The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/1059-5422.htm

Received 29 August 2023
Revised 31 October 2023
8 January 2024
Accepted 9 February 2024

The role of foreign MNEs in China's twin transition: a study on the organization of green and digital innovation processes

Chris Brueck
Institute of Economic and Cultural Geography, Leibniz University Hannover, Hannover, Germany

Abstract

Purpose – The purpose of this study is to shed light on the twin transition in China in the organization of innovation processes in artificial intelligence (AI) and green technology (GT) development and to understand the role of foreign multinationals in Chinese innovation systems.

Design/methodology/approach – A qualitative research approach is used by interviewing executives from German multinationals with expertise in AI and GT development and organization of innovation processes in China. In total, 11 semi-structured interviews were conducted with companies, and the data were analysed with a thematic qualitative text analysis.

Findings – The findings show that AI applications for GT are primarily developed in cross-company projects that are led by local and regional authorities through the organization of industrial districts and clusters. German multinationals are either being integrated, remaining autonomous or being excluded from these twin transition innovation processes.

Originality/value – This paper aims to fill the gap in the literature by providing one of the first qualitative approach towards twin transition innovation processes in China and exploring the integration of multinational enterprises in cluster organizations. To the best of the author's knowledge, this is one of the first twin transition studies from this perspective in emerging economies.

Keywords China, Clusters, Artificial intelligence, Green technology, Twin transition

Paper type Research paper

Funding: This work was supported by the German Federal Ministry of Education and Research (BMBF) under grant number 01DO21011A. The funding source had no involvement in the research, writing, and submission process.

The author would like to thank the participating companies for their time and openness, as well as the Asia-Pacific Committee of German Business and the German Chamber of Commerce Greater China for their support in identifying suitable candidates. Earlier versions of this paper were presented at the 2023 RSA Annual Conference in Ljubljana, the German Congress for Geography (DKG'23) in Frankfurt and the 7th Geography of Innovation Conference in Manchester. The author greatly benefited from the participants' comments. Many thanks to the editor and the two anonymous referees for their very valuable and helpful comments. Special thanks to Ingo Liefner, Sebastian Losacker, and Yang Liu for valuable comments and suggestions.

Competitiveness Review: An International Business Journal
Vol. 34 No. 7, 2024
pp. 44-60
Emerald Publishing Limited
1059-5422
DOI 10.1108/CR-08-2023-0207

1. Introduction

Two technology paradigms will reshape future economic development at the regional level: green technology (GT), which mitigates the negative environmental impacts of innovations, and whose regional dimensions are explored within the geography of sustainability transitions literature (Hansen and Coenen, 2015; Truffer and Coenen, 2012), and digital technology, which is digitizing innovation activities and transforming economic processes through new technologies and applications such as artificial intelligence (AI) (Balland and Boschma, 2021; Capello and Lenzi, 2021; Corradini *et al.*, 2021). The emerging concept of a "twin transition" suggests that these transformative processes are closely linked and should complement each other (Muench *et al.*, 2022). In this context, a twin transition might be achieved through the coupling of green and digital technologies, with the goal that digital applications can facilitate and accelerate GT, whereas the green transition can, in turn, shape the priorities and objectives of digital technological innovation. Existing research on the twin transition primarily focuses on the relationship, similarities and potentials of green and digital technologies, often from a quantitative perspective by investigating twin transition processes through patent data analysis. These studies indicate that many digital technologies can combine to constitute the development of GT at the regional level (Kopka and Grashof, 2022; Cicerone *et al.*, 2022; Montresor and Vezzani, 2023). Furthermore, the research highlights numerous potentials of digital technologies for sustainability, with general-purpose technologies, particularly AI, emerging as the most transformative, holding the greatest potential to drive the digital transformation of the economy and offering several sustainability applications (Cockburn *et al.*, 2019; Mouthaan *et al.*, 2023).

However, two major research gaps remain, which are addressed in this paper. Firstly, there is a gap in how these technologies can be systematically combined to unlock their full potential and develop digital green applications. Previous research has primarily focused on how regional knowledge of green and digital technologies mutually influence each other and has not yet investigated innovation modes within company-level internal innovation processes or collaborations (Montresor and Quatraro, 2020; Santoalha *et al.*, 2021; Montresor and Vezzani, 2023). Secondly, the role of the twin transition in local innovation agglomerations such as clusters or industrial districts is still a relatively under-explored perspective. Recent research has shed light on how clusters undergo digital or green transition processes. Götz and Jankowska (2017) already suggested that clusters might facilitate digital transformation, requiring a certain level of expertise in the field, despite the common assumption that digital technology contradicts local and regional aspects due to its global interconnected nature. Additionally, Bettiol *et al.* (2021) demonstrated that companies in industrial districts tend to invest more in technologies related to the fourth industrial revolution. Hervás-Oliver (2021) also examined Industry 4.0 adoption in industrial districts and showed that collaborations are essential for digital transformation. Conversely, the sustainability transformation through clusters is also gaining attention (Lis and Mackiewicz, 2023). Although research on the green and digital transition of clusters is growing, there is still a lack of knowledge on how cluster organizations are systematically used to combine digital and green technologies, thus triggering twin transition processes. Overall, twin transition research has primarily focused on Western economies, with research on twin transition dynamics in emerging economies still being relatively new. This is surprising given the potential of emerging economic systems, such as China, to adapt to new technologies. On the one hand, this is due to China's comprehensive promotion of AI and its commitment to both the sustainability transition through GT and the pursuit of twin transition ideas (Filiou *et al.*, 2023). On the other hand, it is related to the potential of the fast-acting state-led innovation system, which grants local innovation actors experimental freedom (Heilmann *et al.*, 2013). These conditions show the potential for rapid innovation development in new technology domains, making China a crucial study area.

In this paper, the two research gaps are addressed by examining the twin transition in China, with a specific focus on AI technology used for GT, e.g. machine learning models regulating and efficiently managing energy distribution from renewable energies. The paper particularly focuses on the combined utilization of these technologies, as they can be classified as radical twin innovations and hold the greatest potential for a twin transition (Mäkitie *et al.*, 2023). Furthermore, it is investigated whether and how companies internally develop these twin innovations and how collaborative development through state-led cluster organizations is promoted and managed. Specifically, this matter is examined from the perspective of German multinational enterprises (MNEs) operating an R&D centre in China. In doing so, insights are gained from the angle of foreign multinationals, which have been instrumental in China's innovation system in the past decades. However, this role has become increasingly uncertain due to geopolitical shifts since the COVID-19 pandemic and China's shift in innovation policy that affects the integration of MNEs in clusters. Hence, the paper aims to emphasize the role of multinationals in twin transition technology domains in China. The following two research questions were formulated to address the two research gaps from the perspective of MNEs in China:

RQ1. How do foreign multinationals develop AI, GT and twin innovations (AI/GT) in China?

