

The Battle over Knowledge: Multinationals, Diffusion, and Governance*

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Abstract

Multinational corporations (MNCs) are the dominant institutions for creating and distributing knowledge across borders. Their activities generate geopolitical externalities when cross-border knowledge spillovers enhance a rival state's strategic capabilities in ways neither internalized by firms nor priced by markets. This review examines MNC-mediated knowledge creation and diffusion and the governance regime that has emerged in response. We distinguish three types of knowledge — codified, tacit, and organizational — that differ in their transmission channels and governability, and trace how each is created within MNC networks, diffused within and across firm boundaries, and targeted by policy instruments. Evidence shows that controls induce compensating responses, including redirected innovation, supply-chain reconfiguration, and organizational restructuring, with uncertain net effects. Linking the theory of the multinational firm to the economics of geopolitical rivalry, the review highlights the trade-offs that knowledge governance imposes on the global economy.

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1 Introduction

Multinational corporations (MNCs) are the central institutions of global knowledge creation and diffusion. They account for more than a third of global GDP, two-thirds of international trade, and 90 percent of private R&D spending worldwide (OECD, 2019; World Intellectual Property Organization, 2024). Yet the significance of MNCs lies not just in their scale but in their organizational function: multinationals exist to exploit intangible assets across borders while managing the appropriability problems that would otherwise inhibit knowledge diffusion (Markusen, 2002; Antràs and Yeaple, 2014). This paper examines how the properties that make MNCs the primary vehicles for cross-border knowledge diffusion also make them the central channel through which that diffusion generates geopolitical consequences.

MNCs produce and transmit three types of knowledge that differ in form, value, and governability. Codified knowledge, embedded in capital goods, designs, and licensing agreements, transfers most readily but is also most substitutable. Tacit knowledge, embodied in human capital and collaborative relationships, is the most strategically valuable but diffuses only through personal interaction. Organizational knowledge, comprising the internal routines, coordination structures, and supplier networks that constitute the firm, transfers with ownership rather than through arm’s-length transactions. The productivity gains from these transfers are well documented: MNCs raise productivity in host economies through supply-chain linkages, labor mobility, and competitive pressure (Javorcik, 2004; Keller and Yeaple, 2009; Alfaro and Chen, 2018), and for most of the postwar period these spillovers were analyzed as growth externalities whose welfare consequences were fundamentally about economic development.

But the same knowledge flows that raise productivity in host economies can enhance a rival state’s strategic capability. When an MNC transfers knowledge abroad, it optimizes over its private global network and does not internalize the consequences for its home country’s strategic position. Knowledge diffusion that reduces a rival’s dependence on foreign inputs can erode leverage at technological chokepoints, and knowledge that enables self-sufficiency in security sectors can alter the balance of power in ways that dwarf economic costs. We define this as a *geopolitical externality*: a cross-border knowledge spillover, often mediated by MNCs, that enhances a rival state’s strategic capability and is not internalized by the investing firm or priced by markets. Unlike standard economic externalities, which can arise whenever an MNC operates across borders and are addressable through trade-policy instruments, geopolitical externalities operate through state capability, leading policy response toward security instruments that would be difficult to justify on economic grounds alone.

China’s technological trajectory over the past three decades made this distinction conse-

quential. MNC-led joint ventures, supply-chain integration, and R&D investment accelerated China’s technological upgrading through precisely the channels the spillover literature had documented (Holmes et al., 2015; Bai et al., 2025; Jiang et al., 2024). As China approached the frontier, knowledge flows once analyzed as benign development externalities came to be viewed as sources of geopolitical vulnerability. The policy response has been sweeping: since 2018, governments have deployed a layered regime of instruments targeting each knowledge channel. Export controls and entity lists restrict codified knowledge at the product level; the U.S.-person rule extends restrictions to tacit knowledge by requiring licenses for individuals supporting advanced semiconductor production at Chinese facilities; inbound and outbound investment screening and subsidy guardrails target organizational knowledge at the transaction and firm level. These instruments also reach codified and tacit flows that product-level and person-level controls cannot. A rapidly emerging geoeconomics literature has begun to formalize the strategic interactions these instruments address (Clayton et al., 2026; Becko et al., 2025; Liu and Yang, 2025). Yet the effectiveness, costs, and unintended consequences of these instruments remain largely open questions.

Understanding both the rationale and the limitations of the emerging regime requires tracing the full arc from the properties of knowledge that explain why MNCs exist, through the channels by which they diffuse knowledge, to the instruments governments deploy when that diffusion enhances the strategic capabilities of a rival state. We first establish the conceptual foundations: the properties of knowledge, the codified-tacit-organizational typology, the theory of the MNC, and a definition of the geopolitical externality. We then document MNCs as producers and organizers of global knowledge, tracing the evolution from home-country-centered R&D to increasingly decentralized innovation networks. Next, we examine knowledge diffusion both within and across firm boundaries, with China as the pivotal case in which MNC-mediated spillovers transformed a recipient economy into a technological rival. Finally, we analyze the governance regime channel by channel, evaluating the instruments deployed against each knowledge type and the empirical evidence on their effectiveness and unintended consequences.

The review contributes to three strands of literature. First, it connects the theory of the multinational firm (Markusen, 2002; Antràs and Yeaple, 2014; Bernard et al., 2018) to the rapidly emerging geoeconomics literature (Clayton et al., 2025; Mohr and Trebesch, 2025): the same properties that make MNCs efficient vehicles for knowledge diffusion — nonrivalry, partial excludability, and the tacit and organizational dimensions of knowledge — are precisely what make knowledge flows difficult to govern across jurisdictions. Second, it extends the FDI spillover literature (Keller, 2004, 2010; Harrison and Rodríguez-Clare, 2010) by identifying the conditions under which productivity spillovers become geopoliti-

cally consequential — specifically, when the recipient economy approaches the technological frontier and knowledge flows shift from augmenting a complementary economy to enabling a strategic rival state. Third, it provides an analytical framework for the contemporary knowledge-governance regime organized by knowledge type, highlighting a coverage-precision tradeoff across instruments and a persistent tendency toward externality conflation, in which interventions designed to address geopolitical externalities extend to knowledge flows that generate only economic ones. The analysis also shows that controls induce compensating responses, including redirected innovation, supply-chain reconfiguration, and organizational restructuring, whose magnitude relative to the intended effects of the controls remains uncertain. A central tension across all knowledge channels is that the flows most consequential for the geopolitical externality are often inseparable from those that sustain the home country’s own innovation frontier.

2 Foundations: Knowledge, Multinational Firms, and Geopolitical Externality

A central reason multinational firms sit at the heart of modern globalization is that the most valuable object they deploy across borders is not a rival input such as labor or physical capital, but knowledge. Economic research has long emphasized that knowledge differs from standard goods along two dimensions: *nonrivalry* and *excludability*. The interaction of these dimensions generates both gains from diffusion and conflicts over control. This section establishes the conceptual foundations that discipline the remainder of the paper: the properties of knowledge that generate increasing returns and growth, three types of knowledge that differ in their governability, the theory of the multinational firm as an organizational technology for managing knowledge across borders, and the geopolitical externality that arises when knowledge diffusion enhances the strategic capabilities of a rival state.

2.1 Properties of Knowledge

Knowledge is nonrival: one agent’s use of an idea does not reduce its availability for others. A design, formula, or algorithm, once created, can be used simultaneously across many plants or markets at near-zero marginal cost. This property is the core microfoundation for increasing returns in modern growth theory: Romer (1990) shows that intentional investment in nonrival ideas can sustain long-run growth, because the fixed cost of idea creation is spread over an expanding base of users. Grossman and Helpman (1991*b*) and Aghion and Howitt (1992) extend this framework through quality-ladder and expanding-variety models, and

subsequent work refines the relationship between innovation inputs and aggregate outcomes.¹ As Romer (1990) emphasizes, the nonrivalry of ideas means that restricting their use forgoes gains at near-zero marginal cost. This tension becomes particularly acute when restrictions are motivated by geopolitical concerns that lie outside the growth framework.

Nonrivalry alone, however, would not produce a private incentive to create knowledge. Many ideas are also partially excludable through patents, trade secrecy, tacit know-how, complementary assets, and platform governance, and it is this excludability that underpins investment in knowledge creation (Arrow, 1962; Scotchmer, 2004). But excludability is incomplete: Arrow (1962) shows that assessing the value of information often requires disclosure that erodes the seller’s ability to appropriate returns. Empirically, firms rely on a portfolio of appropriability strategies, such as secrecy, lead time, and complementary capabilities (Cohen et al., 2000), and social returns to R&D systematically exceed private returns due to spillovers, imitation, and worker mobility (Bloom et al., 2013).

These two properties generate the familiar innovation-diffusion tradeoff: stronger protection raises innovation incentives but reduces diffusion (Grossman and Helpman, 1991*a*; Scotchmer, 2004). The emergence of geopolitical rivalry between countries close to the technological frontier, however, transforms this tradeoff: the welfare consequences of diffusion depend not only on the innovation-incentive and access-cost margins but also on the strategic implications of who controls frontier knowledge. Both the pace of diffusion and the capacity to govern it depend on the form in which knowledge is embedded.

2.2 Codified, Tacit, and Organizational Knowledge

While knowledge is nonrival in principle, its diffusion is neither automatic nor costless: ideas move through specific channels, such as trade, FDI, scientific collaboration, and input-output linkages, whose effectiveness depends on distance, institutions, and absorptive capacity. The ease with which governments can govern these channels depends on the form in which knowledge is embedded. We distinguish three types throughout the paper:

Codified knowledge is embedded in goods, equipment, designs, blueprints, datasets, and

¹Bloom et al. (2020) document declining research productivity across industries, consistent with the view that sustaining growth requires ever-larger investments in knowledge creation. Klette and Kortum (2004) connect these dynamics to firm-level heterogeneity, explaining why a small number of firms, including MNCs, account for a disproportionate share of aggregate R&D. A related literature endogenizes diffusion itself, showing how imitation, trade, and idea flows jointly shape the productivity distribution and long-run growth (Perla and Tonetti, 2014; Sampson, 2016; Buera and Oberfield, 2020; Perla et al., 2021; Benhabib et al., 2021); for early empirical work on international R&D spillovers see Coe and Helpman (1995) and Keller (2004).

publications. It is the most observable form of knowledge, but codification also makes it substitutable: encoding an idea in a transferable form enables replication by others with sufficient absorptive capacity.

