
International relocation of innovation activities in German industry – is Germany losing its innovation cores?

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Abstract: This paper analyses the international relocation and functional reconfiguration of innovation activities in the German metal and electrical industry. Based on a survey of 240 companies, the study reveals a growing internationalisation of innovation alongside a clear functional specialisation across locations. While Germany remains the central hub for research and product development, production-related and market-oriented innovation activities are increasingly shifted abroad. The findings highlight the emergence of globally distributed but strategically orchestrated innovation networks, in which companies leverage location-specific advantages while retaining control over core technological capabilities. The results point to a potential erosion of domestic innovation depth and underline the importance of balancing global efficiency with organisational resilience and technological sovereignty.

Keywords: globalisation of innovation; international R&D; R&D relocation; global innovation networks; innovation location; locational advantages; technological sovereignty; industrial innovation; manufacturing industry

1 Problem

Industrial innovation has long been regarded as a core strength of the German innovation system, particularly within the German manufacturing industry. Historically, Germany's competitive advantage has rested on the close integration of research, development, production, and incremental process innovation within strong regional industrial ecosystems. However, accelerating geopolitical tensions, rising costs, digital transformation gaps, and the increasing modularisation of innovation processes are

fundamentally reshaping where and how industrial innovation takes place. This raises the critical question of whether Germany's industrial "innovation cores" are at risk of gradual erosion.

2 Background and research questions

The international relocation and functional reconfiguration of industrial innovation activities can be understood at the intersection of the globalisation of innovation, global innovation networks (GINs), locational advantages, and technological sovereignty. Together, these perspectives provide a comprehensive theoretical lens to explain why companies increasingly distribute innovation activities across borders while selectively retaining strategic capabilities at home.

The *globalisation of innovation* reflects a structural shift from nationally embedded R&D systems toward internationally dispersed and functionally specialised innovation processes. Early contributions on the internationalisation of R&D highlight firms' motives to access heterogeneous knowledge bases, specialised talent, cost advantages, and lead markets (Cantwell and Zaman, 2018; Lewin et al., 2009; Papanastassiou et al., 2020; Siedschlag et al., 2013). More recent research conceptualises innovation not as a monolithic activity but as a decomposable value chain, in which distinct phases, such as research, development, adaptation, and industrialisation, can be geographically distributed according to their specific requirements (Belitz and Lejpras, 2026; Dachs et al., 2024; Papanastassiou et al., 2020;). This perspective implies that the spatial organisation of innovation is driven by a combination of efficiency-seeking, knowledge-seeking, and market-seeking motives (Dunning et al., 1998). At the same time, it emphasises that internationalisation is not uniform across activities. Highly tacit, system-relevant knowledge tends to remain geographically concentrated, whereas more standardised or application-oriented activities are more easily relocated (Brennan et al., 2015; Herstad et al., 2014; Kinkel et al., 2014).

The concept of *global innovation networks* (GINs) provides a relational and systemic view of internationally distributed innovation. GINs describe how companies organise, coordinate, and govern innovation activities across multiple geographically dispersed nodes, integrating internal units and external partners into a coherent knowledge system (Ambos et al., 2021; Ernst, 2006; Herstad et al., 2014; Sachwald, 2008). Within this framework, innovation is understood as a networked process characterised by knowledge flows, interdependencies, and differentiated roles of locations. Central nodes, which are often located in the home country, typically retain system integration capabilities, architectural knowledge, and strategic control, while peripheral nodes specialise in context-specific activities such as local adaptation, development, or production-related innovation. This aligns with the notion of home-base augmenting and home-base exploiting R&D, where companies simultaneously leverage domestic strengths and tap into foreign knowledge pools (Ambos et al., 2006; Kuemmerle, 1997). Theory also highlights the importance of governance mechanisms, coordination capabilities, and knowledge integration, which become increasingly critical as innovation activities are spatially dispersed (Dhanaraj and Parkhe, 2006; Hurmelinna-Laukkanen and Nätti, 2017; Nambisan and Sawhney, 2011).

