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Investigating firm's use of AI in achieving sustainable development goals – a large language model approach

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Abstract

Could the use of AI affect firms' ESG (environmental, social and governance) scores? The current literature presents divergent perspectives. In this study, we argue that the impact of AI on ESG scores is not monotone. According to the United Nations, there are 17 distinct Sustainable Development Goals (SDGs). While some goals may be more connected with AI, others might present greater challenges. In a quantitative analysis, we collected annual reports over the past ten years from 85 leading firms of four major economies: China, India, Germany and the USA. We then proposed a large language model (LLM) approach that leverages self-designed prompts to analyze the texts. We present how the results vary across different SDGs, over time, by industry, and by country. This study equips managers, policymakers, and ESG analysts with the insights needed to uncover both opportunities and blind spots in leveraging AI for sustainability strategies.

Keywords: artificial intelligence, large language models, sustainable development goals, ESG, text analysis

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Introduction

As stakeholders increasingly emphasized firms' corporate social responsibility (CSR), the concept of ESG (Environment, Social and Governance) gradually formed and was first put forth by the United Nations in 2004. In recent years, global interest in ESG has skyrocketed. Nearly three-quarters of executives said in a recent survey that they viewed ESG as a source of competitive advantage (Thomson Reuters, 2024). ESG performance reflects a fundamental shift in redefining today's business success.

This transition is taking place in the digital era when artificial intelligence (AI) has undergone transformational breakthroughs. A number of studies have explored the role of AI in affecting ESG scores. Although AI has brought substantial benefits across a wide range of domains, its impact on firms' ESG performance remains contested in the literature. For example, while some believe the use of AI improves firms' ESG scores (Xiao and Xiao, 2025), some others argue that AI deteriorates ESG performance by exacerbating inequalities and increasing carbon emissions (Nishant et al., 2020).

We argue that the impact of AI on ESG is not monotonic. According to the United Nations, there are in total 17 Sustainable Development Goals (SDGs), which all represent concrete manifestations of ESG. However, the extent to which AI contributes to each goal may vary substantially. While certain goals may be more amenable to AI-driven solutions, others may present greater challenges or the use of AI may even have unintended consequences. Examining the impact of AI on ESG performance necessitates a goal-level analysis that captures the nuanced and potentially divergent effects across different SDGs.

Some studies have already started the investigation. Vinuesa et al. (2020) and Nahar (2024) surveyed experts for their opinions and Kopka and Grashof (2022) applied a systematic literature review approach. Both find evidence that AI can either enable or inhibit the delivery of all 17 SDGs. However, these studies are all qualitative and externally focused, offering limited insights into how firms internally experience and quantify the intersection of AI and ESG.

In this study, we examine the role of AI in supporting firms' corporate sustainability effort by quantifying the relationship between AI and the UN's 17 SDGs. We collected annual reports of 85 leading listed firms from China, Germany, India and the USA from 2013 to 2024. Unfortunately, such reports tend to be lengthy and contain a substantial amount of unstructured data. Traditional coding methods are not only time-consuming but also prone to subjective bias. We proposed a large language model approach that leverages self-designed prompts to enable AI to autonomously analyze the content of annual reports.

We found that, since 2020, firms across the entire world began to mention AI and SDGs with markedly increased frequency. The perceived impact of AI on sustainability is primarily concentrated in the domain of economic development—particularly in relation to SDG 9 (Industry, Innovation, and Infrastructure) and SDG 8 (Decent Work and Economic Growth). AI's relevance to environmental and ecological goals, such as SDG 14 (Life Below Water) and SDG 15 (Life on Land), is significantly undiscovered.

Regarding industry, Information Technology sector leads AI-SDG engagement, reflecting the high integration of AI in digital transformation. Conversely, traditional sectors such as

Energy, Consumer Discretionary, and Healthcare lag behind in AI-driven sustainability efforts. This suggests limited AI adoption for sustainability in resource-heavy and consumer-facing industries. The relatively low intersection with Healthcare is particularly notable, given AI's potential in public health sustainability, medical waste reduction, and AI-assisted diagnostics. This raises concerns about the potential underutilization of AI in socially impactful sustainability areas.