RQ2. How are innovation processes combining AI/GT organized and administered in clusters, and how are multinationals involved in the innovation processes and integrated into Chinese innovation systems?

For the empirical part of the paper, 11 expert interviews were conducted with executives from German multinationals in China. The interview data were analysed using thematic qualitative text analysis.

The remainder of the paper is structured as follows: Section 2 delves into background literature concerning twin transition perspectives in China, the organization of innovation and the role of multinationals. Section 3 outlines the methodological approach, explaining data collection, analysis and evaluation. The results are presented in Section 4, and the paper concludes with a discussion and conclusion in Sections 5 and 6.

2. Background literature

2.1 Green, digital and twin innovation in China

In Western nations, various policy programs have been launched in recent years to exploit and systematically promote certain potentials of a twin transition. For example, the Joint Research Center of the European Commission summarizes the key requirements for a successful twin transition in the EU (Muench *et al.*, 2022). However, research on twin transition is still relatively new and not yet comprehensively understood. For now, there are only a few studies on the impact, effects and potentials of a twin transition, and there is a current focus on Western economies in twin transition research. Cicerone *et al.* (2022) observe that AI knowledge positively influences green-tech specialization in EU-28 regions, although certain constraints need to be considered, such as the prerequisite of existing green knowledge within regions. Kopka and Grashof (2022) presented similar findings and examined the link between AI and sustainability in German regions. They demonstrate that regional industrial structure needs to be understood to establish the link between AI and sustainability. Bianchini *et al.* (2023) examined the impact of digital and green technologies on greenhouse gas emissions in European regions. They find that while digital technologies can contribute to negative environmental impacts, linking them with existing green technologies can help reduce these impacts. Benedetti *et al.* (2023) discussed European features of a twin transition by investigating the impact of digitalization on energy efficiency and found a positive impact of digitalization across EU member states. Additionally, Almansour (2022) explored the twin transition from a qualitative perspective indicating that digital features influence the consumer adoption of electric vehicles. Scholars also show that the combination of digital and green technologies at the firm level can positively contribute to the twin transition, for example by increasing green competitive advantage (Rehman *et al.*, 2023), or that urban firms can better exploit the potential of digital technologies compared to rural firms (Cattani *et al.*, 2023). Furthermore, Collini and Hausemer (2023) took an agency-based approach to understanding twin transition pathways. They conceptualize that systemic change agents, such as clusters, influence twin transition pathways.

Overall, twin transition research in Western nations indicates that the combination of digital and green technologies at the regional, local and firm levels has great potential for harnessing twin innovations. Although these research findings demonstrate the necessity of a local perspective in comprehensively understanding the twin transition in industrialized countries, the regional and local factors contributing significantly to the twin transition in emerging economies remain largely unknown. To understand these local features of the twin transition, China makes an excellent study area, shaping the global innovation landscape in both digital and green technologies and increasingly affecting the digital and green transformation worldwide.

China is establishing a comprehensive AI strategy focusing on development and implementation across several industries and is thus building on AI as a pivotal factor for digital transformation (Pan, 2016; Wu *et al.*, 2020; Yu and Zhang, 2021). In the Chinese policy context, AI is defined from three perspectives: the basic perspective (infrastructure and hardware), the technological perspective (e.g. machine learning) and the application perspective (e.g. smart city). This paper deliberately concentrates on AI technology that can contribute to sustainability or facilitate the development and improvement of GT. Consequently, technological and application perspectives of AI are considered, and this approach is also supported by AI definitions in the economics literature (Agrawal *et al.*, 2019). Apart from the AI strategy, China has become a leading innovation nation in several GT domains in the past years (Huang and Lema, 2021). Due to massive investments in GT to address pollution and environmental crises, there is a growing amount of scholarly interest in how GT emerged and diffused in China (Horbach, 2014; Losacker and Liefner, 2020b). In this paper, the terms GT, eco-innovation and environmental technology are treated as synonyms. Therefore, definitions provided by Kemp *et al.* (2019) and Barbieri *et al.* (2020) are used, which consider GT as new or improved products or practices that lower environmental impacts or mitigate or reverse the negative effects of human action on the environment.

Research on GT and AI in China appears to be extensive; however, the systematic combination of these technologies remains largely obscure in the scholarly literature, although initial studies on twin transition in China are emerging. For instance, Zhang and Du (2023) showed how the digital economy in Chinese cities reduces urban carbon emissions, highlighting regional variations in the potential of digital technology for green applications. Gao *et al.* (2023) delved into the role of big data in green innovation and demonstrated its positive effects. Furthermore, Ahmad *et al.* (2023) asserted that China's technological innovation fosters sustainable development – a view shared by Chen *et al.* (2023), who determined that fiscal science and technology expenditure can lower CO_2 emissions, albeit with regional disparities. Li *et al.* (2023) discussed tangible applications of machine learning for urban sustainability in a review paper. The comprehensive political AI strategy also aligns with sustainability objectives. Xu *et al.* (2023) demonstrated that China's smart city policy positively influences green technological innovation. Furthermore, Filiou *et al.* (2023) explored the joint impacts of green and digital policies, analysing their influence on the emergence of eco-innovation. They assert that city-based AI policies significantly contribute to the increase in green patents. Collectively, a number of studies in recent years have examined the relationship between green and digital technologies in China. Nonetheless, a distinct perspective on innovation processes from a spatial standpoint remains notably absent.