Tacit knowledge is embodied in people: researchers, engineers, managers, and the collaborative relationships among them. It is acquired through experience, difficult to articulate, and transferred primarily through sustained personal interaction. Its value cannot be demonstrated without the kind of disclosure that erodes appropriability.

Organizational knowledge is embedded in the firm: its internal routines, coordination architecture, and supplier relationships. It is acquired through accumulation, and accessing it typically requires acquiring, or at least partnering with, the firm.

These three types are not mutually exclusive, but differ in how easily they can be governed, whether by firms seeking to appropriate returns or by states seeking to control cross-border flows. Codified knowledge is the most transferable of the three, embodied in traded goods and inputs that can be identified and tracked as they cross borders. Tacit knowledge is difficult for firms to transact and equally difficult for governments to target without disrupting the flows of talent and collaboration on which innovation depends. Organizational knowledge is nearly inseparable from the firm, accessible to outside parties primarily through acquisition or partnership, and largely opaque to policy instruments. The properties that make knowledge difficult to transact through arm's-length markets shape the boundary of the firm and, in particular, the multinational firm.

2.3 Multinationals: Knowledge and Firm Boundaries

The theory of the multinational firm originates in the observation that foreign production requires firm-specific advantages sufficient to overcome the inherent informational advantages of local competitors (Hymer, 1960; Caves, 1971). The internalization theory (Buckley and Casson, 1976; Hennart, 1982) argues that knowledge assets are subject to market failures in arm's-length transactions, and that MNCs arise to govern knowledge flows within the firm's organizational boundary, where monitoring and coordinated deployment are feasible. Dunning (1981)'s OLI paradigm synthesizes the determinants of FDI into ownership advantages rooted in intangible assets, location advantages that govern where those assets can be profitably applied, and internalization advantages that determine whether cross-border deployment occurs within or across firm boundaries.

The knowledge-capital model (Carr et al., 2001; Markusen, 2002) connects firm-level knowledge assets to the pattern of FDI, showing how the choice between exporting and establishing foreign affiliates depends on trade costs, market size, and the skill intensity of

production. A key mechanism underlying this choice is the spatial friction in knowledge transfer: Keller and Yeaple (2013) show that the costs to transfer disembodied knowledge quantitatively account for much of the gravity in multinational activity, explaining why affiliate sales fall with distance and why knowledge content in intra-firm flows is higher in more knowledge-intensive industries.

The property-rights approach to firm boundaries (Grossman and Hart, 1986; Antràs, 2003) adds that the choice between integration and outsourcing determines which knowledge flows are internal to the firm and which occur through arm's-length transactions. Heterogeneous-firm models complement this framework by embedding knowledge in firm-level productivity: the most productive firms self-select into exporting and, at the top of the distribution, into FDI (Melitz, 2003; Helpman et al., 2004; Antràs and Helpman, 2004; Helpman, 2006; Yeaple, 2009, 2013). Although these models treat knowledge in reduced form, productivity differences reflect accumulated intangible assets that are partly nonrival and partly excludable. Ramondo and Rodríguez-Clare (2013) embed multinational production into a multi-country framework and show that the gains from multinational production are quantitatively distinct from and additive to the gains from trade.

These frameworks explain why MNCs are central actors in cross-border knowledge flows: they are organizational technologies for scaling nonrival assets across borders while managing the appropriability problems that would otherwise inhibit diffusion. But because MNCs integrate knowledge creation across jurisdictions, their activities generate not only the economic externalities emphasized in the strategic-trade-policy literature but also a distinct category of externality that arises when knowledge diffusion alters the strategic capability of a rival state.

2.4 Geopolitical Externality

Cross-border knowledge diffusion has long been understood to generate economic externalities: rent-shifting, terms-of-trade effects, and erosion of agglomeration spillovers (Spencer and Brander, 1983; Brander and Spencer, 1985; Krugman, 1991). The strategic-trade-policy literature (Brander, 1995) develops the framework for evaluating optimal intervention in these settings. These economic externalities are important, but they arise whenever an MNC operates across borders, regardless of whether the host country is an ally or a rival, and in principle addressable through tariffs, production subsidies, R&D tax credits, and competition policy.

What has changed is the emergence of a second, analytically distinct category: a *geopolitical externality*, which arises when a privately optimal cross-border knowledge transfer

reduces the home country’s strategic position by enhancing a rival state’s technological autonomy, standard-setting capacity, or resilience to economic coercion. MNCs are a central source of such externalities: by deploying knowledge abroad through joint ventures, supply-chain relationships, or internal allocation of R&D, the firm optimizes over its private global network and does not internalize these strategic consequences. Knowledge diffusion that reduces a rival state’s dependence on foreign inputs can erode the home country’s leverage, and knowledge that enables a rival to achieve technological self-sufficiency in security-relevant sectors may alter the balance of power in ways that dwarf any associated economic cost.

The mechanism is rooted in the economics of interdependence as leverage. Farrell and Newman (2019) argue that economic interdependence creates chokepoints that states can exploit, and Clayton et al. (2026) formalize this logic, modeling how hegemonic powers coordinate threats across economic relationships to extract concessions from foreign entities. A direct implication from these frameworks is that when knowledge diffusion reduces a rival’s vulnerability at those chokepoints, it can undermine the future capacity for such leverage, transforming what might otherwise appear welfare-improving into a source of strategic vulnerability for the originating country.

What further distinguishes the geopolitical externality from economic externalities is that the welfare loss operates through state capability rather than market competition. The relevant cost, such as a rival’s technological autonomy, coercive capacity, or ability to set global standards, is not measured in units amenable to standard cost-benefit aggregation. The properties of knowledge established in this section thus acquire a dimension absent from the growth framework in which they were originally analyzed: who produces the knowledge and who receives it may matter as much as the rate of diffusion itself.

Although the two externality categories are analytically distinct, the same governance instruments may serve both rationales, and affected firms may hold opposing preferences over interventions. Domestic firms that compete directly with foreign rivals benefiting from MNC-mediated knowledge diffusion may favor tighter controls to prevent profit-shifting to competitors abroad, a motive grounded in rent retention rather than national security. In contrast, MNCs whose operations span adversarial jurisdictions bear the direct costs of restrictions. How these externalities arise in practice and who gains and who loses depend on the scale, geography, and organizational structure of MNC knowledge creation.

3 Multinational Firms as Producers and Organizers of Global Knowledge

MNCs are the core organizational units of global knowledge creation. In this section, we document the scale and concentration of MNC R&D and trace how the internal organization of knowledge production has evolved from home-country-centered hierarchies to increasingly decentralized innovation networks in which affiliates generate frontier research and cross-border collaborations increase steadily.

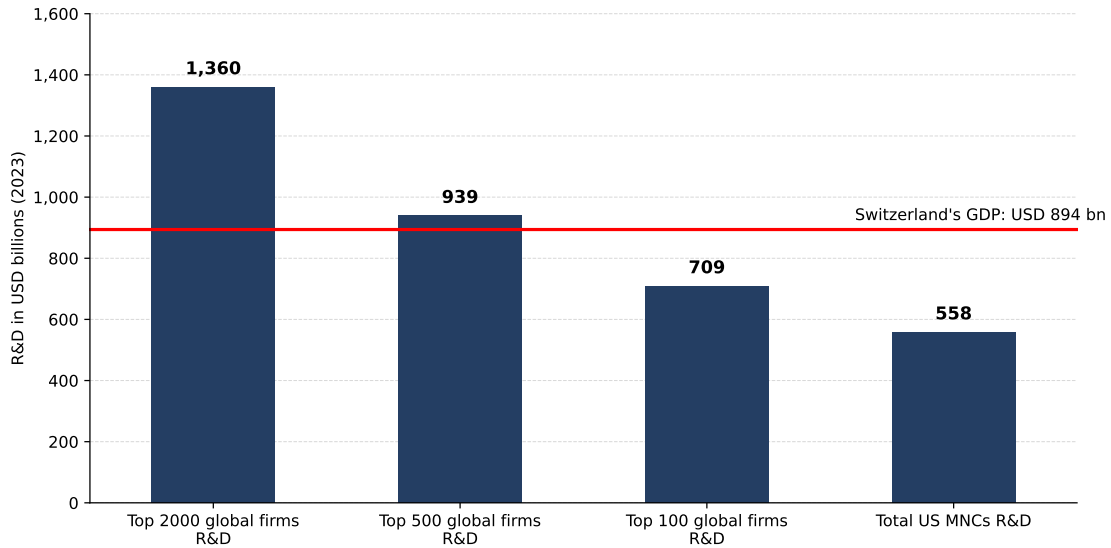
3.1 The Role of Multinationals in Global Knowledge Creation

Section 2.3 established that MNCs exist because the properties of knowledge often make internal organization across borders more efficient than arm’s-length alternatives. A direct prediction is that multinational firms should be disproportionately productive and R&D-intensive. The evidence confirms the hypothesis. MNCs are systematically more productive, more skill-intensive, and more trade-oriented than domestic firms in the same industries, with the most productive self-selecting into the widest range of markets (Helpman et al., 2004; Yeaple, 2009; Chen and Moore, 2010). Within host economies, foreign-owned establishments pay higher wages and employ a larger share of skilled workers than their domestic counterparts (Setzler and Tintelnot, 2021), consistent with the prediction that MNCs deploy superior intangible assets requiring complementary human capital.