Among the countries studied, U.S. firms referred to AI most frequently, whereas German companies ranked lowest in this regard. However, U.S. firms did not consistently link AI to the SDGs in their discussions. In contrast, German firms were more likely to connect AI with sustainability-related discussions.

Methodology

Our primary source of data was firms' annual reports from four representative countries: China, Germany, India, and the United States. For each country, we identified around 20 leading firms based on their market influence, size, and prominence in their respective sectors. The time frame for the annual reports was set from 2014 to 2023, as the SDGs were formally adopted by the United Nations in 2015. We finally collected 814 annual reports from 85 firms.

Our further text analysis consisted of three steps (Figure 1).

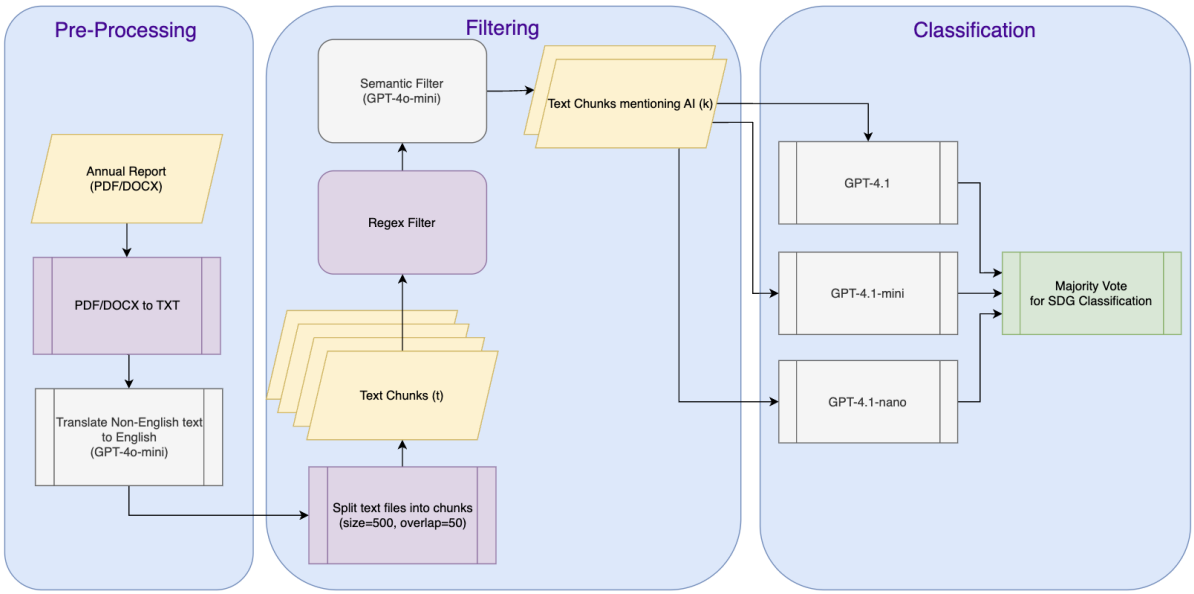

Figure 1: The text data are analyzed in three steps

Data pre-processing: Conversion of raw PDF files into clean and unified texts

The first step was to convert PDF and DOCX files into plain texts by using PyMuPDF and Python-docx package, respectively. The next step was to scan and translate all texts into English. We prompted a base gpt-4o-mini model via API to translate Hindi into English, as only a single firm published their reports in Hindi. For firms in China, a manual analysis revealed a huge discrepancy between AI mentions in Traditional/Simplified Chinese reports and English reports. So, we analyzed the firms in China by collecting the reports in Traditional/Simplified Chinese, and adjusted the prompts (mentioned in the next sections) accordingly by translating them. We further used Unidecode to convert non-English Latin text into English.

AI-related passage filtering: Exclusion of passages unrelated to AI

The next step involved extracting AI-related passages from a collection of 814 texts of annual reports. On average, each text file contained approximately 132,000 words, making them highly memory-intensive for downstream processing. To address this, we first split each text file into smaller, more manageable chunks or passages using a sliding window of 500 characters with an overlap of 50 characters. This approach ensured complete coverage of the text without omitting any content. The window size of 500 characters was selected as a trade-off between cost and accuracy for downstream classification tasks. In total, this process produced over 1.6 million passages across the entire corpus.