2.2 Organization of innovation and the role of multinational enterprises in Chinese innovation systems

The innovation development in China is mainly characterized by a state-led innovation system that combines top-down processes with bottom-up dynamics (Heilmann *et al.*, 2013; Lauer and Liefner, 2019; Fischer *et al.*, 2021). Therefore, China's policy aims to establish cluster-based organizations of innovation actors, which facilitate innovation and are guided by authorities. This organization of innovation processes has historically revolved around pilot zones, which offer innovation actors experimental freedoms and are designed to initiate transformation and technological change in specific industries. Prominent examples include technology parks and science cities, as well as special economic zones (SEZ), which have been instrumental for attracting foreign companies' investment in the past (Teng *et al.*, 2020; Zeng *et al.*, 2011). Through this approach to inducing innovation, local and regional authorities can specifically address the economically heterogeneous nature of China and stimulate transformation processes in regional innovation systems (Xue *et al.*, 2021; Liefner *et al.*, 2021). This paper mainly refers to cluster organizations, which describe the state-led organization of innovation processes in clusters and industrial districts. The clusters are primarily created through pilot and demonstration zones, which establish networks between participating actors. In recent years, China extended these cluster organizations for developing technological solutions for green or digital domains, e.g. eco-cities for GT and sustainability applications (Chang *et al.*, 2016; Wu *et al.*, 2023), and AI pilot zones for AI applications (Arenal *et al.*, 2020; Yang and Huang, 2022). Although certain processes and structures (especially in eco-cities) have already been studied, research on AI clusters is still in its initial stage and has not yet been able to show exactly how innovation processes take place and how AI/GT applications are developed.

In this context, it is also unclear what role foreign MNEs play in the innovation process in twin technologies. MNEs and foreign direct investment (FDI) have played an important role in these Chinese innovation systems. Starting in SEZs, regions attempted to spatially cluster FDI and attract MNEs resulting in rapid economic growth and the establishment of well-functioning innovation systems. Hereby, MNEs have not only acted as conduits for technology transfer and knowledge spillover, importing managerial expertise, advanced technologies and best practices but have also contributed to China's technological capabilities by driving industry advancement. The establishment of R&D centers by MNEs in China has adapted products to the local market and initiated technological progress and innovation. Therefore, MNEs have been crucial in fostering innovation through knowledge diffusion and technology upgrading (Blomstrom and Kokko, 1998; Liefner *et al.*, 2013; Hayter and Han, 1998).

Many MNEs are essential components in existing innovation capacities that have been in place for a long time and are also involved in organizations and innovation dynamics, especially in several technology domains (Du and Krusekopf, 2023). However, because the Xi Government took office, there has been a strategic realignment of the national innovation strategy (Fischer *et al.*, 2021). Starting with the "Made in China 2025" strategy, the country is increasingly relying on its own innovation activities and promoting indigenous innovations (Losacker and Liefner, 2020a). The involvement of foreign MNEs in new technology domains, in which China aims to establish itself as a leader (especially in AI and GT), is becoming increasingly uncertain. Research on this topic is still relatively scarce, particularly in the area of twin transition technology. In this context, it seems important to understand the international linkages and entanglements in the organization of innovation processes.

3. Methods

3.1 Data collection and analysis

To answer the research questions, this paper uses a case study approach to examine the twin transition in China (Yin, 2017). The paper studies both internal innovation processes within the companies and the organization of innovation processes in AI/GT led by state actors. In doing so, the matter is examined from the perspective of German multinationals in China that are involved in innovation development, either by having an R&D centre or being well-versed in the field. The contact was initiated with the support of business representatives and committees that specifically approached various German companies with an R&D presence in China. The prerequisite for these companies was that they possessed expertise in either AI, GT or both. The interviewees were required to be knowledgeable about the innovation processes within the company and capable of assessing organizational structures and collaborations in China. The interview participants consist of 10 companies from several industries with an R&D centre in China and one management consulting company that is engaged in and advises on digital and green innovation projects. The positions of the participants are all top-level executives. The companies are predominantly major listed corporations that possess extensive global market shares in their respective industries and have contributed a large volume of investment to China. For this study, German companies were selected as the research object because they offer two advantages: firstly, German companies are among the most active FDI drivers, especially in China, where they have been an established part of the economy and innovation development for decades, and secondly, the features of German multinational firms' participation in FDI activities do not differ significantly from those of other developed countries. German MNEs can therefore provide new information on how exactly innovation processes take place in China, and they can also serve as a model for investments by other industrialized countries in China (Chen and Reger, 2006).

To carry out the exploratory approach, semi-structured interviews were conducted using interview guides (Meuser and Nagel, 2009). The interviews took place from February to June 2023 using video calls. Subsequently, the interviews were transcribed and anonymized. The research approach and the three sections of the interview guide are illustrated in Figure 1. Various descriptive data of the interview sample are summarized in Table 1.

The interview data were analysed using a thematic qualitative text analysis, as outlined by Kuckartz (2014). Based on the research questions and theoretical considerations, the main

Source: Created by author

Figure 1. Research approach and sections of the interview guide

Table 1.
Description of interview sample

ID	Industry	Expertise (GT, AI)	Position	Duration (min.)
I1	Waste technology	GT	Executive manager	69
I2	Engineering and technology	AI, GT	Head of corporate research and technology	57
I3	Chemistry	AI, GT	Vice president	76
I4	Chemistry	AI, GT	Head of corporate research centre	41
I5	Software and IT technology	AI	CTO	86
I6	IT and security technology	AI	CEO	56
I7	Chemistry	GT	Head of corporate research centre	70
I8	IT, security and finance technology	AI	CFO	57
I9	Energy and heating technology	GT	Executive manager	64
I10	Software and IT technology	AI	CEO	49
I11	Digitalization and innovation consulting	AI, GT	Partner	53

Source: Created by author

categories were formed through a deductive approach, which is divided into development, organization and participation. Building on this, an inductive approach was used to form subcategories on the material, thus identifying specific approaches of different companies. This approach ensures that both the theoretical framework and the exploratory content provided by the experts are included in the analysis. The data analysis was conducted with the assistance of the qualitative data analysis tool MAXQDA.

4. Results

4.1 Artificial intelligence and green technology innovation development of German multinational enterprises

The approaches of German MNEs with R&D centers in China to develop AI innovations for environmental protection and sustainability are highly heterogeneous. Across all companies, there was a consensus on the importance of GT and how AI and other digital technologies can contribute to achieving the objective of becoming carbon neutral. However, the implementation of these twin innovations is still in an early stage. Therefore, while most of the companies interviewed have engaged with both technology fields, they have not yet developed comprehensive integrated solutions. In fact, the companies interviewed were either more familiar with GT, researching sustainable alternatives to comply with environmental regulations in China and offer more sustainable alternatives in the market, or were more acquainted with digital technologies, having closer connections to digital solutions, products or processes and thus having previous experience with AI technology. The interviews reveal that companies with more experience in environmental technology development are more actively seeking ways to apply AI to GT. In the interviews, these were mainly self-learning applications for increasing energy efficiency in core products (I9), complex process flows in material extraction and allocation (I3, I7) or waste management coordination (I1, I4):

> We use AI explicitly for our product development and optimization, as it helps us to operate the energy processes within our applications (I9).