The spatial distribution of innovation activities is further explained by the concept of *location advantages*. Drawing on international business theory, firms select innovation

locations based on the availability and quality of location-specific assets, including skilled labour, technological infrastructure, complementary knowledge, cost advantages, institutional stability, and proximity to markets and partners (Dunning, 1998; Lewin et al., 2009; Papanastassiou et al., 2020; Siedschlag et al., 2013). In the context of globally distributed innovation, location advantages are not static but function-specific. Different regions offer distinct value propositions for particular innovation activities: advanced economies often provide strong research infrastructures and institutional quality, while emerging economies may offer cost efficiencies, market proximity, and growing technological capabilities (Lewin et al., 2009). At the same time, the co-location of production and innovation activities remains relevant (Castellani and Lavoratori, 2019; Mudambi et al., 2018), as production-related learning and feedback loops are critical for incremental and process innovation (Dachs et al., 2015; D'Agostino, 2015; Fuller et al., 2017).

The concept of *technological sovereignty* introduces a strategic and policy-oriented dimension to the globalisation of innovation. It refers to the ability of companies and countries to maintain control over critical technologies, knowledge bases, and innovation capabilities that are essential for economic competitiveness and strategic autonomy (Edler et al., 2023; March and Schieferdecker, 2023). From a firm-level perspective, technological sovereignty shapes location decisions by influencing which innovation activities are considered strategically sensitive and therefore less mobile. Core research, system architecture, and key enabling technologies are often retained in the home country to safeguard intellectual property, ensure control over critical knowledge, and maintain long-term innovation capacity (Belderbos et al., 2013; Cui et al., 2022). At the same time, increasing geopolitical tensions, supply chain vulnerabilities, and technological competition reinforce the importance of balancing global knowledge sourcing with the preservation of domestic innovation capabilities (Edler et al., 2023; Kinkel and Richter, 2023). This creates a fundamental tension between global efficiency through dispersion and strategic control through concentration.

Taken together, these theoretical perspectives suggest that the international relocation of innovation activities is not a simple process of offshoring, but rather a strategic reconfiguration of innovation systems. Companies design global innovation networks that combine geographically dispersed capabilities while maintaining central control over critical knowledge domains. Against this background, the study addresses the following **research questions**:

1. Given the current climate of geopolitical tensions and intense pressure on innovation systems in industrialised nations, how do industrial companies distribute innovation activities between domestic and international locations?
2. How do industrial companies expect this distribution to evolve over the coming years?

More specifically, the study investigates (1) which types of innovation activities are most strongly anchored in Germany today, (2) which activities are increasingly internationalised or planned to be shifted abroad, (3) how different regions of the world assume distinct roles within companies' global innovation networks, and (4) which location factors influence these strategic decisions. By doing so, the study aims to *assess early signals of a potential erosion* of Germany's industrial innovation cores.

3 Research design

The study is based on a quantitative online survey conducted between May and June 2025 among 240 companies in the German metal and electrical industry. Respondents are specialists and managers with decision-making authority regarding corporate location decisions, mainly members of the top management (CEO, C-level – 89%). In terms of company size, the sample is appropriately distributed. It comprises 52% small and medium-sized enterprises (SMEs) with 10 to 249 employees, 27% medium-sized companies with 250 to 999 employees and 21% large enterprises with 1,000 or more employees. In terms of sectors, all key segments of the German metal and electrical industry are represented. The most strongly represented sectors are mechanical engineering (33%), metal production (28%), the automotive and supplier industry (15%) and manufacturers of electronic and optical products (11%). The broad scope allows conclusions about the diverse realities of companies within the German metal and electrical industry.

The survey differentiates seven distinct product- and process-oriented innovation activities (Tidd and Bessant, 2024):

1. **Scouting** refers to the systematic search for, identification and evaluation of new technologies, trends or partners with a view to identifying external sources of innovation at an early stage.
2. **Research** involves the systematic acquisition of new scientific or technical knowledge in order to understand fundamental principles, technologies or processes.
3. **Product development** refers to the conception, design, technical implementation and testing of new products right through to market launch.
4. **Product adaptation** is the modification of existing products to adapt them to specific customer needs, legal requirements or regional market characteristics.
5. **Process innovation** involves the introduction of new or significantly improved technical or organisational production methods or value-added processes.
6. **Production ramp-up** is the phase in which production capacities are ramped up and series production of a new or significantly improved product commences.
7. **Production of new product generations** encompasses the manufacturing of products that represent a new development or significant redesign.

