

The geography of digital and green (twin) firms in Germany

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REGIONAL GRAPHIC



The geography of digital and green (twin) firms in Germany

Lukas Kriesch ^a, Milad Abbasiharofteh ^b and Sebastian Losacker ^{a,c}

ABSTRACT

The twin transition, which combines green and digital innovation in economic activities, is increasingly central to policy agendas and is also receiving growing attention in regional research. However, accurately mapping green, digital and twin (both green and digital) economic activities across regions remains challenging, particularly due to data constraints. In this study, we advance this research frontier and present a geographic analysis of digital, green and twin economic activities in Germany, using a web-mined dataset of website texts from 678,381 firms, collected through web scraping in 2023. By processing over 44 million text paragraphs from these websites and applying a cosine similarity filter with green and AI-related terms, we filtered firms that are likely engaged in green, digital and twin activities. Based on this subset, 1437 text paragraphs were manually annotated to fine-tune two transformer models within a SetFit framework, accurately classifying firms as green, digital or both. We aggregate this firm-level data into hexagonal cells to reveal the geographic concentration of the twin transition in Germany. The final map shows a higher number of firms involved in green activities, widely spread across Germany, while AI activities are concentrated in urban centres. We identify 23,819 firms engaged in both green and digital activities, with major hubs like Berlin and Munich leading, and peripheral regions potentially being left behind. Our findings offer critical insights into the geography of the twin transition and highlight the need for policies that address potentially induced spatial inequalities.

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Twin transition; web-mining; green transition; digital transition; natural language processing; Germany

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The twin transition, which refers to the combined shift of economies toward greener and more digital modes of production, is highly prioritised on the political agenda in Europe

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and many countries worldwide. Its proponents hope that it will address major societal and ecological challenges while also contributing to economic development. Popular twin transition technologies include smart grids and precision farming, among other areas where the green and digital domains overlap. While the idea of potential synergies between digital and green activities has existed for longer (Faucheux & Nicolai, 2011), the term ‘twin transition’ gained momentum through the European Commission’s New Industrial Strategy for Europe, introduced in 2020 (European Commission, 2020). Recently, the topic has gained attention within the regional studies community, with researchers working to understand the drivers that enable regions to jointly foster green and digital economic activities (Brueck et al., 2025; Cattani et al., 2025; Cicerone et al., 2023; Faggian et al., 2025; Fazio et al., 2025). However, accurately measuring and mapping green, digital and twin (both green and digital) economic activities remains challenging due to the limitations of relying on administrative industry or technology classifications (Cicerone et al., 2024).

In this regional graphic, we address these challenges and present an accurate representation of digital, green and twin economic activities in Germany. Our analysis is based on a dataset containing textual data from websites of 678,381 firms in Germany, collected from the CommonCrawl web archive in 2023. In a first step, we processed the website texts into 44,221,656 meaningful paragraphs and we computed text embeddings of the extracted paragraphs for further analysis. To identify green and digital economic activities, we filtered the text embedding data using a cosine similarity approach with green and AI-related terms. Then, we manually annotated 1437 paragraphs to fine-tune two pre-trained transformer models. A firm was flagged as contributing to the twin transition if at least one paragraph of its website was classified as describing AI products or services, and at least one other or the same paragraph was classified as reflecting green activities. We refer to the algorithm as the *TwinTransition Mapper*, which we have also released as open source for further use (see <https://bit.ly/3AMgiYs>). To validate the algorithm, we randomly selected 500 web text paragraphs and manually annotated whether the web texts showcase a firm’s goods or services related to the twin transition. The final model reaches an F1-score of 90%, indicating a very good performance. More information on the web scraping approach can be found in Kriesch (2023) and Kriesch and Losacker (2024), while additional information on the *TwinTransition Mapper* can be found in Abbasiharofteh and Kriesch (2024).