Contrarily, companies from the digital sector are significantly investing in AI research and its implementation in corporate processes. Nevertheless, it becomes evident that the explicit exploration of AI/GT, i.e. active research aimed at connecting these technologies, is not of utmost importance. It tends to be more of a positive side-effect that often accompanies these efforts, but is not the primary motivation:

> Sustainability is in our identity; however, our aim is not to develop use cases of AI for environmental technology, it is more of a byproduct of AI which often comes along due to positive effects of the technology (I6).

> For us, AI is integral, which means that we do not look top-down for sustainable application strategies, but apply it everywhere and thus naturally also within the scope of our environmental technologies (I2).

In addition to these diverse approaches to AI/GT, the interviews conducted reveal that the two technologies are perceived as spatially distinct. According to the interviewees, innovation development in GT primarily occurs in localized and streamlined manners, while innovation development in AI originates from a national level in China. From the perspective of some companies, regional factors are particularly responsible for funding and development of GT:

> The promotion of AI strongly originates from the central government at the national level and is then adopted or expanded by regions or local governments. [. . .] In the sustainability and GT domain, this is much more locally nuanced. For example, in Northern China, waste recycling aligns with agriculture; they have a lot of straw and are considering how to transform it into chemicals and utilize it intelligently (I3).

4.2 Organization of innovation and participation of German multinational enterprises

Chinese organization of innovation processes: The interviews show that new cluster organizations arise from the specific AI pilot and demonstration zone approach. These are managed and operated differently, and involve different innovation actors to former high-tech parks and science cities with a new focus on green and digital technologies. The clusters consist of different industrial districts, each with a specific thematic focus determined by the regional government. There are multiple levels to these clusters, and a network is actively built between the companies and other actors, controlled and monitored by state-owned enterprises (SOEs). Moreover, being included in such a cluster organization brings numerous incentives. However, the orientation here also depends on regional factors. For instance, a local company can significantly influence the strategic orientation of the regional government:

> The parks, as part of the pilot zones, are organized to provide very comprehensive assistance (talent, infrastructure, service) to all companies and research institutions [. . .], the management of the parks is controlled or directed by the regional or municipal governments through state-owned companies, [. . .] we are in close contact with the park management, they help us to solve any issue (I5).

The role of the local and regional government is particularly significant in the case of AI clusters. The government plays a steering role by setting clear project objectives that affect the companies supported, which must fulfil these requirements no matter what. The government then takes on a supportive role, giving companies space to operate. There is consensus among AI-oriented companies regarding the future role of data, which is an essential foundation for the self-improvement capability and functionality of AI. Through monitoring tasks, the local and regional authorities have access to this data and can use or provide knowledge in projects. The new data protection laws in China require that this data remains in the country and allow local and regional governments to access it by taking on monitoring and review tasks. Through this access, the data and knowledge can be used and provided in cross-cutting projects, resulting in a significant advantage, especially when data is seen as a production factor for AI (Cockburn *et al.*, 2019):

> Regional authorities set a target and provide massive support for companies to achieve this target, how this is done doesn't really matter, but often the path leads to AI and often AI helps to be more sustainable (I7).

> There are several laws in China that prohibit the transport of data out of China. [. . .] the innovation processes are kept in the country by monitoring tasks of the regional governments; this allows regional and local governments to review the data. [. . .] so data can actually be seen as a production factor and this means that China has a massive advantage in terms of the access to data and the possibilities to train AI applications (I2).

Through the interviews, it becomes clear that the role of the regional government is also crucial for the combination of AI/GT, as they often set targets for innovation projects within the organizational structures (clusters and networks). These projects are encouraged by high funding amounts and state support for process flows, prompting them to leverage their respective entrepreneurial capabilities and potentials. As a result, AI technologies are much more likely to be used for GT or sustainability, as different actors from different backgrounds collaborate on a larger scale, with the regional government providing the framework:

> We have been part of an innovation project where we contributed GT and a large Chinese software company contributed AI applications which improved our product. [. . .] in the project the regional government brought us all together and explained what they wanted from us, we then collaborated with the other companies to develop an inter-city waste disposal system which was based on a self-improving AI application and therefore helped us to be much more efficient since it could coordinate and redirect the waste disposal within the city (I1).

Participation of German MNEs: The involvement of German multinationals in clusters and their inclusion in the innovation system within the technology development of AI/GT is highly diverse. The situation of German companies can be described from three directions. Firstly, companies that are important for the innovation system and developments in China have access to and are actively included in these cluster organizations. The companies sometimes receive state subsidies, including for the development of AI/GT. They collaborate with local or regional authorities and cooperate closely with Chinese companies, research institutes, startups or universities to develop products or processes. Furthermore, they are involved in large-scale innovation projects that bring together various innovation actors. When collaborating in the field of AI/GT in large-scale projects, these companies contribute significantly, although large Chinese software companies mostly undertake AI development:

> We collaborate with other companies, but in the field of AI implementation mainly or actually only with the Chinese tech giants, they have the expertise in the field and it is only possible to work with them when we want to work on smart city projects which are led by the government. [. . .] They (Chinese tech giants) receive the main AI funding (I10).

Secondly, autonomous companies that exclusively conduct research in their fields in China serve the local and regional markets. They do not wish to be involved in the clusters and are not included. These companies have primarily come to China because the market for their technologies is particularly attractive, and they conduct research that serves the local market. However, they continue to pursue global innovation processes within the company and thus do not want to be involved in regional innovation processes:

> We don't want to work closely with other companies or in these state clusters, we want to serve the local market first and foremost and do research for the market by localizing here, to do this we get ideas from academia or startups into the company – with the goal of outside-in (I2).

Thirdly, companies that would like to benefit from the innovation system but cannot access the cluster organizations are systematically excluded from these local innovation processes. These companies feel systematically marginalized and would like to collaborate with other institutions to bring together AI/GT, but they lack connections to decision-makers and are not actively included in the network:

> We would like to participate more in digitization funding programs, but we are excluded as a foreign company, we don't have access to the clusters or local funding sources by the regional government (I8).