Companies were asked about the current and expected future localisation of these activities, key target regions, and the perceived importance and quality of location factors.

4 Findings

The results reveal a nuanced but clear pattern of increasing internationalisation combined with a differentiated functional division of innovation labour. Overall, the German metal and electrical industry remains highly innovative. Nearly all surveyed companies are active in at least one innovation field. Product adaptation (around 90%) and product development

(approximately 75%) are the most widespread activities, reflecting strong customer and market orientation. About half of the companies conduct in-house research, which remains concentrated among larger and technologically specialised companies due to the resource intensity and long-term nature of research investments.

Germany continues to be the central location for industrial innovation, but no longer the exclusive one. Depending on the innovation activity, between 57% and 68% of activities are currently located in Germany (Figure 1). Research and product development are particularly strongly anchored domestically, reflecting the strategic importance of core technological knowledge and intellectual property. In contrast, production-related innovation activities, such as process innovation or production ramp-up, show substantially higher foreign shares. Overall, the international share of all innovation activities already amounts to nearly 40%. Remarkably, this level of internationalisation is not confined to large corporations, as small and medium-sized enterprises exhibit similar patterns, indicating that global innovation is becoming a structural feature across company sizes.

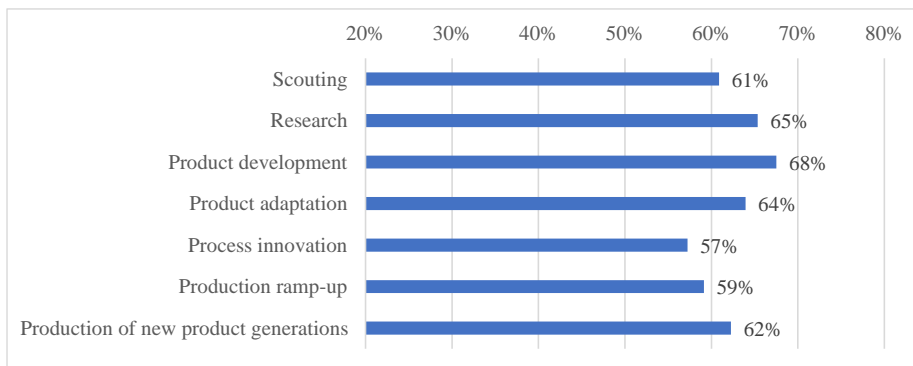


Figure 1 Share of domestic innovation activities (%).

To date, Germany remains the most important location for innovation activities for the vast majority of the companies surveyed. In almost all fields, more than 80% of companies cite Germany as the primary location for their innovation work. Only in the areas of scouting (77%) and producing new product generations (74%) does this proportion fall below the 80% mark. With regard to specific localisation, the study uncovers a regionally differentiated architecture of *global innovation networks*. Central and Eastern European EU countries play a major role in production-related innovation activities, particularly in manufacturing of new product generations (the primary location for 9%) and production ramp-up (the primary location for 7%). Northern and Western European countries are especially relevant for scouting (the primary location for 9%) and research (the primary location for 6%). China has become important across all innovation activities (with share of 3-7% as most important location), while the United States mainly attracts research projects in selected technology fields (the primary location for 5%) and India is gaining relevance for product development and adaptation (the primary location for 3%).

Future expectations point towards an acceleration of these trends. Almost half of the companies plan to further expand innovation activities abroad (Figure 2). The strongest dynamics are observed in production ramp-up, production of new product generations, and scouting activities, where about half of the companies foresee increased internationalisation. Research and process innovation are also expected to further

internationalise, though to a lesser extent (38% each). On the other hand, fewer than one in seven companies expects innovation activities in Germany to increase.

