeser, C.K., Glaeser, S., Labro, E., 2023. Proximity and the management of innovation. Manag. Sci. 69, 3080–3099. https://doi.org/10.1287/mnsc.2022.4469.
Glaeser, S., 2018. The effects of proprietary information on corporate disclosure and transparency: evidence from trade secrets. J. Account. Econ. 66, 163–193. https://doi.org/10.1016/j.jacceco.2018.04.002.
Glaeser, S., Lang, M., 2024. Measuring innovation and navigating its unique information issues: a review of the accounting literature on innovation. J. Account. Econ. 78, 101720. https://doi.org/10.1016/j.jacceco.2024.101720.
Glaeser, S., Michels, J., Verrecchia, R.E., 2020. Discretionary disclosure and manager horizon: evidence from patenting. Rev. Acc. Stud. 25, 597–635. https://doi.org/10.1007/s11142-019-09520-0.
Goodman-Bacon, A., 2021. Difference-in-differences with variation in treatment timing. J. Econom. 225, 254–277. https://doi.org/10.1016/j.jeconom.2021.03.014.
Griliches, Z., 1990. Patent Statistics as Economic Indicators. NBER, Cambridge, MA.
Gumpert, A., Steimer, H., Antoni, M., 2022. Firm organization with multiple establishments. Q. J. Econ. 137, 1091–1138. https://doi.org/10.1093/qje/qjab049.
Hall, B., Jaffe, A., Trajtenberg, M., 2005. Market value and patent citations: a first look. RAND J. Econ. 36, 16–38.
Henderson, A.D., Fredrickson, J.W., 1996. Information-processing demands as a determinant of CEO compensation. Acad. Manage. J. 39, 575–606. https://doi.org/10.5465/256656.
Holmstrom, B., 1989. Agency costs and innovation. J. Econ. Behav. Organ. 12, 305–327. https://doi.org/10.1016/0167-2681(89)90025-5.
Huber, G.P., 1990. A theory of the effects of advanced information technologies on organizational design, intelligence, and decision making. Acad. Manag. Rev. 15, 47. https://doi.org/10.2307/258105.
IRS Treas. Reg. §1.482, n.d. United States Treasury Regulations Section 1.482.
Knott, A.M., Turner, S.F., 2019. An innovation theory of headquarters value in multibusiness firms. Organ. Sci. 30, 19–39. https://doi.org/10.1287/orsc.2018.1231.
Kogan, L., Papanikolaou, D., Seru, A., Stoffman, N., 2017. Technological innovation, resource allocation, and growth. Q. J. Econ. 132, 665–712.
Koh, Y., Li, J., Xu, J., 2025. Subway, collaborative matching, and innovation. Rev. Econ. Stat. 107, 476–493. https://doi.org/10.1162/REST_A_01279.
Lanjouw, J.O., Schankerman, M., 2004. Patent quality and research productivity: measuring innovation with multiple indicators. Econ. J. 114, 441–465.
Lerner, J., Seru, A., 2017. The Use and Misuse of Patent Data: Issues for Corporate Finance and Beyond. National Bureau of Economic Research, Cambridge, MA. https://doi.org/10.3386/w24053.
Lin, C., Liu, S., Manso, G., 2021. Shareholder litigation and corporate innovation. Manag. Sci. 67, 3346–3367. https://doi.org/10.1287/mnsc.2020.3626.
Lo, D., Brahm, F., Dessein, W., Minami, C., 2022. Managing with style? Microevidence on the allocation of managerial attention. Manag. Sci. 68, 8261–8285. https://doi.org/10.1287/mnsc.2021.4269.
Lunnan, R., Zhao, Y., 2014. Regional headquarters in China: role in MNE knowledge transfer. Asia Pac. J. Manag. 31, 397–422. https://doi.org/10.1007/s10490-013-9358-4.
Mack-Smith, D., 2013. UK Broadband Impact Study Impact Report.
Magelssen, C., 2020. Allocation of property rights and technological innovation within firms. Strateg. Manag. J. 41, 758–787. https://doi.org/10.1002/smj.3103.
Majumdar, A.K., 2019. Basics of worldwide broadband wireless access independent of terrestrial limitations. In: Optical Wireless Communications for Broadband Global Internet Connectivity. Elsevier, pp. 5–38.
Malhotra, A., Majchrzak, A., Rosen, B., 2007. Leading virtual teams. Acad. Manag. Perspect. 21, 60–70. https://doi.org/10.5465/amp.2007.24286164.
Manso, G., 2011. Motivating innovation. J. Finance 66, 1823–1860. https://doi.org/10.1111/j.1540-6261.2011.01688.x.
March, J.G., Simon, H.A., 1958. Organizations. Wiley, Oxford.
McShane, B.B., Gal, D., Gelman, A., Robert, C., Tackett, J.L., 2019. Abandon statistical significance. Am. Stat. 73 (S1), 235–245. https://doi.org/10.1080/00031305.2018.1527253.
Nell, P.C., Ambos, B., 2013. Parenting advantage in the MNC: an embeddedness perspective on the value added by headquarters. Strateg. Manag. J. 34, 1086–1103. https://doi.org/10.1002/smj.2058.