The final map (Figure 1) includes a hexbin visualisation showing the number of firms identified by our model as digital (B), green (C) or both (A). The map reveals, first, that the number of firms engaged in green activities (249,483) is considerably higher than those engaged in AI activities (57,669). It also shows significant regional differences in the distribution of these activities: AI activities are primarily found in major urban centres, while green activities are more widely distributed, with numerous firms active in rural regions of Germany. We identify 23,819 firms that engage in both green and digital activities, primarily concentrated in major economic hubs such as Berlin, Munich, Hamburg and Frankfurt, as well as in specialised cities like Aachen, Stuttgart and Karlsruhe. We conclude that the regional twin transition is currently driven primarily by innovative hotspots, leaving peripheral regions as potential blind spots. This finding should alert policymakers to the risk of regional inequalities arising from the twin transition.

Our map not only enhances the understanding of the geography of the twin transition within the regional studies community, but it also serves as a powerful example of how researchers can leverage novel data sources and natural language processing techniques (Abbasiharofteh et al., 2023, 2024; Kriesch & Losacker, 2024).

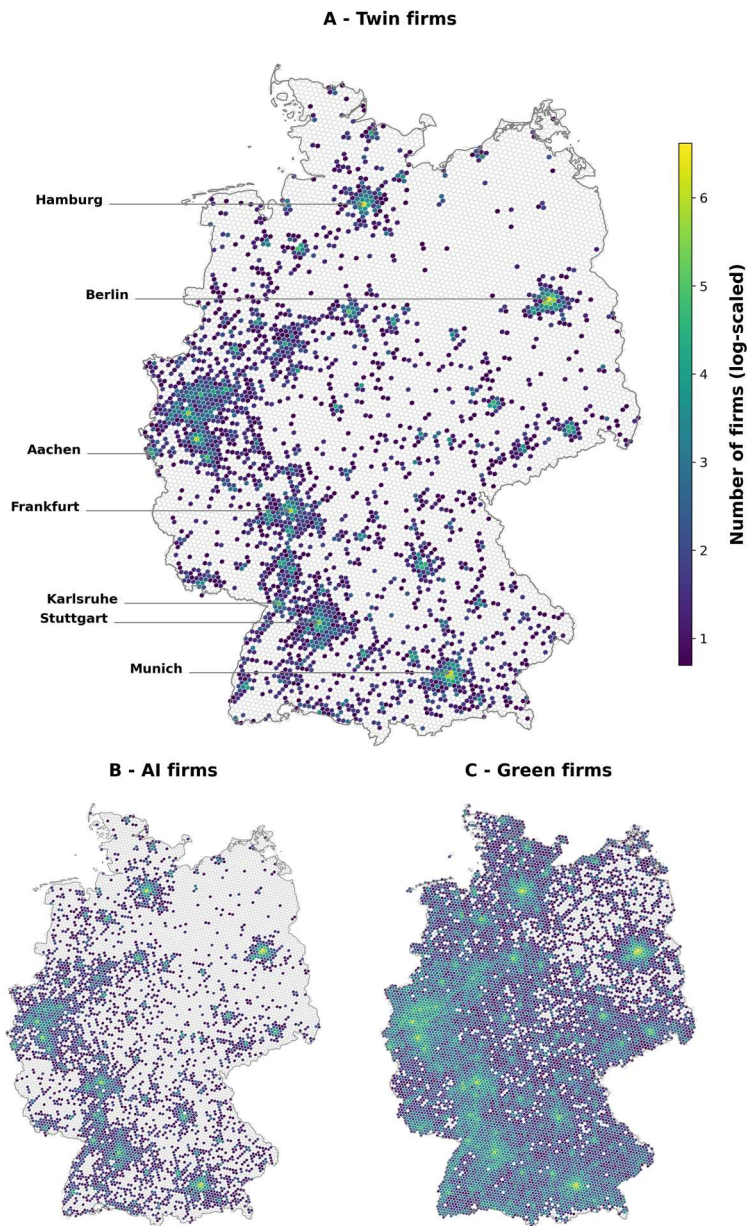


Figure 1. Spatial distribution of digital, green and twin firms in Germany: The maps are plotted using a hexbin visualisation. In Map A, we show the spatial distribution of the number of firms identified by our models as engaging in twin transition activities, i.e., firms with at least one paragraph on their website referring to green activities and at least one other (or the same) paragraph referring to AI activities. Map B displays the distribution of the number of firms engaged in AI, i.e., firms with at least one paragraph referring to AI activities, while Map C shows all firms involved in green activities, i.e., those with at least one paragraph on their website referring to green activities. Naturally, the firms displayed in Map A are those in the intersection of Maps B and C. In the online supplemental material, we provide an interactive HTML version of the maps, with the hexbins overlaid on an Open-StreetMap background. In the interactive version, one can zoom in and explore all three layers (green, digital, twin) in great detail, allowing for exploration of different regions and cities in Germany.

DATA AVAILABILITY STATEMENT

The data used in the article is not publicly available.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the author(s).