The analyses also show that large companies in particular are driving forward the establishment of overseas innovation centres. Significant differences are mainly evident in the areas of product development and adaptation, as well as process innovation. It is striking that companies with 250 to 999 employees operate almost as internationally as large companies with 1,000 or more employees; only small and medium-sized enterprises (SMEs) with 10 to 249 employees are, as expected, significantly more cautious in this regard. These differences reflect the resource and governance advantages of large organisations: they have proven experience in establishing international centres of excellence, leverage economies of scale, ensure compliance and IP protection professionally, and are generally more experienced in managing the complexity of distributed innovation processes. SMEs, by contrast, continue to internationalise more selectively, often driven by partners or customers and following low-risk entry paths.

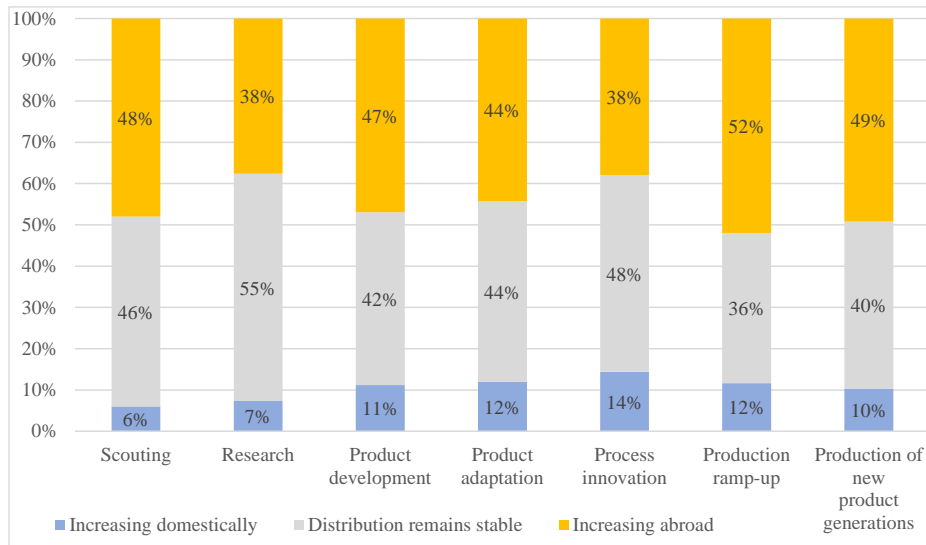


Figure 2 Future shift in the location of innovation activities.

The ongoing global and function-specific diversification of industrial companies' innovation activities is also evident from an analysis of the target regions that will be most important in the future. Depending on the type of innovation activity, Germany will remain the most important innovation location for 40% to 60% of the companies surveyed. This is least pronounced in the case of scouting (41%), which traditionally takes place predominantly within the respective markets. For other product-oriented innovation activities, the figures are consistently below 50%. The strongest domestic focus in the future is emerging in the area of process innovation, with 58% of mentions as primary location. This confirms Germany's traditional role as a centre for the development of new production processes at world-class level.

When looking at the top three foreign target regions for each type of innovation activity, the regional division of labour reveals clear patterns (Table 1):

- China will tend to play an even more important role in all innovation activities in the future, ranks first in five areas and second in two areas. It displays a focus on the product-oriented innovation activities of scouting, research and development of new products, but is also important for production-related innovations.
- Central and Eastern Europe is increasingly becoming the centre of production-related innovation activities, but is also important for product adaptation and development.
- Northern and Western Europe is increasingly serving as a location for scouting and research.
- India is coming into focus for product development and adaptation.
- The USA is becoming particularly attractive for research activities, albeit to a limited extent in relation to the country's scientific and economic importance.

Table 1 Top 3 foreign target regions for future innovation activities and percentage of mentions as the most important country (%)

R a n k	Scou-ting	Re-search	Product develop-ment	Product adap-tation	Process inno-vation	Production ramp-up	Production of new product generations
1	China (25%)	China (19%)	China (16%)	China (14%)	China (12%)	Central and Eastern EU (15%)	Central and Eastern EU (18%)
2	Northern and Western EU (12%)	Northern and Western EU (8%)	India (11%)	Central and Eastern EU (10%)	Central and Eastern EU (11%)	China (14%)	China (13%)
3	India (5%)	USA (8%)	Central and Eastern EU (8%)	India (9%)	Northern and Western EU (4%)	ASEAN (7%)	India (8%)