MNCs also invest disproportionately in R&D. As shown in Figure 1, the aggregate R&D spending of the world’s top 2,000 firms, most of them multinationals, exceeded USD 1.3 trillion in 2023, more than the GDP of Switzerland. The top 100 firms alone invested at levels comparable to the size of large national economies (EU Industrial R&D Investment Scoreboard). This spending is heavily concentrated by sector: pharmaceuticals, semiconductors, software, and automotive account for the bulk of corporate R&D, and within each sector a handful of firms dominate (Bernard et al., 2018). The sectoral composition matters because the mix of codified, tacit, and organizational knowledge differs across industries, and with it the channels through which knowledge diffuses and the feasibility of governing those flows.

The concentration of knowledge creation in a relatively small number of firms carries a direct implication: the location and organizational decisions of MNCs shape which countries participate in frontier innovation and under what terms. When a semiconductor firm locates advanced R&D in China through a joint venture, or when an MNC builds fabrication capacity that trains engineers who later move to domestic competitors, the decision allocates not only capital but knowledge-creating capacity whose cross-border diffusion may generate

Figure 1: MNC R&D Spending (2023)



Notes: Author's calculations based on data from the EU Industrial R&D Investment Scoreboard (European Commission Joint Research Centre) and the U.S. Bureau of Economic Analysis (BEA). All data for 2023.

geopolitical externalities that the firm does not internalize. The next subsection traces how the internal architecture through which these decisions are made has evolved.

3.2 The Geography of Intra-firm Knowledge Creation

The geography of MNC knowledge creation has shifted substantially over the past three decades. What was once a headquarters-centered activity has become increasingly distributed across affiliates and collaborative networks, with consequences for both the pace of innovation and the feasibility of governing its cross-border flow.

The Organization of Innovation and Production The traditional MNC organization features a clear division of labor: the headquarters focuses on core research and control over key intangible assets, while the affiliates specialize in production, distribution, and adaptation to local markets (Cantwell, 1989). A large body of work formalizes the joint determination of global production and innovation structures, showing how the allocation of tasks across locations depends on trade costs, communication costs, and the degree of complementarity between innovation and production (Ramondo and Rodríguez-Clare, 2013; Keller and Yeaple, 2013; Arkolakis et al., 2018; Bilir and Morales, 2020).

An important implication from the last of these determinants is that when learning-by-doing or feedback from manufacturing to design is central to technological progress, co-locating innovation and production can accelerate capability accumulation (Fuchs, 2014).

Consequently, when production is moved overseas, the host country may gain not only manufacturing capacity but also the tacit knowledge, process expertise, and human-capital accumulation that both raise its current innovative capacity and accelerate future technological progress, while the home country forgoes these dynamic benefits. This mechanism underlies much of the policy concern about the erosion of domestic innovative capacity that motivates the governance instruments analyzed later in the paper.

The organizational boundary itself is endogenous to the nature of the knowledge involved. Production is more likely to be integrated within the firm when headquarters' intangible inputs represent a larger share of relationship-specific value, particularly in non-routine tasks (Costinot et al., 2009), in proximate production stages (Alfaro and Charlton, 2009), or when activities share technology linkages and capital-good externality (Alfaro and Chen, 2014). The ability to redraw these boundaries across stages and locations has fueled the fragmentation of production in global value chains, in which MNCs organize cross-border flows of goods and services under varying ownership structures (Antràs and Yeaple, 2014).² For most of the postwar period, these forces kept the geography of MNC innovation heavily centered in the home country. That pattern has changed.

The Evolving Geography of Multinational R&D The geography of multinational R&D has shifted markedly in recent decades. Across OECD countries, foreign affiliates now account for a substantial share of business R&D expenditure, exceeding 50 percent in smaller open economies (Eurostat Inward Foreign Affiliates Statistics, 2025). R&D spending by foreign affiliates of U.S. MNCs more than doubled between 2004 and 2023 (U.S. Bureau of Economic Analysis). This decentralization reflects multiple motives: access to specialized local talent pools, proximity to large or rapidly growing markets, cost differentials, and interaction with complementary knowledge producers (Fan, 2025).³ The shift does not simply represent the offshoring of previously home-based R&D but an expansion of the firm's internal innovation network, which allocates different knowledge-creation tasks across locations while maintaining governance over core intangible assets.

Bircan et al. (2024) document the shift at the micro level using patent data. As shown in Table 1, a significant share of MNC patents are generated in foreign affiliates rather than exclusively at headquarters, though the degree of decentralization varies widely. In the

²Antràs and Chor (2013) and Alfaro et al. (2019) show that greater upstream contractibility reduces the need for organizational arrangements to incentivize early-stage suppliers.

³Ide and Talamàs (2025) show that AI may further reshape this geography: basic AI substitutes for routine problem-solving in ways that reduce advanced-economy net exports of knowledge-intensive services, while sophisticated AI complements the most knowledgeable workers and reinforces existing trade patterns.

Netherlands and Switzerland, nearly half of MNC patents originate solely in foreign affiliates, while 6-8 percent are produced exclusively at headquarters. Chinese MNCs represent an extreme: over two-thirds of their patents are produced solely by foreign-affiliate inventors, and less than one percent are generated exclusively by headquarters.⁴ This pattern suggests that Chinese outbound investment has served as a systematic channel for accessing frontier knowledge, generating reverse knowledge flows that may constitute geopolitical externalities when the investing country’s strategic objectives diverge from those of the host.

At the same time, MNCs’ organization of global innovation has become increasingly collaborative. As shown in the fifth column of Table 1, joint HQ-affiliate collaborations account for between 23 and 43 percent of all patents obtained by Western-headquartered MNCs, and 32 percent of patents by Chinese MNCs. Bircan et al. (2024) document the steady rise of such collaborations since the 1980s, which they attribute in part to telecommunication liberalization, which reduced the cost of coordinating research across distance.

Table 1: Patenting by MNCs’ Foreign Affiliates: 1980-2014

HQ Country	Number of patent families	Only HQ inventors (%)	Only foreign affiliate inventors (%)	HQ-affiliate collaboration (%)	China-based inventors (%)
US	76,772	60.60	16.33	23.06	0.69
DE	34,078	58.62	12.93	28.45	0.34
FR	17,353	50.81	24.91	24.28	0.77
GB	7,031	34.79	32.20	33.01	0.38
SE	6,384	48.29	26.10	25.61	1.16
IT	5,311	55.71	13.22	31.07	0.11
NL	4,796	8.42	48.81	42.76	0.15
CH	4,571	5.73	55.83	38.44	0.31
JP	110,277	88.71	5.82	5.47	0.31
KR	13,555	77.29	6.54	16.17	0.44
CN	1,133	0.79	67.43	31.77	n.a.

Source: Bircan et al. (2024). Patents granted at all three major patent offices: US Patent and Trademark Office (USPTO), European Patent Office (EPO) and Japanese Patent Office (JPO).

The increasing decentralization and cross-border collaboration documented above suggest that MNCs now create knowledge across borders — codified, tacit, and organizational — rather than producing it only at headquarters and deploying it outward. These features have a direct implication for governability: when frontier innovation occurs in affiliates rather than at headquarters, the knowledge being governed is no longer unidirectional, and instruments designed to restrict outward flows must contend with the fact that restricting affiliate innovation may simultaneously reduce the MNC’s global knowledge stock.

⁴Japanese MNCs, in contrast, exhibit the most centralized innovation structure, with nearly 89 percent of patents involving only headquarters-based inventors.

4 Multinational Firms as Diffusers of Knowledge

MNCs are not only the dominant producers of global knowledge but also principal transmitters across borders. Knowledge flows through their global networks of affiliates, suppliers, and managers, diffusing ideas, technologies, and organizational practices both within and beyond the boundaries of the firm. These flows shape productivity dynamics in host economies, integrate local firms into global value chains, and ultimately influence the geography of innovation. This section reviews the evidence on three channels: intra-firm transmission from headquarters to affiliates and back, diffusion along global value chains, and horizontal spillovers to domestic competitors.

4.1 Intra-firm Transmission

Knowledge transfer within MNCs takes several forms, which differ in how easily they can be transmitted across locations and map directly onto the typology developed in Section 2.2.

First, firms transfer codified knowledge embodied in production technologies, capital equipment, and intermediate inputs, which can be replicated across affiliates relatively easily. Empirical evidence from foreign acquisitions documents significant productivity effects. Using Indonesian manufacturing census data, Arnold and Javorcik (2009) show that foreign acquisitions increase investment in machinery and reliance on imported inputs, boosting total factor productivity in acquired establishments by 13.5 percent after three years. Guadalupe et al. (2012) find that foreign acquisitions of Spanish firms increase both product and process innovation as well as technology adoption, while Bircan (2019) documents a 13-percent increase in physical productivity (TFPQ) among acquired establishments in Turkey. Studies comparing foreign to domestic acquisitions in advanced economies also find positive productivity effects, though these tend to be delayed by several years (Wang et al., 2025). A consistent finding is that productivity gains are concentrated in acquisitions by MNCs from advanced economies and are larger in majority-ownership transactions.

Second, MNCs transmit tacit knowledge, which is disembodied, difficult to codify, and transferable through direct communication between workers at headquarters and affiliates. Keller and Yeaple (2013) estimate that the costs of transferring knowledge within MNCs are high, helping explain why headquarters retain the most knowledge-intensive activities while affiliates specialize in tasks that benefit from local proximity. Evidence from foreign divestments underscores the importance of continuous headquarters engagement: Javorcik and Poelhekke (2017) show that divestments reverse the productivity gains from foreign acquisitions, while Bilir and Morales (2020) demonstrate that headquarters innovation within the United States positively affects affiliate performance within the same multinational firm:

the median MNC realizes abroad 20 percent of the return to its U.S. R&D investment.