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References

- Abbasiharofteh, M., Kinne, J., & Krüger, M. (2024). Leveraging the digital layer: The strength of weak and strong ties in bridging geographic and cognitive distances. *Journal of Economic Geography*, 24(2), 241–262. <https://doi.org/10.1093/JEG/LBAD037>
- Abbasiharofteh, M., & Kriesch, L. (2024). *Not all twins are identical: The digital layer of “twin” transition market applications* (2024/16; Papers in Innovation Studies).
- Abbasiharofteh, M., Krüger, M., Kinne, J., Lenz, D., & Resch, B. (2023). The digital layer: Alternative data for regional and innovation studies. *Spatial Economic Analysis*, 18(4), 507–529. <https://doi.org/10.1080/17421772.2023.2193222>
- Brueck, C., Losacker, S., & Liefner, I. (2025). China’s digital and green (twin) transition: Insights from national and regional innovation policies. *Regional Studies*, 59(1), 2384411. <https://doi.org/10.1080/00343404.2024.2384411>.
- Cattani, L., Montresor, S., & Vezzani, A. (2025). Firms’ eco-innovation and industry 4.0 technologies in urban and rural areas. *Regional Studies*, 59(1), 2243984. <https://doi.org/10.1080/00343404.2023.2243984>.
- Cicerone, G., Faggian, A., Montresor, S., & Rentocchini, F. (2023). Regional artificial intelligence and the geography of environmental technologies: Does local AI knowledge help regional green-tech specialization? *Regional Studies*, 57(2), 330–343. <https://doi.org/10.1080/00343404.2022.2092610>
- Cicerone, G., Losacker, S., & Ortega-Argilés, R. (2024). *Regional diversification into green and digital economic activities—The case of UK Local Authorities* (2024–07; ESCoE Discussion Paper).
- European Commission. (2020). *A new industrial strategy for Europe* (COM/2020/102). <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0102>.
- Faggian, A., Marzucchi, A., & Montresor, S. (2025). Regions facing the ‘twin transition’: Combining regional green and digital innovations. *Regional Studies*, 59(1), 2398555. <https://doi.org/10.1080/00343404.2024.2398555>.
- Faucheux, S., & Nicolai, I. (2011). IT for green and green IT: A proposed typology of eco-innovation. *Ecological Economics*, 70(11), 2020–2027. <https://doi.org/10.1016/J.ECOLECON.2011.05.019>
- Fazio, G., Maioli, S., & Rujimora, N. (2025). The twin innovation transitions of European regions. *Regional Studies*, 59(1), 2309176. <https://doi.org/10.1080/00343404.2024.2309176>.
- Kriesch, L. (2023). *Web mining und natural language processing als methodisches Komplement in der Wirtschaftsgeographie*. <https://doi.org/10.22029/JLUPUB-15686>
- Kriesch, L., & Losacker, S. (2024). Bioeconomy firms and where to find them. *Region*, 11(1), 55–78. <https://doi.org/10.18335/region.v11i1.523>