These developments suggest a shift in Germany's role towards that of a strategic system leader, focusing on system architecture and governance, while scale- and market-oriented innovation phases move closer to international production and sales markets. Particularly in the mechanical engineering sector, companies anticipate a stronger relocation of the production of new product generations as well as product adaptation, which is noteworthy given the sector's macroeconomic importance. At a regional level, the mechanical engineering sector places greater emphasis on China, India and the US than other industries, whilst Central and Eastern Europe appears comparatively less attractive as a hub for innovation. This pattern is plausible, as the mechanical engineering sector is characterised by customer-focused and application-oriented adaptations and short iteration cycles in key markets. Geopolitical developments, as well as the rapid growth in expertise among Chinese and Indian competitors, are also driving the differentiation of activities across the triad of markets.

5 Discussion

German industry has a broad, internationally competitive innovation profile, but is facing a structural shift. Almost half of the German industrial companies plan to base more of their innovation activities abroad in the future, particularly in production-related phases. This points to the expansion of international hubs that combine cost advantages, access to talent, proximity to suppliers and market access (Lewin et al., 2009; Papanastassiou et al., 2020; Siedschlag et al., 2013). Research and process innovations are being internationalised to a more moderate extent, which speaks for Germany's continued high standing in the development of new production technologies and new products.

The increasing international division of labour follows a clear functional and regional logic. Central and Eastern Europe are establishing as an innovative production region, China and India as development centres, and Northern/Western Europe and the USA as research hubs. The findings suggest that the globalisation of innovation activities of the German industry has entered a more mature phase, moving beyond simple geographic dispersion toward systematic functional specialisation. Whereas in the past, internationalisation was often understood as a further expansion or relocation of R&D activities, the results demonstrate that companies increasingly differentiate between distinct innovation stages and allocate them globally according to their specific requirements (Dachs et al., 2024).

Overall, there are signs of a shift away from nationally centred strategies towards globally distributed innovation networks (Ambos et al., 2021; Ernst, 2006; Herstad et al., 2014). However, the empirical evidence also challenges overly decentralised interpretations of GINs. Instead of fully distributed systems, the observed patterns indicate strategically orchestrated networks, where the hub acts as strategic centre that coordinates heterogeneous locations by exerting structural power through resources and position (Dhanaraj and Parkhe, 2006; Nambisan and Sawhney, 2011; Hurmelinna-Laukkanen and Nätti, 2017). Germany retains a central role as a system integrator and governance hub, but is losing operational depth.

At the same time, the growing importance of multiple foreign locations indicates an increasing polycentricity of innovation networks (Binz and Truffer, 2017). If investments in innovation capabilities will be increasingly taking place abroad, this could also prove to be a critical development for Germany as a centre of innovation. Existing key capabilities could lose value in the medium to long term due to technological dynamics, whilst new activities are predominantly being established outside Germany.

Germany's strengths and locational advantages include the high qualifications of its skilled workforce, the protection of intellectual property, political stability and a culture of innovation. Weaknesses lie in particular in high levels of regulation, high costs for innovation activities, the limited availability of skilled workforce, and the digital infrastructure. Proximity to universities or government funding programmes play a lesser role than expected; what is decisive today is rather speed, scalability and the ability to implement. Personal responsibility, competition and stability are regarded as essential prerequisites for successful innovation.

The findings reinforce the view that *location advantages* are activity-specific and combinatory, rather than universally applicable across all innovation stages (Narula and Santangelo, 2012). Theoretical models of location advantages and choice must move beyond static comparisons of national environments toward multi-location transborder optimisation frameworks. At the same time, the results highlight the continued importance

of co-location effects, particularly between production and innovation (Castellani and Lavoratori, 2019; Mudambi et al., 2018). The relocation of production-related innovation activities suggests a gradual decoupling of these linkages, raising concerns about the erosion of cumulative learning processes in the home country. This supports and extends arguments on hollowing-out dynamics (Dachs et al., 2015; D'Agostino, 2015; Fuller et al., 2017), but grounds them in a more differentiated, activity-level perspective.