5. Discussion

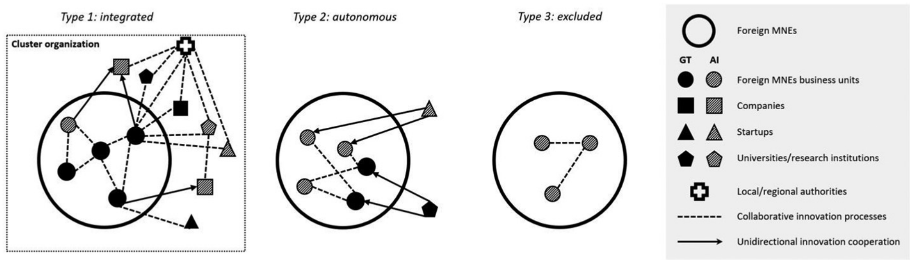
The results already show that multinationals more focused on GT are more inclined to explore AI applications for GT innovations. Conversely, multinationals more familiar with AI are not necessarily seeking GT applications for their AI advancements. Although this outcome was not entirely anticipated, given the AI/GT innovation potentials of companies within China and research indicating the interconnectedness of these processes, particularly in the Chinese context (Wang *et al.*, 2023; Gao *et al.*, 2023), it is not entirely unexpected. Some of the companies aligned with GT mentioned that while they aim to apply AI within their organizations for innovation processes, they might not yet have reached a stage where AI is comprehensively integrated and used for operations. Furthermore, it is intriguing that companies more oriented towards AI specifically come to China to explore the digital market and seem to largely overlook the potential applications of GT within their AI endeavours, even if not every company is willing and able to develop twin innovations.

Even though AI/GT twin innovations are still in their early stages, several companies are already systematically researching internal applications. However, these twin innovations are primarily implemented through state-led collaborations within innovation projects. These large-scale projects are initiated by regional and local governments, establishing a framework of goals and assembling a network of companies, startups and research institutions from various domains to jointly develop solutions. This approach enables faster and more effective utilization of both AI and GT in innovations. This aspect has been less emphasized in existing literature, yet it becomes clear that regional governments play a pivotal role, particularly in driving the twin transition at the regional level. Thus, the modes of innovation in the Chinese twin transition rely more on collaboration than intra-company innovation processes.

Furthermore, the findings indicate that the role of local and regional governments is not only crucial for initiating twin innovation but also for organizing the clusters, networks and innovation agglomerations of actors. The cluster organizations emerging from pilot and demonstration zones are primarily established by the local and regional authorities. The management and control of cluster organizations are then handled by SOEs. Moreover, it has become apparent that the role of data, especially as a production factor for AI applications, is becoming increasingly vital. While this is already a consensus in AI research (Roberts *et al.*, 2022; Cockburn *et al.*, 2019), the interview observations provide a novel perspective. Due to the active involvement of the government and SOEs, data is often exchanged with authorities or SOEs within organizational structures, granting them considerable data sovereignty. This raises questions about data handling and utilization that could not be answered within the scope of this study.

Finally, the paper demonstrates that the role of German companies is multifaceted. German multinational engagements fall into three types: integrated, autonomous and excluded. This result builds on the previous understanding that particularly for the combination of AI/GT, it is crucial to be integrated into the cluster organizations. Once access to networks and clusters is established, and contributions in specific technology domains are possible, advanced innovation projects can be initiated, often led by local or regional authorities involving several interdisciplinary actors. If not part of these network structures, decoupling processes seem to take place. This pattern is also consistent with the revisited Uppsala internationalization process model by Johanson and Vahlne (2009). According to this model, the liability of outsidership leads to systematic disadvantages and uncertainties for companies arising from network structures. Moreover, it appears that certain technology fields remain predominantly reserved for Chinese companies, even when foreign multinationals participate in larger innovation projects and networks. In such cases, large Chinese software companies often take on the tasks of developing and applying AI models. This development can be discussed within the framework of technology sovereignty. China's mission-oriented innovation policy aims to develop technologies according to its goals, designating AI (partially also GT) as critical to future economic competitiveness (Edler *et al.*, 2023). This may explain why foreign multinationals are excluded from the innovation processes in certain domains.

The companies also differ in their focus on twin innovations. Integrated companies are incorporated into cluster organizations and thereby contribute to the development of local twin innovations, which arise within the framework of innovation projects. They are deeply integrated into existing innovation processes and have strong connections with various innovation actors from different domains, as well as local authorities. Autonomous companies rely on internal innovation processes and partially develop internal AI/GT solutions. They are not very engaged in knowledge exchange and primarily aim to bring in external knowledge through unidirectional innovation cooperations that involve universities or startups. Excluded companies hardly develop AI/GT applications but rather focus on one technology domain. On the one hand, this is due to the limited R&D exchange with other innovation actors and the lack of integration into existing Chinese innovation systems. On the other hand, it is also due to the absence of other global innovation activities and individual goals, which mainly differentiate them from autonomous companies. Figure 2 visualizes the connections between the type of foreign MNE and various collaborative innovation actors. Table 2 illustrates the types of foreign multinationals in China and reveals the role they take within Chinese cluster organizations and their collaborative actors.



Source: Created by author

Figure 2. Collaborative innovation processes of foreign MNE types

	Type 1: integrated	Type 2: autonomous	Type 3: excluded
Development of twin innovations (AI/GT)	Mostly in contributing to a specific number of cross-company innovation projects led by local and regional authorities	To some degree within the company; more focused on bringing outside knowledge and solutions into the company	Very thin to non-existent
Role within Chinese cluster organizations	Strong integration into existing cluster organizations in AI and GT, relying on a strong network	Weak integration due to own motives in being detached from the innovation system, only unidirectional ties with specific research contractors	Mostly no integration into existing organizations of innovation
Collaborative actors	Interdisciplinary: local and regional authorities, companies, startups, universities, research institutions	Selective: universities, startups	Deficient: mostly non-existent

Source: Created by author

Table 2. Three types of foreign MNEs in China

The findings suggest that integration into cluster organizations can indeed facilitate the twin transition. The role of foreign companies in China is thus greatly dependent on their integration into the Chinese innovation system, especially in the domains of green and digital technologies. Therefore, foreign companies in China should consider the role they play within the Chinese innovation system and the implications this has on their twin innovation processes. Local circumstances can significantly influence the role within their technology fields as well as the integration into cluster organizations.