The wage effects of foreign acquisitions provide complementary evidence of tacit knowledge transfer. Arnold and Javorcik (2009) find a 41-percent wage gain in acquired plants in Indonesia, Hijzen et al. (2013) document a 6-percent increase for incumbent workers and a 16-percent gain for movers in Brazil, and Alfaro-Ureña et al. (2022) report a 9-percent premium for movers in Costa Rica. Studies in advanced economies find qualitatively similar effects, though smaller in magnitude.⁵

Finally, MNCs transmit organizational knowledge, such as managerial systems, quality protocols, and coordination routines, that reshapes how affiliates operate. Using firm-level surveys across countries, Bloom and Van Reenen (2007) show that foreign affiliates systematically adopt superior monitoring, target-setting, and incentive practices relative to domestic firms, and that these practices are strongly correlated with productivity. Bloom et al. (2012) demonstrate that U.S. MNCs, in particular, are highly effective at transplanting organizational routines abroad, helping to explain the persistent U.S. productivity advantage. Evidence from foreign acquisitions reinforces the point: acquisitions in Portugal are associated with an increase in hierarchical layers and wage inequality between top and bottom layers (Bastos et al., 2018), while acquisitions in France lead to a reduction in work-related accidents and an increase in organizational layers (Javorcik et al., 2025).

Importantly, these internal flows are not unidirectional. Griffith et al. (2006) show that U.K. manufacturing firms with an innovative presence in the U.S. absorbed U.S. R&D spillovers through their internal networks. Using matched panels of U.K. and U.S. firms linked to patent data, they estimate that growth in the U.S. R&D stock during the 1990s was associated with at least 5 percent higher TFP for U.K. manufacturing firms by 2000, with the majority of benefits accruing to firms that had established a high proportion of inventors based in the U.S. by 1990. This evidence suggests that MNCs' internal channels transmit knowledge not only from headquarters outward, but also from affiliates back to headquarters. The bidirectionality of intra-firm knowledge flows complicates governance: restricting outward transmission to affiliates in rival jurisdictions may simultaneously reduce the reverse flows that sustain the home country's own innovation.

4.2 Knowledge Diffusion across Firm Boundaries

The transmission of knowledge does not occur just within the boundaries of the multinational. MNCs are embedded in global supply chains, and the technologies and practices they

⁵Heyman et al. (2007) find a post-acquisition premium of 2-6 percent in Sweden, consistent with Norwegian estimates of a 3-percent gain for workers moving to foreign-owned firms (Balsvik, 2011).

deploy inevitably spill over to local suppliers, customers, and even competitors.⁶

Knowledge Diffusion along GVCs A substantial body of research documents how knowledge flows outward from MNCs to domestic firms along GVCs. Javorcik (2004) provides foundational evidence that local suppliers linked to foreign affiliates in Lithuania experience significant productivity gains: a one-standard-deviation increase in foreign presence in the sourcing sectors is associated with a 15-percent rise in output of domestic firms in the supplying industries. Subsequent work establishes that this vertical channel is robust across settings. Javorcik and Spatareanu (2008) show that technology transfer is stronger where contractual frictions are lower. Alfaro-Ureña et al. (2022) confirm the channel using administrative tax data tracking firm-to-firm transactions in Costa Rica, finding that domestic firms experience gains four years after starting to supply a MNC buyer, with 26 percent more workers, 4–9 percent higher TFP, and 20 percent greater sales to other buyers.

Ahn et al. (2025) provide firm-level evidence across countries, showing that FDI raises bidirectional patent citation flows between investor and host countries by 11-13 percent within five years of the investment, with greenfield investment generating stronger and broader diffusion than M&A. Kee (2015) demonstrates that sharing suppliers with multinationals is associated with improved performance of domestic firms, explaining a quarter of their product scope expansion and a third of the productivity gains. These findings suggest that supply-chain linkages transmit knowledge even beyond the direct supplier relationship.

Knowledge Diffusion within Industries Knowledge also spreads horizontally to local competitors. Bloom et al. (2013) demonstrate that R&D generates large positive externalities even amid strong product-market rivalry. Keller and Yeaple (2009) find economically large positive horizontal spillovers in U.S. manufacturing, especially in technology-intensive industries, accounting for about 14 percent of productivity growth in U.S. firms between 1987 and 1996. Micro-level evidence identifies worker mobility as a key channel: Balsvik (2011) and Poole (2013) show that domestic firms employing workers with prior MNC experience enjoy significant productivity and wage gains. Recent work examines horizontal spillovers through the lens of organizational culture: Tang and Zhang (2021) show that foreign affiliates from countries with more gender-equal cultures employ more female workers and managers, and that this pattern diffuses to domestic firms in the same industry or city.

The evidence is not uniform, however. Meta-analyses (Görg and Greenaway, 2004; Havránek and Irsova, 2011) caution that horizontal spillovers are less consistently docu-

⁶See Harrison and Rodríguez-Clare (2010) for a comprehensive survey of the channels through which trade and FDI affect productivity in developing economies.

mented than vertical ones. Some studies find that competition effects dominate: Aitken and Harrison (1999) find negative productivity effects on domestic firms in Venezuela, and Lu et al. (2017), exploiting variation from China’s WTO accession, find that FDI presence in the same industry reduces domestic firms’ productivity. The asymmetry is intuitive: MNCs have incentives to transfer knowledge to suppliers whose upgrading raises the value of the relationship, but no incentive to do so for competitors.

What is clear is that MNCs reshape the competitive landscape in host economies: Al-faro and Chen (2018) show that MNC entry raises aggregate industry productivity through both productivity spillover and selection, with the latter accounting for the majority of the aggregate gains, while Bao and Chen (2018) find that domestic firms improve productivity and innovation even in response to the threat of foreign entry.

In summary, MNCs are not simply conduits of capital but diffusers of knowledge. Across both vertical and horizontal channels, MNCs diffuse all three knowledge types identified in Section 2.2: codified knowledge through quality specifications and equipment, tacit knowledge through training and worker mobility, and organizational knowledge through management practices and coordination routines transmitted to suppliers and, inadvertently, competitors. The breadth of the knowledge diffusion mechanisms helps explain the pervasive, if heterogeneous, impact of MNCs on productivity growth in host economies. It also explains the governance challenge: the same channels that transmit growth externalities also transmit the knowledge that, in the framework of Section 2.4, can generate geopolitical externalities when the host economy is a strategic rival. China’s rise represents the most consequential instance and the setting to which we turn next.

5 China: From Knowledge Recipient to Technological Rival

China’s technological trajectory over the past three decades represents the most consequential instance of MNC-mediated knowledge diffusion. It is also a case that transformed the policy landscape: the same channels that generated growth externalities for China simultaneously built the technological capabilities that gave rise to the geopolitical externality defined in Section 2.4.

5.1 Foreign MNCs as Vehicles for Technological Upgrading

China’s integration into MNC knowledge networks proceeded through the channels documented in Section 4, but with a distinct institutional architecture: the state structured the terms of market access to induce knowledge transfer as a condition of MNC entry. The central instrument was the joint-venture requirement, which mandated shared domestic and foreign ownership in key sectors and was reinforced by the Catalogue for the Guidance of Foreign Investment Industries, which channeled FDI toward state-designated priority sectors.⁷

The ownership structure matters for the pattern of spillovers. Javorcik and Spatareanu (2008) show that MNCs transfer less sophisticated technologies to partially owned affiliates but these affiliates source more from local suppliers, generating stronger vertical spillovers to domestic firms. Joint ventures thus embody an institutional design that trades depth of intra-firm technology transfer for breadth of inter-firm diffusion.

The aggregate consequences of this quid pro quo have been formalized by Holmes et al. (2015), who model the forced technology-transfer channel and show that it raised Chinese domestic consumption by nearly 5 percent while reducing consumption in advanced economies by 0.3-0.5 percent and weakening global incentives to create new technology capital. The critical implication is that quid pro quo is individually optimal for China despite the distortions it may impose on MNCs’ home countries. MNCs accepted these terms because the scale of the Chinese market made expected returns sufficiently large to justify the extraction. Micro-level evidence from the automobile industry confirms the mechanism: Bai et al. (2025) show that domestic automakers affiliated with foreign joint-venture partners systematically adopted their partners’ quality strengths, with worker flows and supplier networks mediating the spillovers and accounting for roughly 8 percent of affiliated firms’ quality improvement between 2001 and 2014.

The knowledge transfers map onto each element of the typology developed in Section 2.2. Codified knowledge arrived through capital equipment imports, licensing agreements, and technology-sharing arrangements inherent in joint-venture operations (Jiang et al., 2024). Tacit knowledge accumulated through labor mobility between MNC affiliates and domestic firms and through cross-border coinvention between foreign and local research teams (Branstetter et al., 2015). Organizational knowledge transferred through sustained exposure to MNC management practices, quality systems, and supply-chain coordination within joint ventures (Bai et al., 2025). Gong (2023) provides evidence that these channels operate

⁷See Branstetter (2018) for a detailed account of forced technology transfer mechanisms and Sykes (2021) for a law-and-economics analysis of forced technology transfer via joint-venture requirements, including an evaluation of WTO consistency and IP enforcement limits.

locally: innovation by U.S. multinational subsidiaries raised the productivity of co-located Chinese domestic firms, with stronger effects where absorptive capacity was higher and technological proximity to the foreign investor was closer.