Then, we needed to filter out those passages that were not related to AI at all. To do so, we first designed a list of keywords that are semantically similar to "artificial intelligence" using gpt-4o-mini. After that, we manually checked the results and ensured their validity. We then designed a prompt (Figure 2) to determine whether AI was mentioned in the text chunks.

FILTERING

```
Given the following PASSAGE from an annual report of a firm that mentions artificial intelligence or related
keywords like machine learning, computer vision, deep learning, natural language processing, classify it as
YES if it mentions deploying or developing Artificial Intelligence or related technologies mentioned above.
If it does not then classify it as NO. Also give a short one line explanation for your classification.
Provide the output in the following format:
{
  "Classification": "YES" or "NO",
  "Explanation": "One line explanation for your classification."
}
Here's the PASSAGE :
```

Figure 2: The prompt to filter out passages unrelated to AI

Figure 3 shows an example of the output of the prompt. The highlighted text demonstrates its relevance to AI. We manually checked all the outputs in order to avoid hallucination.

```
{"chunk": "Digitalizing our plants and systematically analyzing data enables us to further automate processes.
In this way, we steer the capacity, availability and efficiency of our plants in line with market conditions,
for example, by simulating value streams within our Verbund  structure or through predictive maintenance.
Linking data from different sources and using artificial intelligence (AI) opens up  numerous opportunities
for us to manage our business more",

"classification": {"Classification": YES,
                   "Explanation": "The passage explicitly mentions the use of artificial intelligence (AI)
                   in managing business processes."}}
```

Figure3: Example of a BASF 2023 report passage that passed the AI filter and underwent manual review

We dropped passages unrelated to AI, retaining only a fraction (4,940) of total passages that were semantically relevant to AI and related technologies across all reports.

SDG target classification: Allocation of AI-related passage into the SDGs

After extracting AI-related passages, we used an ensemble of LLMs (Mao et al., 2025) from the GPT-4.1 family of models to classify each passage to one or more sub-targets from a list of 169 from the SDGs defined by the UN. Specifically, we use GPT-4.1, GPT-4.1-mini and GPT-

4.1-nano to map each passage to sub-targets. These models represent some of the most up-to-date language models available as of the time of this study, with a knowledge cut-off date of June 1, 2024 (OpenAI, 2025). A preliminary manual test indicated that the models had been trained on the 169 sub-targets of the SDGs, as they were able to list these targets without relying on web search. This made them a suitable choice for the classification task at hand. Figure 4 shows an example of the classification with GPT-4.1-mini along with the prompt used for classification.

CLASSIFICATION

```
Given the following PASSAGE containing text about AI or related technologies, classify it into one or more of
the 169 sub-targets of the 17 Sustainable Development Goals developed by the United Nations, based on use of
AI towards these sub-targets.

Also give a short one line explanation for your classification.

Provide the output in the following format:
{
  "SUB-TARGET1": "Explanation",
  "SUB-TARGET2": "Explanation"
}

For example:
{
    "9.c": "explanation1",
    "16.1": "explanation2"
}

If it does not use AI towards any of the 169 sub-targets then classify it as goal 0 as following
{
    "0": "No Classification"
}
Here's the PASSAGE :
```

Figure 4: The prompt to classify passages into one or more SDGs

Figure 5 shows an example of the output of the prompt. The highlighted text demonstrates its relevance to the SDG. We manually checked all the outputs in order to avoid hallucination. Note, not all passages that mention AI-related keywords got classified into one or more SDGs.


```
{"chunk": "Digitalizing our plants and systematically analyzing data enables us to further automate processes.
In this way, we steer the capacity, availability and efficiency of our plants in line with market conditions,
for example, by simulating value streams within our Verbund  structure or through predictive maintenance.
Linking data from different sources and using artificial intelligence (AI) opens up  numerous opportunities
for us to manage our business more",
"classification": {"9.4": "Use of AI to enhance industry infrastructure and increase resource-use efficiency
                   through digitalization and automation.",
                   "8.2": "Improving productivity and technological modernization in business processes
                   with AI."}}
```