The interviews also revealed that these different approaches are influenced by various factors. Formal and informal institutions, as well as informal connections to regional authorities or other key actors, play a role in the participation in AI clusters or other cooperation endeavours. Nonetheless, decoupling processes can be observed in the interviews. On the one hand, decoupling processes occur through the systematic exclusion of German multinationals that seek involvement in the innovation processes of new twin technology domains. On the other hand, decoupling processes also involve German companies contemplating diversification of their economic activities in China due to geopolitical situations.

It is important to acknowledge the limitations of this work. Firstly, it is crucial to note that the study primarily examined MNEs headquartered in Germany. These companies may be subject to formal or informal differences at the national level that distinguish them from MNEs from other countries. Nevertheless, German companies and their international operating strategies exhibit characteristics that are rather typical of investments from other industrialized nations. Furthermore, it is worth noting that the number of expert interviews seems relatively modest. However, the analysis of these interviews revealed that theoretical saturation was reached, which underlines the richness of insights obtained. This saturation is attributed to the study's deliberate focus on German MNEs with R&D centers in China, which provides a highly specific perspective that enhances the depth and relevance of the findings.

Additionally, the field in which German MNEs operate in China is also very much shaped by geopolitical tensions and developments between the EU and China. Although FDI often remains very long-term, short-term developments and thus the participation of foreign multinationals in China are partly dependent on the current political situation. Future research could dive deeper into the innovation processes of cluster organizations in the twin transition through AI/GT and compare the role of foreign multinationals with indigenous companies.

6. Conclusion

This paper has investigated the development and organization of the twin transition in China through interviews with German multinationals. To do so, two research questions addressed the research gaps identified. The findings related to the first research question, "How do foreign multinationals develop AI, GT and twin innovations (AI/GT) in China?" indicate that internal AI/GT development within companies is more often carried out by companies closely aligned with GT in their core business. Across companies, there are innovation projects guided by local or regional authorities, which involve various stakeholders and lead to the development of twin innovations. Regarding the second research question, "How are innovation processes combining AI/GT organized and administered in clusters, and how are multinationals involved in the innovation processes and integrated into Chinese innovation systems?", the organization continues to function through China-specific cluster organizations, where the role of local and regional government gains significance due to new data processes. Additionally, various involvements of German multinationals in twin innovation processes can be observed, with the companies either being integrated, remaining autonomous or being excluded. Integrated companies contribute to the development of twin innovation in cross-company projects, even if the task of AI development remains primarily with large Chinese software companies. Autonomous companies partially develop AI/GT innovations on their own and stay out of collaborative innovation. Initial decoupling processes in twin innovations can be observed through excluded companies, which mostly stay out of AI/GT innovation development. Foreign companies should be aware of their role in the Chinese innovation system (integrated, autonomous and excluded) and what this means for their innovation processes. Companies that want to participate in twin transition innovations in China in the future must be aware of the local characteristics. The findings offer new insights into achieving a twin transition through twin innovations (AI/GT applications) and can provide context for the prospective participation of foreign multinationals in these innovation processes. Consequently, the paper contributes valuable insights into the development and organization of innovation processes within the twin transition in an emerging economy, demonstrating the importance of being involved in local cluster organizations.

References

Agrawal, A., Gans, J. and Goldfarb, A. (Eds) (2019), *The Economics of Artificial Intelligence: An Agenda, National Bureau of Economic*, "Research conference report", The University of Chicago Press, Chicago.

Ahmad, N., Youjin, L., Žiković, S. and Belyaeva, Z. (2023), "The effects of technological innovation on sustainable development and environmental degradation: evidence from China", *Technology in Society*, Vol. 72, p. 102184.

Almansour, M. (2022), "Electric vehicles (EV) and sustainability: consumer response to twin transition, the role of e-businesses and digital marketing", *Technology in Society*, Vol. 71, p. 102135.

Arenal, A., Armuña, C., Feijoo, C., Ramos, S., Xu, Z. and Moreno, A. (2020), "Innovation ecosystems theory revisited: the case of artificial intelligence in China", *Telecommunications Policy*, Vol. 44 No. 6.

Balland, P.-A. and Boschma, R. (2021), "Mapping the potentials of regions in Europe to contribute to new knowledge production in Industry 4.0 technologies", *Regional Studies*, Vol. 55 Nos 10/11, pp. 1652-1666.

Barbieri, N., Perruchas, F. and Consoli, D. (2020), "Specialization, diversification, and environmental technology life cycle", *Economic Geography*, Vol. 96 No. 2, pp. 161-186.

Benedetti, I., Guarini, G. and Laureti, T. (2023), "Digitalization in Europe: a potential driver of energy efficiency for the twin transition policy strategy", *Socio-Economic Planning Sciences*, Vol. 89, p. 101701.

Bettiol, M., Capestro, M., Marchi, V.D., Di Maria, E. and Sedita, S.R. (2021), "Industrial districts and the fourth industrial revolution", *Competitiveness Review: An International Business Journal*, Vol. 31 No. 1, pp. 12-26.

Bianchini, S., Damioli, G. and Ghisetti, C. (2023), "The environmental effects of the 'twin' green and digital transition in European regions", *Environmental and Resource Economics*, Vol. 84 No. 4, pp. 877-918.

Blomstrom, M. and Kokko, A. (1998), "Multinational corporations and spillovers", *Journal of Economic Surveys*, Vol. 12 No. 3, pp. 247-277.

Capello, R. and Lenzi, C. (2021), "4.0 Technologies and the rise of new islands of innovation in European regions", *Regional Studies*, Vol. 55 Nos 10/11, pp. 1724-1737.

Cattani, L., Montresor, S. and Vezzani, A. (2023), "Firms' eco-innovation and industry 4.0 technologies in urban and rural areas", *Regional Studies*, pp. 1-13.

Chang, I.-C.C., Leitner, H. and Sheppard, E. (2016), "A green leap forward? Eco-state restructuring and the Tianjin–Binhai eco-city model", *Regional Studies*, Vol. 50 No. 6, pp. 929-943.

Chen, X. and Reger, G. (2006), "The role of technology in the investment of German firms in China", *Technovation*, Vol. 26 No. 3, pp. 407-415.