Also, the concept of *technological sovereignty* gains relevance through the observed persistence of core innovation activities in the home country. Research and system-critical capabilities remain disproportionately concentrated domestically, indicating deliberate firm-level strategies to retain control over key knowledge assets (Belderbos et al., 2013; Cui et al., 2022). However, the findings also reveal emerging tensions. The increasing internationalisation of adjacent innovation activities, particularly those linked to production and market adaptation, may gradually erode the knowledge base that underpins technological leadership. This suggests that technological sovereignty is not a static condition but a dynamic and path-dependent outcome (Edler et al., 2023; March and Schieferdecker, 2023), shaped by cumulative location decisions.

6 Conclusions

The study makes several contributions to innovation research and management. It provides rare, large-scale, firm-level empirical evidence on the international division of *differentiated industrial innovation activities* in a leading manufacturing economy. By explicitly distinguishing seven innovation activities, the study moves beyond aggregate R&D and innovation indicators and offers a more fine-grained understanding of how innovation is spatially reorganised. The inclusion of small and medium-sized enterprises shows that global innovation is no longer an exclusive strategy of large firms, challenging assumptions about the organisational prerequisites for international innovation.

The findings contribute to the literature on GINs by empirically substantiating that internationalisation does not imply a simple displacement of innovation away from the home country, but rather a reconfiguration in which the home base (Germany) retains strategic and systemic roles while operational depth in production-related innovation declines. This supports and extends theoretical arguments on the coexistence of global dispersion and home-base augmentation (Belitz and Lejpras, 2026; (Sachwald, 2008)).

A key theoretical implication is that the effectiveness of GINs depends less on the breadth of dispersion and more on the quality of orchestration and coordination mechanisms (Hurmelinna-Laukkanen and Nätti, 2017). The findings shift the focus of GIN theory from structural configurations toward governance capabilities, including the management of knowledge flows, role allocation, and interdependencies across locations. The results also suggest limits to dispersion. Excessive internationalisation of certain innovation stages, particularly those closely linked to production, may weaken feedback loops and learning processes (Castellani and Lavoratori, 2019; Mudambi et al., 2018). This pronounces the notion of optimal network configurations, where the benefits of foreign innovation activities must be balanced against coordination costs and knowledge fragmentation.

The study also advances debates on industrial resilience and innovation system sustainability. While prior research has warned of hollowing-out effects resulting from the separation of innovation and production (D'Agostino, 2015; Fuller et al., 2017), empirical

evidence has often remained fragmented. The present findings identify *early signals of potential erosion of industrial innovation cores* in German industry, particularly where production-related learning processes are concerned.

This also leads to important conclusions for the concept of technological sovereignty. It must be conceptualised as a multi-layered construct (Edler et al., 2023), encompassing not only core research capabilities but also the broader ecosystem of complementary innovation activities. In addition, the preservation of technological sovereignty requires a minimum level of operational depth in domestic innovation systems. If production-related learning processes are systematically relocated, the long-term viability of core technological capabilities may be at risk.

7 Practical implications

For companies, the results underline the importance to *proactively and strategically design global innovation networks* rather than allowing quick relocation decisions to accumulate. Strategic clarity on the roles of headquarters, competence centres, and international sites is essential, as is investment in digital capabilities to coordinate the dispersed innovation activities. In particular, companies should take the following aspects into account:

- **Take a holistic approach to innovation location decisions:** avoid prioritising short-term cost considerations over medium- to long-term resilience and innovation capacity.
- **Systematically map uncertainties and trade risks in scenarios;** drive forward the diversification of locations across different regions of the world with varying governance structures.
- **Develop a target architecture for global innovation networks:** clearly define the mandates of steering bodies, centres of excellence and ramp-up units.
- **Fill the talent pipeline:** Actively capitalise on the current favourable labour market situation and target international specialists and knowledge holders.

For policymakers, the findings signal an urgent need to strengthen Germany's attractiveness for production-related innovation through faster regulatory processes, improved digital infrastructure, and proactive skilled-labour strategies. Without such measures, Germany risks retaining strategic control while losing the operational learning processes that underpin long-term industrial innovation performance.

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