Knowledge transfer also operates through two qualitatively distinct mechanisms: market-mediated exchange (technology licensing, collaborative R&D, supply-chain linkages, and labor mobility) versus forced extraction and outright misappropriation. The distinction matters for governance because the welfare implications differ sharply. Market-mediated diffusion may be welfare-improving even from the home country’s perspective when it expands the global knowledge frontier; forced transfer and misappropriation unambiguously reduce home-country welfare and weaken MNCs’ incentive to innovate. Smarzynska Javorcik (2004) shows that weak IP protection shifts the composition of FDI away from technology-intensive sectors, while Branstetter and Saggi (2011) formalize the mechanism: weak protection deters MNCs from deploying their most advanced technologies abroad and slows global innovation. Evidence from China’s gradual strengthening of IP enforcement over the 2000s confirms the logic: reducing misappropriation not only curtailed forced transfer but also increased the volume and sophistication of voluntary technology transfer by MNC affiliates (Branstetter and Lardy, 2008).

In the absence of geopolitical externality, the policy implications are straightforward: misappropriation warrants targeted IP enforcement and investment screening, while market-mediated spillovers may require no intervention. The governance challenge arises when the same knowledge flow simultaneously constitutes benign diffusion and geopolitical externality.

5.2 From Recipient to Rival

The mechanisms that made China the largest beneficiary of MNC-mediated knowledge diffusion also produced the conditions under which that diffusion became both economically and geopolitically consequential. The transition is visible across corporate R&D capacity, outbound investment, and innovation output.

Among the top 2,000 companies worldwide by R&D spending, China’s share surged from 5 percent two decades ago to 25 percent by 2023 (EU Industrial R&D Investment Scoreboard). Table 2 compares the top ten R&D spenders in China and the United States. While U.S. firms invest roughly three times more in absolute terms, several Chinese firms, notably Huawei and ZTE, display substantially higher ratios of R&D to capital expenditure. Equally important is the composition of China’s R&D leaders: several are state-owned enterprises, which means that the distinction between commercially and strategically motivated R&D is structurally harder to draw (Branstetter et al., 2022). This identification problem, i.e.,

Table 2: Top 10 Companies by R&D Spending (2023): China vs the United States

Rank	China				United States			
	Company	R&D	R&D/ Capex	Profit/ Capex	Company	R&D	R&D/ Capex	Profit/ Capex
1	HUAWEI	19,939	4.41	1.15	ALPHABET	39,804	1.36	2.61
2	TENCENT	8,118	3.05	7.62	META	33,229	1.34	1.59
3	ALIBABA	6,620	1.63	3.05	APPLE	27,243	2.73	10.43
4	CHN STATE CONST.	5,830	1.35	3.27	MICROSOFT	26,874	0.66	2.46
5	BYD	4,729	0.31	0.28	INTEL	14,613	0.62	0.07
6	CHN MOBILE	3,912	0.17	0.74	JOHNSON&J	13,972	3.38	7.92
7	CHN RAILWAY GP	3,768	1.15	1.72	MERCK	11,704	3.33	0.85
8	CHN COMM. CONST.	3,460	1.88	2.50	PFIZER	9,633	2.71	1.17
9	CHN RAIL. CONST.	3,389	0.77	1.32	GM	9,016	0.40	0.40
10	ZTE	3,136	6.18	2.83	ELI LILLY	8,481	2.70	1.99
	Mean	6,290	2.09	2.45	Mean	19,457	1.92	2.94

Notes: R&D spending in EUR millions. R&D/Capex and Profit/Capex are ratios of R&D investment and net income, respectively, to capital expenditure. *Source:* The 2024 EU Industrial R&D Investment Scoreboard.

whether the R&D is aimed at commercial competitiveness or at capabilities with dual-use applications, is precisely the challenge that investment screening regimes confront when evaluating inbound investments, as we discuss in Section 6.

China’s outbound investment trajectory mirrored its R&D ascent. The Go Abroad strategy, announced in 2000, set three objectives for overseas investment: securing natural resources, acquiring technology, and enhancing the global competitiveness of Chinese enterprises. Early outbound FDI was dominated by state-owned enterprises investing in resource-rich, politically risky host countries (Buckley et al., 2007), but the technology-acquisition objective gained weight as domestic industrial-policy priorities sharpened. Fang et al. (2025) document this shift: analyzing over 770,000 policy documents from 2000 to 2022, they show that state support is increasingly concentrated in strategic and emerging industries, with promotion of strategic sectors appearing in 22 percent of documents and support for technology R&D and adoption in 24 percent, consistent with the emphasis on technological upgrading.

The return from China’s R&D and outbound investments is visible in the research output data. Its share of global patent filings rose from 35 percent in 2014 to 49 percent by 2024 (WIPO, World Intellectual Property Indicators), and China has also overtaken the United States in science and engineering publications and in the share of the world’s top 1% most-cited papers (National Science Board, 2024). Bircan et al. (2024) show that between 1980 and 2014 over two-thirds of triadic patents attributed to Chinese MNCs were generated by inventors located in foreign affiliates, a share far higher than for any other major economy (Table 1). Wei et al. (2017) identify rising wages and expanding market opportunities as key drivers of the shift. The quality-adjusted picture is more nuanced. Branstetter et al.

(2022) find that government R&D subsidies have not translated into higher-quality patents or productivity growth among recipient firms, and Sun et al. (2021) show that government patenting targets triggered end-of-year filing surges that boosted quantity at the expense of innovative performance. What is unambiguous is that the scale of China’s R&D investment and the depth of its cross-border innovation networks have transformed the knowledge landscape in which MNCs operate and in which the governance instruments function.

5.3 Geopolitical Externality and Implications for Knowledge Governance

China’s trajectory illustrates the central tension motivating the governance framework developed in Section 6. The same MNC knowledge networks that generated growth externalities simultaneously built the technological capabilities of a state whose strategic objectives may diverge from those of the countries whose MNCs transmitted the knowledge. The Chinese case defines the governance challenge in three respects.

First, the economic growth and geopolitical externalities were concurrent. The same knowledge flow that raised productivity in a Chinese semiconductor firm could also have contributed to that firm’s capacity to produce dual-use goods. This concurrence explains why the distinction between the two externality categories, though analytically sharp, is institutionally difficult to operationalize: any governance instrument that restricts the geopolitical externality simultaneously reduces the growth externality, and the welfare effect depends on the relative magnitude of the two.⁸

Second, the channel of knowledge transfer—market-mediated spillover versus policy-induced extraction versus outright misappropriation—determines the appropriate governance response. Restricting market-mediated diffusion through blunt controls imposes costs on MNCs and their home economies that may exceed the geopolitical benefits; targeting forced transfer and misappropriation through IP enforcement and investment screening can reduce the geopolitical externality with smaller collateral effects on benign diffusion.

Finally, China’s innovation capacity now generates knowledge flows in the opposite direction. Chinese firms lead globally in solar panel manufacturing, with 89 percent of global solar patent filings and 63 percent of production by 2019 (Banares-Sanchez et al., 2026);

⁸Huang et al. (2025) quantify this tension, showing that China’s rapid productivity growth reduced the U.S. share of global GDP but raised U.S. aggregate welfare through lower consumer prices. That governments have nevertheless responded with the most sweeping knowledge-governance interventions since the Cold War underscores that the geopolitical externality operates on a dimension that standard welfare analysis does not capture.

in battery technology with costs declining by more than 90 percent over the past decade (Barwick et al., 2025); as well as in 5G telecommunications and drone production. Their outbound knowledge flows can generate both growth and geopolitical externalities for other countries, including the United States. The governance challenge is, therefore, no longer unidirectional: it is not a matter of whether advanced economies should restrict flows to a catching-up rival, but a multi-directional problem in which both sides possess knowledge the other seeks and both may deploy instruments to manage the resulting externalities.

6 The Governance of Global Knowledge

The preceding sections documented how MNCs generate, organize, and transmit knowledge across borders and how, in the most consequential case, those flows transformed a recipient economy into a technological rival. This section examines how governments have responded, through export controls targeting codified knowledge, person-level restrictions targeting tacit knowledge, investment-screening and subsidy regimes targeting organizational knowledge, and industrial policy aimed at rebuilding domestic capabilities. A rapidly emerging geoeconomics literature has begun to model the strategic interactions that motivate these interventions.⁹ This section maps the policy interventions onto the types of knowledge being governed and draws on the empirical literature to assess their effectiveness and unintended consequences.¹⁰

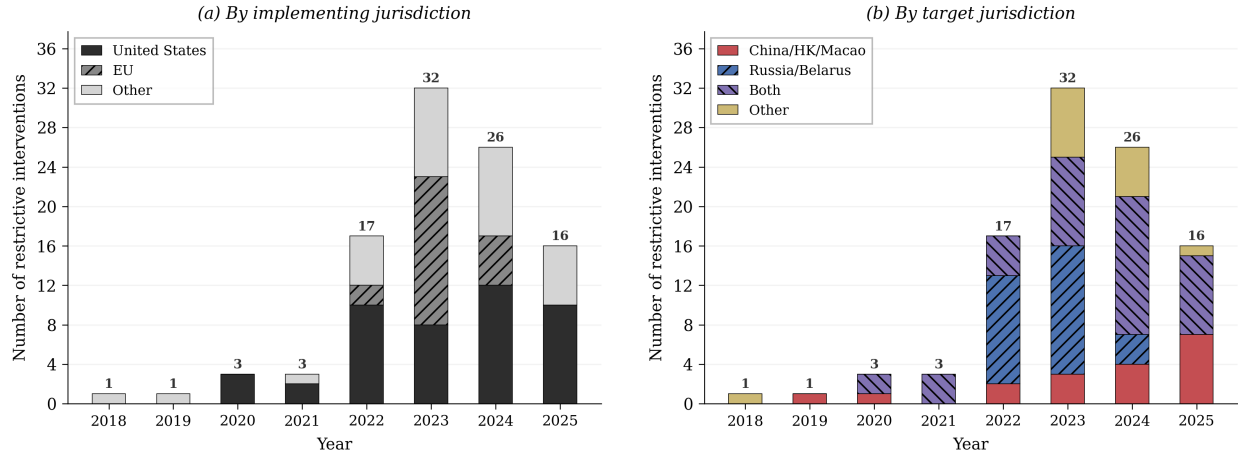
6.1 Codified Knowledge: Technology Denial and Its Limits

Codified knowledge is the domain where governments have the longest institutional experience with knowledge governance. As Section 2.2 noted, the property that makes codified knowledge governable, i.e., its embodiment in goods and inputs that can be traded, also makes it the most substitutable because codification enables replication. This tension be-

⁹Clayton et al. (2026) show how hegemonic powers leverage economic interdependencies, including technological chokepoints, to exert coercive pressure. Becko et al. (2025) derive optimal tariffs when great powers value the geopolitical alignment of trading partners. Liu and Yang (2025) construct a model-consistent measure of international power based on asymmetric import dependence. Mohr and Trebesch (2025) survey this nascent literature.