Figure 5: Example from BASF's 2023 report classified under SDGs 8 and 9 and manually verified

Findings

The distribution of AI mentions across SDGs (Figure 6) reveals that AI is predominantly linked to SDG 9 (Industry, Innovation, and Infrastructure), followed by SDG 8 (Decent Work and Economic Growth). This finding aligns with the strong presence of AI in industrial automation, smart infrastructure, and economic productivity enhancements. This also suggests that the application of AI is more focused towards economic growth and not yet as an environmental tool. In contrast, AI's role in marine conservation (SDG 14: Life Below Water) and biodiversity preservation (SDG 15: Life on Land) is significantly underexplored. This lack of AI integration in environmental sustainability fields suggests an opportunity for targeted AI applications in climate resilience, ocean health, and biodiversity conservation.

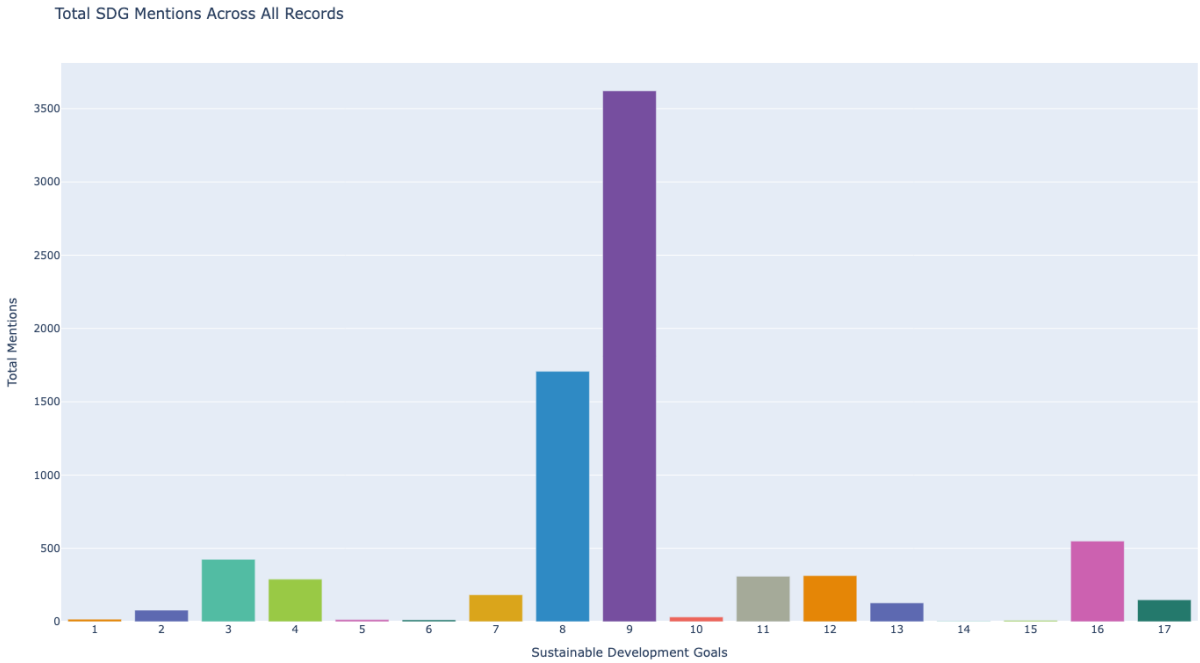

Figure 6: Number of passages that mention the application of AI towards each SDG from the annual reports

We observe an explosive overall growth in mentions of SDGs across the span of 10 years, with a remarkable jump after 2020 (Figure 7). The two largest colored bands each year are the same goals (the thickest stripes), reflecting that SDG 9 (Industry, Innovation & Infrastructure) and SDG 8 (Decent Work & Economic Growth) dominate the conversation. In the early years, only a handful of SDGs appeared. By 2023, almost every goal has some visible bar segment i.e. companies are talking about the full 17 SDGs, even if not equally. The growth of AI adoption skyrocketed after Chat-GPT was released (November 2022), with an increase in compute used for running LLMs. This in turn, could lead to more regulations around corporate reporting regarding more sustainable use of AI compute, hence the big jump in between 2022 and 2023. A slight dip in total mentions around 2021 could suggest COVID-related reporting disruptions.