Chen, J., Li, Y., Xu, Y., Vardanyan, M., Shen, Z. and Song, M. (2023), "The impact of fiscal technology expenditures on innovation drive and carbon emissions in China", *Technological Forecasting and Social Change*, Vol. 193, p. 122631.

Cicerone, G., Faggian, A., Montresor, S. and Rentocchini, F. (2022), "Regional artificial intelligence and the geography of environmental technologies: does local AI knowledge help regional green-tech specialization?", *Regional Studies*, Vol. 57 No. 2, pp. 1-14.

Cockburn, I., Henderson, R. and Stern, S. (2019), "The impact of artificial intelligence on innovation. An exploratory analysis", in Agrawal, A., Gans, J. and Goldfarb, A. (Eds), *The Economics of Artificial Intelligence: An Agenda, National Bureau of Economic Research Conference Report*, The University of Chicago Press, Chicago.

Collini, L. and Hausemer, P. (2023), "Place-based pathways for the twin transition: the role of systemic change agents", *Competitiveness Review: An International Business Journal*.

Corradini, C., Santini, E. and Vecciolini, C. (2021), "The geography of industry 4.0 technologies across European regions", *Regional Studies*, Vol. 55 Nos 10/11, pp. 1667-1680.

Du, J. and Krusekopf, C. (2023), "Locations, city connectivity and innovation zones in China: a dynamic perspective of knowledge community", *Competitiveness Review: An International Business Journal*, Vol. 33 No. 3, pp. 579-601.

Edler, J., Blind, K., Kroll, H. and Schubert, T. (2023), "Technology sovereignty as an emerging frame for innovation policy. Defining rationales, ends and means", *Research Policy*, Vol. 52 No. 6, p. 104765.

Muench, S., Stoermer, E. and Jensen, K., European Commission, Joint Research Centre (2022), *Towards a Green and Digital Future: Key Requirements for Successful Twin Transitions in the European Union, JRC Science for Policy Report, EUR 31075 EN*, Publications Office of the European Union, Luxembourg.

Filiou, D., Kesidou, E. and Wu, L. (2023), "Are smart cities green? The role of environmental and digital policies for eco-innovation in China", *World Development*, Vol. 165, p. 106212.

Fischer, D., Gohli, H. and Habich-Sobiegalla, S. (2021), "Industrial policies under Xi Jinping: a steering theory perspective", *Issues and Studies*, Vol. 57 No. 4.

Gao, Q., Cheng, C. and Sun, G. (2023), "Big data application, factor allocation, and green innovation in Chinese manufacturing enterprises", *Technological Forecasting and Social Change*, Vol. 192, p. 122567.

Götz, M. and Jankowska, B. (2017), "Clusters and Industry 4.0 – do they fit together?", *European Planning Studies*, Vol. 25 No. 9, pp. 1633-1653.

Hansen, T. and Coenen, L. (2015), "The geography of sustainability transitions: review, synthesis and reflections on an emergent research field", *Environmental Innovation and Societal Transitions*, Vol. 17, pp. 92-109.

Hayter, R. and Han, S.S. (1998), "Reflections on China's open policy towards foreign direct investment", *Regional Studies*, Vol. 32 No. 1, pp. 1-16.

Heilmann, S., Shih, L. and Hofem, A. (2013), "National planning and local technology zones: experimental governance in China's torch programme", *The China Quarterly*, Vol. 216, pp. 896-919.

Hervás-Oliver, J.-L. (2021), "Industry 4.0 in industrial districts: regional innovation policy for the toy valley district in Spain", *Regional Studies*, Vol. 55 Nos 10/11, pp. 1775-1786.

Horbach, J. (2014), "Do eco-innovations need specific regional characteristics? An econometric analysis for Germany", *Review of Regional Research*, Vol. 34 No. 1, pp. 23-38.

Huang, P. and Lema, R. (2021), "Green innovation in China", in Fu, X., McKern, B. and Chen, J. (Eds), *The Oxford Handbook of China Innovation*, Oxford University Press, New York, NY, pp. 648-674.

Johanson, J. and Vahlne, J.-E. (2009), "The Uppsala internationalization process model revisited: from liability of foreignness to liability of outsidership", *Journal of International Business Studies*, Vol. 40 No. 9, pp. 1411-1431.

Kemp, R., Rammer, C., Miedzinski, M., Tapia, C., Barbieri, N., Türkeli, S., Bassi, A.M., Mazzanti, M., Champman, D., López, F.J.D. and McDowall, W. (2019), "Measuring eco-innovation for a green economy", *Schwerpunkt Nachhaltigkeit: Measuring Eco-Innovation for a Green Economy*, pp. 391-404.

Kopka, A. and Grashof, N. (2022), "Artificial intelligence: catalyst or barrier on the path to sustainability?", *Technological Forecasting and Social Change*, Vol. 175, p. 121318.

Kuckartz, U. (2014), *Qualitative Text Analysis: A Guide to Methods, Practice and Using Software*, SAGE Publications, London.

Lauer, J. and Liefner, I. (2019), "State-led innovation at the city level: policy measures to promote new energy vehicles in Shenzhen, China", *Geographical Review*, Vol. 109 No. 3, pp. 436-456.

Li, F., Yigitcanlar, T., Nepal, M., Nguyen, K. and Dur, F. (2023), "Machine learning and remote sensing integration for leveraging urban sustainability: a review and framework", *Sustainable Cities and Society*, Vol. 96, p. 104653.

Liefner, I., Wei, Y.D. and Zeng, G. (2013), "The innovativeness and heterogeneity of Foreign-Invested high-tech companies in Shanghai", *Growth and Change*, Vol. 44 No. 3, pp. 522-549.

Liefner, I., Kroll, H., Zeng, G. and Heindl, A.-B. (2021), "Regional innovation profiles: a comparative empirical study of four Chinese regions based on expert knowledge", *Zeitschrift Für Wirtschaftsgeographie*, Vol. 65 Nos 3/4, pp. 101-117.

Lis, A.M. and Mackiewicz, M. (2023), "The implementation of green transformation through clusters", *Ecological Economics*, Vol. 209, p. 107842.

Losacker, S. and Liefner, I. (2020a), "Implications of China's innovation policy shift: does "indigenous" mean closed?", *Growth and Change*, Vol. 51 No. 3, pp. 1124-1141.