¹⁰A caveat should be noted at the outset: the empirical evidence is drawn disproportionately from the semiconductor industry, a sector with extreme chokepoint market structures, large geopolitical externalities, and sweeping policy interventions. We note throughout where findings are likely to generalize and where they may be specific to semiconductors' unusual combination of concentrated supply and pervasive cross-border learning spillovers.

Figure 2: Export Controls on Semiconductors, 2018-May 2025



Notes: Author’s calculations based on data from Global Trade Alert. The sample includes export controls affecting the semiconductor sectors (ISIC 471–472). Panel (a) classifies interventions by implementing jurisdiction; EU denotes supranational measures implemented collectively by EU member states; Other includes Japan, United Kingdom, Australia, and additional allied jurisdictions. Panel (b) classifies the same interventions by target jurisdiction based on the affected jurisdictions listed in the GTA database; “Both” denotes interventions listing at least one jurisdiction in each of the China/HK/Macao and Russia/Belarus groups. Counts reflect distinct intervention records. Data for 2025 are through May.

tween observability and substitutability defines the economics of technology denial: controls can be effective when supply is concentrated and the target lacks absorptive capacity, but can also generate unintended dynamics: cost shifting to domestic firms, redirected innovation in the target country, and erosion of the cross-border learning spillovers that sustain the controller’s own technological lead.

The Economics of Chokepoints The effectiveness of codified-knowledge controls depends on two parameters: the market structure of supply (the number of alternative producers) and the target’s absorptive capacity (its ability to develop substitutes independently). Bown and Wang (2024) provide a detailed account of how the United States has attempted to exploit the technology chokepoints. They emphasize that effectiveness depends critically on allied participation and differences in scope and enforcement across jurisdictions create leakage risks. Allied firms that lose revenue from the Chinese market face rent-shifting competition among themselves, making coordination fragile even when the geopolitical externality is shared.

Figure 2 documents the escalation along two dimensions. Panel (a) shows a sharp increase in semiconductor export controls beginning in 2022, with a striking shift in composition: the United States was nearly the sole implementing jurisdiction in 2020-2021, but allied jurisdictions including the EU, United Kingdom, and Japan account for the majority of new

interventions in 2023-2024, consistent with the multilateral coordination that chokepoint effectiveness requires. Panel (b) reveals a parallel shift in targeting. Russia dominated the target profile immediately after the 2022 invasion of Ukraine, but measures targeting China, including those targeting both China and Russia, have grown rapidly, accounting for the majority of interventions by 2024-2025. The expansion of this “Both” category reflects the increasing share of instruments drafted broadly enough to address the geopolitical externality vis-à-vis China and the sanctions regime vis-à-vis Russia within a single regulatory action, an empirical manifestation of the externality conflation analyzed in Section 6.5.

Effectiveness and Costs Crosignani et al. (2026) provide direct firm-level evidence on the effects of export controls: the restrictions reduced sales and market value for affected domestic technology suppliers while Chinese firms developed alternative sources, weakening the effectiveness of technology denial. The costs to domestic firms are not merely transitional. Kim (2025) shows that in an industry where cumulative production experience drives cost reductions, restricting market access slows productivity growth through reduced learning-by-doing and may cause U.S. firms to fall behind competitors who retain access. The cross-border learning spillovers that restrictions disrupt are also the same spillovers that justify subsidies for semiconductor production. Goldberg et al. (2024) highlight that restrictions that sever these channels may erode the externalities that controller’s own industrial policy aims to cultivate.

Redirected Innovation One of the most consequential unintended effects of codified-knowledge controls is that they may stimulate domestic innovation in the targeted country by raising the returns to self-sufficiency. Liu et al. (2025) study the 2007 U.S. “China Military Catch-All Rule,” which restricted exports of dual-use products with military applications to China, and find that affected Chinese firms significantly increased R&D spending by 49.1 percent, patenting by 41.3 percent, and the number of active inventors by 30.4 percent, with responses extending beyond the directly restricted technologies suggesting that controls activated broad-based technical change.

Controls can also redirect the trajectory of innovation. Applying the directed-technical-change mechanism (Acemoglu, 2002) in a geopolitical context, restrictions that raise the relative price of one input can channel the targeted country’s innovative effort toward economizing on that input. Alfaro et al. (2025) show, for example, that China’s export restrictions on rare earth elements increased global innovation aimed at reducing dependence on the constrained inputs. The evidence suggests that unilateral controls on knowledge inputs may redirect the global innovation trajectory in ways that ultimately undermine the controller’s

position, an instance of the “redirected technical change” where restrictions intended to delay a rival’s frontier turn out to accelerate the rival’s investment in self-sufficiency.

The consequences extend to the broader knowledge ecosystem. Chen et al. (2023) show that MNCs facing export restrictions restructure supplier relationships, developing alternative, potentially incompatible technology stacks. Han et al. (2024) provide complementary patent-based evidence: two decades of U.S.-China technological integration have reversed, with firms shifting toward domestically oriented patenting and reducing knowledge content in patents filed where appropriation risk is high. Whether the contemporary regime is producing catch-up delay or bloc fragmentation (Aiyar et al., 2023) depends on whether this divergence remains confined to directly controlled chokepoints or propagates across the broader technology space.

6.2 Tacit Knowledge: Restrictions on Human Capital Flows

Tacit knowledge transfers through personal interaction and decays sharply with organizational distance, making it simultaneously the most strategically valuable form of cross-border knowledge transfer and the most difficult for governments to govern. Unlike codified knowledge, tacit knowledge moves with people, and people respond to incentives, perceptions, and the broader climate of trust in which collaboration occurs.

Person-level Restrictions The U.S.-person rule in the October 2022 semiconductor export controls extended person-based restrictions for the first time beyond weapons of mass destruction and missile proliferation to a commercial technology sector, prohibiting U.S. citizens and permanent residents from supporting advanced semiconductor development at Chinese facilities without a license.¹¹ This intervention illustrates the challenge of regulating the flow of tacit knowledge: goods can be inspected at borders, but tacit knowledge carried by individuals cannot. The resulting governance instrument creates both under-inclusion (activities below the regulatory radar) and over-inclusion (legitimate research chilled by regulatory ambiguity), such that its deterrent effect may substantially exceed its enforcement effect. Firms facing the rule have incentives to separate personnel with U.S.-person status from China-facing operations, fragmenting the internal knowledge networks that the property-rights approach to firm boundaries (Grossman and Hart, 1986; Antràs, 2003) identifies as the reason MNCs exist in the first place.

¹¹Bureau of Industry and Security, 87 Fed. Reg. 62186 (October 13, 2022).

The Chilling Effect on Scientific Collaboration Flynn et al. (2024) quantify the broader costs of rising U.S.-China tensions on scientific collaboration. They find that ethnically Chinese students became 15 percent less likely to enter U.S. doctoral programs, that China-based scientists reduced their citations of U.S. research, and that the productivity of U.S.-based ethnically Chinese researchers declined by 8-11 percent, reflecting a “chilling effect” driven by perceived hostility. Cao et al. (2024) confirm that the operative mechanism is the severing of interpersonal networks: the decline in patenting by entity-listed Chinese firms is driven entirely by those with prior U.S. collaborations. Tacit-knowledge governance thus presents the sharpest tradeoff in the contemporary regime: the same people and networks that carry knowledge to rivals also generate knowledge for the home country. The empirical literature on tacit-knowledge governance is necessarily thin because the instruments are newer and tacit flows are inherently harder to measure, but the early evidence suggests that the costs to the controller’s own innovation ecosystem may be substantial.

6.3 Organizational Knowledge: Governing the Transaction

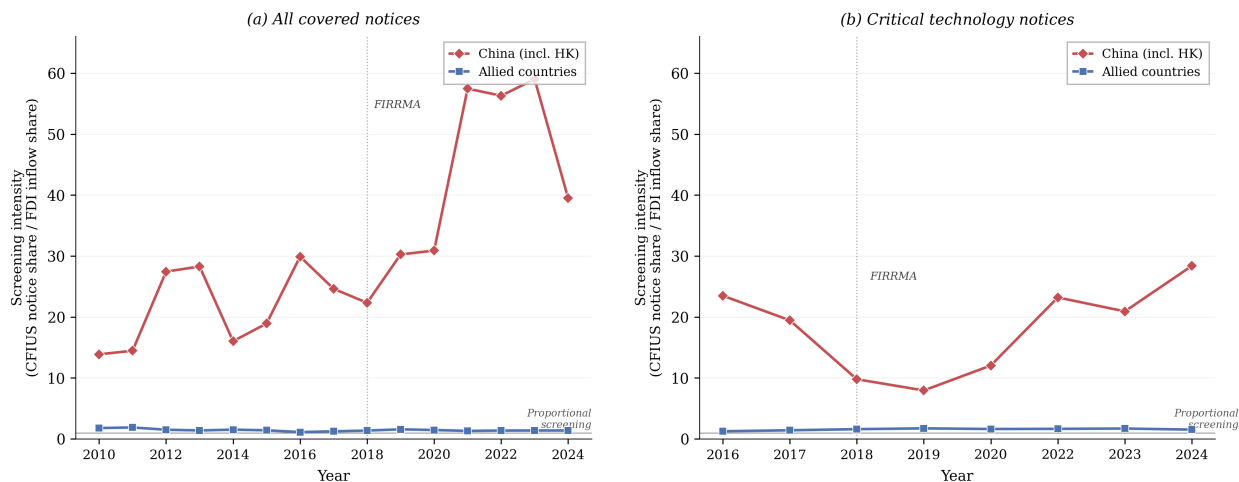
Organizational knowledge, including the firm’s internal routines, coordination architecture, and supplier relationships, is nearly inseparable from ownership itself (Section 2.2). Governments that found product-level and person-level instruments insufficient have accordingly been driven to govern FDI transactions or MNCs directly, because ownership is the mechanism through which organizational knowledge — and through that, access to codified and tacit knowledge — is transferred.