Nell, P.C., Kappen, P., Laamanen, T., 2017. Reconceptualising hierarchies: the disaggregation and dispersion of headquarters in multinational corporations. J. Manag. Stud. 54, 1121–1143. https://doi.org/10.1111/joms.12313.
OECD, 2015. The Development of Fixed Broadband Networks.
OECD, 2017. OECD Transfer Pricing Guidelines for MNEs and Tax Administrations 2017. Paris.
OECD/ITF, 2025. Global Transport Infrastructure Investment Data Update | ITF.
Olden, A., Møen, J., 2022. The triple difference estimator. Econom. J. 25, 531–553.
Pischke, J., 2005. Empirical Methods in Applied Economics.
Polanyi, M., 1966. The Tacit Dimension. Doubleday, Garden City, NY.
Prieger, J.E., 2003. The supply side of the digital divide: is there equal availability in the broadband internet access market? Econ. Inq. 41, 346–363. https://doi.org/10.1093/ei/cbg013.
PwC, 2025. Perspectives from the Global Telecom Outlook 2024–2028.
Rajan, R.G., Wulf, J., 2006. The flattening firm: evidence from panel data on the changing nature of corporate hierarchies. Rev. Econ. Stat. 88, 759–773. https://doi.org/10.1162/rest.88.4.759.
Roller, L.-H., Waverman, L., 2001. Telecommunications infrastructure and economic development: a simultaneous approach. Am. Econ. Rev. 91, 909–923. https://doi.org/10.1257/aer.91.4.909.
Roth, K., Morrison, A.J., 1992. Implementing global strategy: characteristics of global subsidiary mandates. J. Int. Bus. Stud. 23, 715–735. https://doi.org/10.1057/palgrave.jibs.8490285.
Schotter, A.P.J., Stallkamp, M., Pinkham, B.C., 2017. MNE headquarters disaggregation: the formation antecedents of regional management centers. J. Manag. Stud. 54, 1144–1169. https://doi.org/10.1111/joms.12285.
Schreyer, P., 2000. The Contribution of Information and Communication Technology to Output Growth: a Study of the G7 Countries. OECD. https://doi.org/10.1787/151634666253.
Seru, A., 2014. Firm boundaries matter: evidence from conglomerates and R&D activity. J. Financ. Econ. 111, 381–405. https://doi.org/10.1016/j.jfineco.2013.11.001.
Singh, J., 2005. Collaborative networks as determinants of knowledge diffusion patterns. Manag. Sci. 51, 756–770. https://doi.org/10.1287/mnsc.1040.0349.
Sorenson, O., Rivkin, J.W., Fleming, L., 2006. Complexity, networks and knowledge flow. Res. Policy 35, 994–1017. https://doi.org/10.1016/j.respol.2006.05.002.
Szulanski, G., 1996. Exploring internal stickiness: impediments to the transfer of best practice within the firm. Strateg. Manag. J. 17, 27–43. https://doi.org/10.1002/smj.4250171105.
Teece, D.J., 1977. Technology transfer by multinational firms: the resource cost of transferring technological know-how. Econ. J. 87, 242–261. https://doi.org/10.2307/2232084.
Teodorescu, M.H.M., Choudhury, P., Khanna, T., 2022. Role of context in knowledge flows: host country versus headquarters as sources of MNC subsidiary knowledge inheritance. Glob. Strategy J. 12, 658–678. https://doi.org/10.1002/gsj.1434.
Tucker, C., 2008. Identifying formal and informal influence in technology adoption with network externalities. Manag. Sci. 54, 2024–2038. https://doi.org/10.1287/mnsc.1080.0897.
Tushman, M.L., Nadler, D.A., 1978. Information processing as an integrating concept in organizational design. Acad. Manage. Rev. 3, 613–624. https://doi.org/10.5465/amr.1978.4305791.
Wang, Y., Li, P., Gao, H., Li, M., 2024. Do the elite university projects promote scientific research competitiveness: evidence from NSFC grants. Res. Policy 53, 105074. https://doi.org/10.1016/j.respol.2024.105074.
West, J., 2000. Institutions, information processing, and organization structure in research and development: evidence from the semiconductor industry. Res. Policy 29, 349–373. https://doi.org/10.1016/S0048-7333(99)00035-9.
Wooldridge, J.M., 2021. Two-Way Fixed Effects, the Two-Way Mundlak Regression, and Difference-in-Differences Estimators. Available at SSRN 3906345.
World Bank, 2024. Infrastructure Monitor 2024: Global Trends in Private Investment in Infrastructure - Executive Summary. Washington, D.C..
Wu, G.L., Feng, Q., Wang, Z., 2021. A structural estimation of the return to infrastructure investment in China. J. Dev. Econ. 152, 102672. https://doi.org/10.1016/j.jdeveco.2021.102672.
Yoon, H.D., Boudreaux, C., Kim, N., 2024. Connecting the dots between democracy and innovation: the role of pro-market institutions and information processing. Res. Policy 53, 105057. https://doi.org/10.1016/j.respol.2024.105057.
Zhou, Y.M., 2015. Supervising across borders: the case of multinational hierarchies. Organ. Sci. 26, 277–292. https://doi.org/10.1287/orsc.2014.0934.