Losacker, S. and Liefner, I. (2020b), "Regional lead markets for environmental innovation", *Environmental Innovation and Societal Transitions*, Vol. 37, pp. 120-139.

Mäkitie, T., Hanson, J., Damman, S. and Wardeberg, M. (2023), "Digital innovation's contribution to sustainability transitions", *Technology in Society*, Vol. 73, p. 102255.

Meuser, M. and Nagel, U. (2009), "The expert interview and changes in knowledge production", in Bogner, A., Littig, B. and Menz, W. (Eds), *Interviewing Experts*, Palgrave Macmillan, London, pp. 17-42.

Montresor, S. and Quatraro, F. (2020), "Green technologies and smart specialisation strategies: a European patent-based analysis of the intertwining of technological relatedness and key enabling technologies", *Regional Studies*, Vol. 54 No. 10, pp. 1354-1365.

Montresor, S. and Vezzani, A. (2023), "Digital technologies and eco-innovation. Evidence of the twin transition from Italian firms", *Industry and Innovation*, pp. 1-35.

Mouthaan, M., Frenken, K., Piscicelli, L. and Vaskelainen, T. (2023), "Systemic sustainability effects of contemporary digitalization: a scoping review and research agenda", *Futures*, Vol. 149, p. 103142.

Pan, Y. (2016), "Heading toward artificial intelligence 2.0", *Engineering*, Vol. 2 No. 4, pp. 409-413.

Rehman, S.U., Giordino, D., Zhang, Q. and Alam, G.M. (2023), "Twin transitions and industry 4.0: unpacking the relationship between digital and green factors to determine green competitive advantage", *Technology in Society*, Vol. 73, p. 102227.

Roberts, H., Cowls, J., Hine, E., Morley, J., Wang, V., Taddeo, M. and Floridi, L. (2022), "Governing artificial intelligence in China and the European Union: comparing aims and promoting ethical outcomes", *The Information Society, Pp*, Vol. 39 No. 2, pp. 1-19.

Santoalha, A., Consoli, D. and Castellacci, F. (2021), "Digital skills, relatedness and green diversification: a study of European regions", *Research Policy*, Vol. 50 No. 9, p. 104340.

Teng, T., Zhang, Y., Si, Y., Chen, J. and Cao, X. (2020), "Government support and firm innovation performance in Chinese science and technology parks: the perspective of firm and sub-park heterogeneity", *Growth and Change*, Vol. 51 No. 2, pp. 749-770.

Truffer, B. and Coenen, L. (2012), "Environmental innovation and sustainability transitions in regional studies", *Regional Studies*, Vol. 46 No. 1, pp. 1-21.

Wang, N., Xie, W., Huang, Y. and Ma, Z. (2023), "Big data capability and sustainability oriented innovation: the mediating role of intellectual capital", *Business Strategy and the Environment*, Vol. 32 No. 8.

Wu, J., Nie, X., Wang, H. and Li, W. (2023), "Eco-industrial parks and green technological progress: evidence from Chinese cities", *Technological Forecasting and Social Change*, Vol. 189, p. 122360.

Wu, F., Lu, C., Zhu, M., Chen, H., Zhu, J., Yu, K., Li, L., Li, M., Chen, Q., Li, X., Cao, X., Wang, Z., Zha, Z., Zhuang, Y. and Pan, Y. (2020), "Towards a new generation of artificial intelligence in China", *Nature Machine Intelligence*, Vol. 2 No. 6, pp. 312-316.

Xu, A., Wang, W. and Zhu, Y. (2023), "Does smart city pilot policy reduce CO2 emissions from industrial firms? Insights from China", *Journal of Innovation and Knowledge*, Vol. 8 No. 3, p. 100367.

Xue, L., Li, D. and Yu, Z. (2021), "China's national and regional innovation systems", in Fu, X., McKern, B. and Chen, J. (Eds), *The Oxford Handbook of China Innovation*, Oxford University Press, New York, NY, pp. 114-134.

Yang, C. and Huang, C. (2022), "Quantitative mapping of the evolution of AI policy distribution, targets and focuses over three decades in China", *Technological Forecasting and Social Change*, Vol. 174, p. 121188.

Yin, R.K. (2017), *Case Study Research and Applications Design and Methods*, SAGE, London.

Yu, J. and Zhang, Y. (2021), "Chinese firms' move to the forefront in digital technologies", in Fu, X., McKern, B. and Chen, J. (Eds), *The Oxford Handbook of China Innovation*, Oxford University Press, New York, NY, pp. 592-609.

Zeng, G., Liefner, I. and Si, Y. (2011), "The role of high-tech parks in Chinás regional economy: empirical evidence from the IC industry in the Zhangjiang high-tech park, shanghai", *ERDKUNDE*, Vol. 65 No. 1, pp. 43-53.

Zhang, Y.-J. and Du, M. (2023), "Greening through digitalisation? Evidence from cities in China", *Regional Studies*, pp. 1-15.

Appendix. Interview guide

Introduction

Please describe your role for your company and the company's economic activities in China.

AI/GT Innovation development

(1) What role does GT play for your company and how do you develop GT innovations?

(2) What role do digital innovation and AI play for your company and how do you develop AI innovations?

(3) How are AI and GT innovations combined in your company and how do you develop AI/GT innovations (e.g. AI applications for GT/sustainability)?

(4) What special conditions apply to China in terms of AI/GT development in your company?

(5) What potentials and challenges do you see for the future development of AI and/or GT in your company and in China?

Organization of AI/GT innovation processes

(6) How are twin innovation processes (AI/GT) organized and directed by the government (e.g. political support, incentives and state-led innovation projects)?

(7) How is your company involved in AI or GT cluster organizations (AI, GT clusters and networks) and how are the clusters organized (what processes take place)?

(8) How does your company collaborate with other innovation actors (companies, universities, startups and government) to develop AI, GT and AI/GT innovations (involvement in specific cluster organizations or projects)?

(9) What do you see as the advantages and disadvantages of the cluster organizations in developing twin innovations?

Participation of German multinationals in AI/GT innovation processes

(10) What are the differences between German and Chinese companies in innovation development?

(11) What challenges do you see for your company in the field of AI and GT in China in the future?

(12) What kind of support for AI/GT innovations and participation in innovation projects would be desirable for your company in China?

Closing question

Would you like to add anything else to the interview?

Corresponding author

Chris Brueck can be contacted at: brueck@wigeo.uni-hannover.de