The Escalation to Transaction Governance The concern that foreign governments may use FDI to extract knowledge through ownership is not new. Japan’s postwar technology-acquisition strategy, in which MITI directed technology imports through licensing agreements, joint ventures, and targeted acquisitions (Goto and Odagiri, 1993), succeeded in moving Japanese firms from technology importers to frontier innovators by the 1980s. The U.S. response was primarily commercial (trade negotiations, voluntary export restraints) rather than security-oriented, because the underlying concern was rent-shifting, an economic externality addressable through trade-policy instruments.¹²

The institutional response in the U.S.-China context has been a rapid expansion of transaction-level screening. The Committee on Foreign Investment in the United States

¹²The exception was the 1987 Toshiba-Kongsberg affair, in which the sale of submarine-quieting technology to the Soviet Union provoked Congressional sanctions, illustrating that knowledge-sourcing concerns can escalate to the security domain when the acquiring country’s geopolitical alignment shifts.

Figure 3: CFIUS Screening Intensity by Acquirer Country Group, 2010–2024



Notes: Screening intensity is defined as a country group’s share of CFIUS-covered notices divided by its share of positive inward FDI financial transactions (all industries, BEA). FDI shares use five-year centered rolling averages. “Allied countries” include Japan, Canada, the United Kingdom, South Korea, Australia, France, Germany, Netherlands, Israel, Singapore, Sweden, Switzerland, and other OECD members. “China” includes Hong Kong. Panel (a) uses all covered notices; panel (b) uses critical technology acquirer notices (2016–2024; 2021 excluded due to reporting gap). The horizontal line at 1 indicates proportional screening. Sources: CFIUS Annual Reports to Congress; BEA Direct Investment by Country and Industry.

(CFIUS) expanded screening to include non-controlling investments. The rationale was that even minority equity stakes can grant access to a firm’s strategic direction, supplier relationships, and internal coordination architecture, while technology-sharing agreements accompanying such investments can transfer codified and tacit knowledge that product-level and person-level controls would not reach. The tightening is global: the EU, United Kingdom, Japan, Australia, Germany, and Canada have all strengthened FDI screening regimes since 2019 (Bauerle Danzman, 2021). In 2023, the United States also introduced outbound investment screening targeting U.S. investments in Chinese entities active in semiconductors and quantum information technologies, another policy to govern the knowledge accompanying equity investment.¹³

Figure 3 documents the screening intensity across country groups. The figure reports each country group’s share of CFIUS notices divided by its share of inward FDI flows (five-year rolling averages), where a value of one indicates proportional screening. China has been screened at 14-60 times its FDI share throughout 2010-2024, with the ratio rising after the screening expansion as Chinese investment collapsed faster than CFIUS filings declined. Allied countries have been screened at 1.1-1.9 times their FDI share, with no structural

¹³Executive Order 14105, 88 Fed. Reg. 54867 (August 9, 2023). The Treasury Department’s implementing regulations took effect on January 2, 2025.

break at the expansion. Panel (b) restricts attention to critical technology acquirers: China’s screening intensity has ranged from 8 to 28 times its FDI base rate, rising after FIRREA’s full implementation, while allied intensity remained stable at 1.3-1.7.

Geographic Realignment and MNC Boundary Adjustments The knowledge-governance regime is reshaping the geography of FDI and the internal organization of MNCs, though disentangling the effects of knowledge-governance instruments from those of tariffs and broader geopolitical risk remains an empirical challenge. Gopinath et al. (2025) document that cross-bloc trade and FDI have declined roughly 12 and 20 percent, respectively, since the Russian invasion of Ukraine, with non-aligned “connector countries” increasingly intermediating between blocs. This pattern is consistent with Alfaro and Chor (2023)’s finding that countries that gain U.S. import share (primarily Vietnam and Mexico) have simultaneously increased their imports from China, thereby rearranging the geography of intermediate linkages. Knowledge governance through investment realignment thus faces the same substitutability problem as codified-knowledge controls: restricting the direct channel may redirect flows through indirect channels. The IMF (2023) estimates that geoeconomic fragmentation could reduce global GDP by up to 7 percent in severe scenarios, with the largest losses concentrated in developing economies that lose access to MNC-mediated knowledge transfers.

At the firm level, regulatory frictions raise the costs of maintaining integrated operations in adversary jurisdictions, pushing firms toward arm’s-length arrangements that fragment the internal networks through which tacit and organizational knowledge flows. Firm responses include firewalled data systems, compliance-driven restrictions on personnel mobility, and dual-track IP strategies (Bauerle Danzman, 2021), but a systematic measure of these adjustments’ efficiency costs remains an important gap in the literature.

6.4 Industrial Policy and the Knowledge Frontier

The policies reviewed above, which aim at restricting the outflow of knowledge to rivals, are fundamentally defensive. Industrial policy, in particular, the CHIPS Act, pursues a different strategy: affirmative investment in domestic knowledge creation, motivated by concerns about the geographic concentration of advanced semiconductor fabrication and the production-innovation complementarity that links manufacturing experience to frontier design capability. The two policy types are analytically complementary from the geopolitical perspective: restrictions can be less effective without domestic investment, because the dynamic costs they impose on domestic firms (Section 6.1) erode the technological base they are designed to protect; subsidies can be less effective without restrictions, because subsidized knowledge may diffuse to the rivals the policy is meant to disadvantage. Whether the

current policy mix reflects this complementarity or instead generates a self-reinforcing cycle of escalation is an empirical question.

The CHIPS Act and the Logic of Subsidies The CHIPS and Science Act (2022) authorized \$52.7 billion for domestic semiconductor manufacturing and research, with “guardrail” provisions prohibiting recipients from making significant investments in semiconductor capacity in countries of concern for ten years.¹⁴ The guardrails condition knowledge geography through fiscal incentives rather than prohibitions, operating under congressional spending authority rather than executive security discretion. Where export controls govern what can be sold and the U.S.-person rule governs who can participate, the guardrails govern where knowledge-intensive production can be located.

The Act’s rationale rests on the production-innovation complementarity discussed in Section 4: if manufacturing generates process knowledge that feeds back into design improvement (Fuchs 2014; Autor et al. 2020), the migration of fabrication to East Asia may have eroded the domestic knowledge base that sustains frontier innovation. Goldberg et al. (2024) provide evidence consistent with this logic, finding learning-by-doing effects at the firm-product level and economies of scope that link production experience to innovative output. Erten et al. (2026) find that the CHIPS Act led to short-run employment effects in the U.S., with approximately 15,000-16,000 direct jobs in the core semiconductor sector and 28,000–35,000 indirect jobs, though employment gains are a necessary rather than sufficient condition for the capability accumulation that constitutes the Act’s economic rationale. Allied governments have pursued parallel programs such as the EU Chips Act and expanded subsidies in Japan and South Korea, motivated by shared concerns about the geographic concentration of advanced-node production (Bown and Wang, 2024).

The design of these instruments can itself be shaped by the firms they regulate. MNCs with concentrated domestic manufacturing interests have incentives to align with national-security rationales and support subsidies and restrictions that would benefit their competitive position, while MNCs with dispersed global operations bear the costs of these policies. This political-economy dimension of knowledge governance has not yet been examined systematically in the literature.

When Does Protection Generate Learning? The infant-industry literature identifies the conditions under which protection generates durable learning: strong learning-by-doing effects, absorptive capacity, and competitive pressure (Juhász et al., 2024). Juhász (2018) provides causal evidence, showing that regions differentially exposed to protection during

¹⁴CHIPS Act of 2022, Pub. L. No. 117–167. See Bown and Wang (2024) for a comprehensive analysis.

the Napoleonic Continental Blockade experienced persistent gains in industrialization under precisely the conditions the theory predicts.

Evidence from China illustrates the sensitivity of outcomes: protection generated innovation in digital services where scale economies were strong (Zhou, 2024) but produced misallocation in shipbuilding where competitive pressure was absent (Barwick et al., 2024). Liu (2019) shows that welfare implications depend critically on whether policies target sectors with large upstream linkages, a finding directly relevant to semiconductors. For the CHIPS Act, the question centers on whether subsidies can rebuild fabrication capabilities in an economy where the relevant tacit knowledge resides largely in East Asian fabs, and whether the guardrail conditionality on geopolitical alignment generates deadweight losses from misallocation of knowledge-intensive activity.

Countermeasures and the Multi-Player Game China’s own restrictions, such as the Cybersecurity Law (2017), Data Security Law (2021), Personal Information Protection Law (2021), and expanding export controls on critical minerals, transform knowledge governance from a single-player optimization problem into a multi-player game. The “weaponization of interdependence” (Farrell and Newman, 2019) operates in both directions. China’s earlier restrictions on rare earth exports triggered compensating innovation outside China (Alfaro et al., 2025), just as U.S. chip export controls appear to be accelerating Chinese algorithmic efficiency. Both are instances of directed technical change (Acemoglu, 2002): restrictions that raise the relative price of a controlled input redirect innovative effort toward substituting away from it. The relative durability of each side’s leverage depends on the substitution elasticities in the targeted knowledge domains, a parameter the empirical literature has not yet estimated.

The ecosystem-wide divergence documented in Section 6.1 suggests that both sides are pursuing policies that may be individually effective at delaying the other’s frontier progress but that jointly accelerate fragmentation of the global knowledge system. This dynamic has features of a prisoners’ dilemma, though the equilibrium properties depend on the specific payoff structure. Becko and O’Connor (2025) show that a country anticipating future geopolitical conflicts should promote rather than restrict bilateral trade in peacetime to accumulate leverage, suggesting that preemptive decoupling may weaken rather than strengthen the controller’s future bargaining position.

6.5 Mapping Mechanisms to Instruments

The preceding subsections examined each knowledge channel in isolation. The regime’s defining features emerge more clearly when the channels are viewed together. Table 3 maps

Table 3: Mapping Policy Instruments to Knowledge Channels

Instrument	Level	Authority	Codified	Tacit	Organizational
Export controls	Product	Security	Restricts sale of equipment, chips, and design tools	Bars U.S. persons from supporting foreign fabrication	—
Inbound FDI screening	Transaction	Security	Blocks foreign acquisition of domestic suppliers	—	Blocks or conditions foreign acquisition of domestic firms
Outbound investment screening	Transaction	Security	Restricts technology-sharing via joint ventures abroad	Restricts investment in foreign R&D centers	Restricts equity stakes conveying access to foreign knowledge networks
Subsidy guardrails	Firm	Econ.+sec.	Incentivizes reshoring of domestic production capacity	Funds domestic R&D workforce and facilities	Conditions subsidy receipt on geographic alignment of firm operations

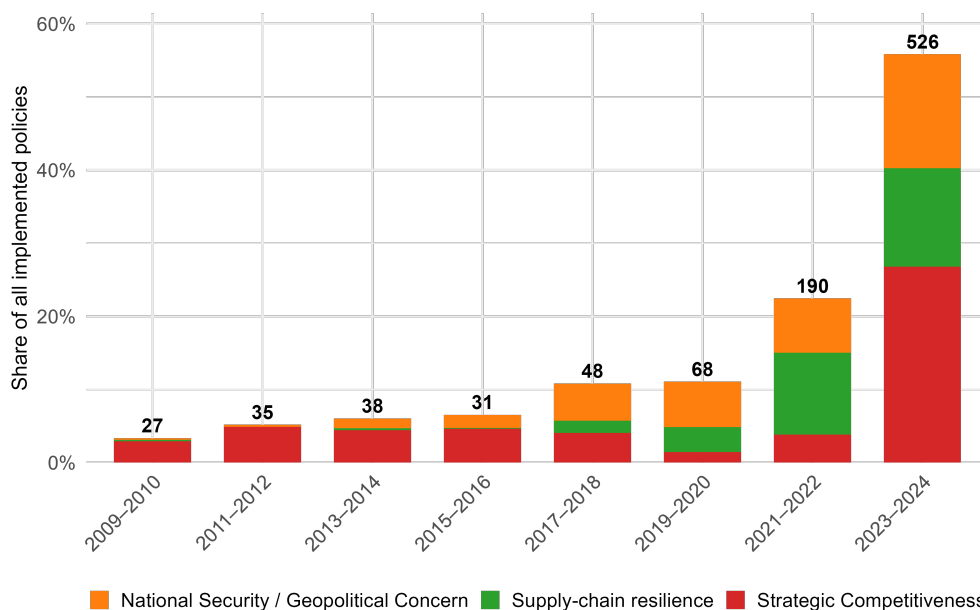
Notes: “Level” indicates governance granularity: product-level instruments target specific technologies; transaction-level instruments target ownership changes; firm-level instruments condition on the geographic choices of the MNC. “Authority” indicates the legal basis: “Security” denotes instruments administered under national security statutes (IEEPA, EAR, CFIUS statute, EO 14105); “Econ.+sec.” denotes spending authority with security-based conditionality (CHIPS Act). Cells marked — identify instrument-channel combinations where no governance tool currently operates.

the instruments systematically.

Two structural patterns are visible. The first is a *coverage-precision tradeoff*. Instruments targeting specific knowledge flows achieve relative precision, but can leave channels ungoverned; instruments aiming to reach all three knowledge channels cannot distinguish between knowledge flows that generate geopolitical externalities and those that do not. The layering of narrow and broad instruments also means that a single MNC may now face multiple governance regimes, administered by different agencies, operating at different levels of granularity, and justified by different externality rationales.

The second is *externality conflation*. Figure 4 documents the pattern: through 2016, U.S. China-targeting interventions were dominated by strategic competitiveness concerns and numbered fewer than 40 per biennium; by 2023-2024, national security and geopolitical concerns accounted for about 30 percent of 526 interventions. The explosion reflects not only an expansion of the regime but a reclassification of its rationale. The distinction between economic and geopolitical externalities is analytically sharp in the framework of Section 2.4, but institutionally blurry. Moreover, the institutional blurring is not accidental: domestic firms that benefit from knowledge controls as rent-protection devices have incentives to frame their support in geopolitical terms, broadening the coalition favoring the most expansive instruments. When economic concerns are governed through security instruments, intervention

Figure 4: U.S. China-Targeting Policies by Stated Motive, 2009-2024



Notes: Author’s calculations based on data from Global Trade Alert. The sample includes all U.S. implemented policies classified as targeting China (including Hong Kong and Macao). Bars show each motive category’s share of all implemented policies in each biennium; italicized numbers report total intervention counts. “Strategic competitiveness” denotes interventions motivated by commercial or industrial-policy objectives; “supply-chain resilience” denotes interventions motivated by input-security concerns; “national security / geopolitical concern” denotes interventions motivated by security or geopolitical rationales.

becomes less targeted than the trade-policy alternatives the externality warrants.¹⁵

Both patterns reflect a deeper mismatch: MNCs organize knowledge creation and diffusion through integrated global networks, whereas every governance instrument reviewed above operates under national legal authority, with fragile multilateral coordination when allied economic interests diverge from shared strategic objectives. Across all three knowledge domains, controls generate compensating responses, including redirected innovation, supply-chain rearrangement, and organizational restructuring, whose magnitudes relative to the intended effects remain poorly measured. Quantifying these magnitudes is among the most important empirical challenges for the next generation of research on multinationals and international trade.

¹⁵The conflation may also be self-reinforcing. Alfaro et al. (2023) show that evidence-based information highlighting the benefits of trade can activate rather than reduce protectionist preferences when it triggers prior concerns about competition with China, suggesting that the public’s failure to distinguish economic from geopolitical rationales reinforces political support for the broadest instruments rather than the most targeted ones.

7 Conclusion

Multinational firms are simultaneously the primary institution for creating and distributing knowledge across borders and the central channel through which knowledge diffusion generates geopolitical externalities. The tension between these two roles and the inadequacy of existing policy frameworks for managing it are the organizing themes of this review, connecting the foundational properties of knowledge to the theory and evidence on MNC organization, knowledge diffusion, and the governance regime.

MNCs account for a dominant share of global private R&D, and the geography of their knowledge creation has evolved: affiliates now contribute frontier research, and cross-border coinventions between headquarters and affiliates have risen steadily. Within firms, knowledge transmission spans codified, tacit, and organizational channels that differ in how easily they can be governed. Across firm boundaries, MNCs diffuse knowledge through supply-chain linkages, labor mobility, and competitive pressure. The same flows that generate productivity gains in host economies also generate geopolitical externalities when the recipient is a strategic rival. The governance instruments deployed in response, spanning export controls, investment screening, person-level restrictions, and subsidy guardrails, differ fundamentally from trade-policy tools in their rationale, effectiveness, and costs. The evidence yields a consistent pattern: controls can disrupt access to chokepoint technologies but generate compensating responses whose magnitudes relative to intended effects have not been established.

These findings point to gaps in the literature and an emerging research frontier. A first priority is quantifying the efficiency costs of geopolitically motivated MNC restructuring. Fragmenting the organizational architecture that is the fundamental source of MNC efficiency imposes costs that current analysis has not captured; without measuring them, the welfare implications of knowledge governance remain incomplete.

A second is estimating the substitution elasticities that determine whether controls achieve their intended effects or trigger compensating dynamics. These elasticities are likely to vary sharply across knowledge domains, from near-zero in leading-edge fabrication equipment to potentially high in AI, where knowledge is codified in forms such as open-source model weights, training algorithms, and publicly available research that existing interventions were not designed to govern.

Finally, the welfare costs of the regime are likely unevenly distributed. Current empirical evidence has concentrated on the semiconductor sector, whose extreme chokepoint market structures may not generalize to other knowledge-intensive industries. Developing economies integrated into MNC knowledge networks face convergence pathways potentially foregone by great-power competition. Within advanced economies, the costs and benefits divide along

supply-chain position: producers of controlled technologies lose export revenue; downstream users face fragmented input markets but may benefit from subsidized domestic capacity, and domestic firms competing with foreign rivals that have benefited from MNC-mediated knowledge diffusion may favor tighter controls for competitive rather than strategic reasons. Quantifying these distributional consequences by knowledge type and supply-chain position and assessing whether they are aligned with the regime’s stated objectives are questions the literature has not yet addressed.

The globalization of knowledge can no longer be understood solely through the economics of market failure and technology diffusion. The same properties of knowledge that explain why multinationals exist are what make cross-border knowledge flows consequential for the strategic balance between rival states. The field has spent decades developing the tools to understand why these flows occur. The next task is to bring comparable rigor to evaluating the consequences of governing them.

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