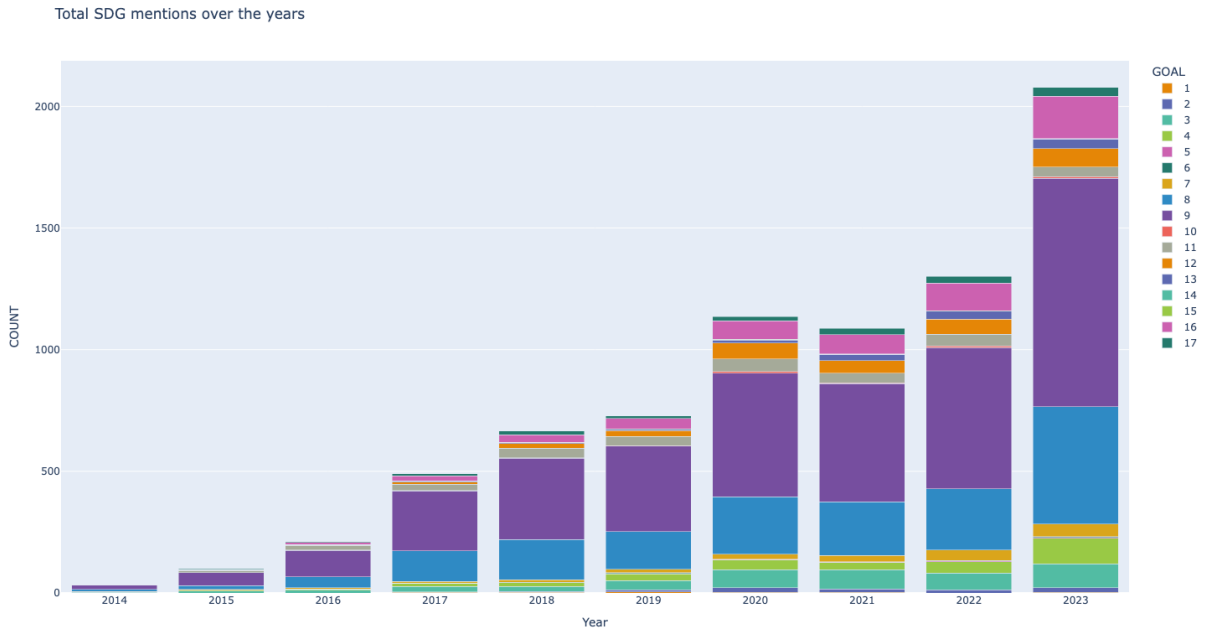

Figure 7: SDG mentions over the years

To account for differences in the number of firms across sectors in our dataset, we normalized SDG mentions by the total number of firms in each sector. SDGs are mentioned most frequently by firms in the IT and communication services sectors (Figure 8). Firms in these sectors typically have strong in-house capabilities in AI and are naturally more agile and equipped to deploy AI-driven solutions.

The industries lagging behind are energy, materials, consumer staples and healthcare. This result appears counterintuitive, given that these sectors indeed possess substantial potential to leverage AI in achieving SDGs. For instance, the energy sector could adopt AI for emission tracking, consumer-facing industries can benefit from AI-enabled optimization of sustainable supply chains and waste reduction, and healthcare firms may use AI in public health forecasting and disease diagnosis. We argue that the low scores observed in these industries can be attributed to the fact that, despite their considerable potential, they still need to transfer the potential to concrete outcomes. In practice, many AI-related initiatives, including those related to SDGs, have not yielded the intended results. Since firms in the IT sector have been more effective in utilizing AI to advance the SDGs, it is advisable for firms in lagging sectors to deepen their strategic partnerships with IT companies, thereby enhancing their capacity to deploy AI solutions aligned with sustainability objectives.

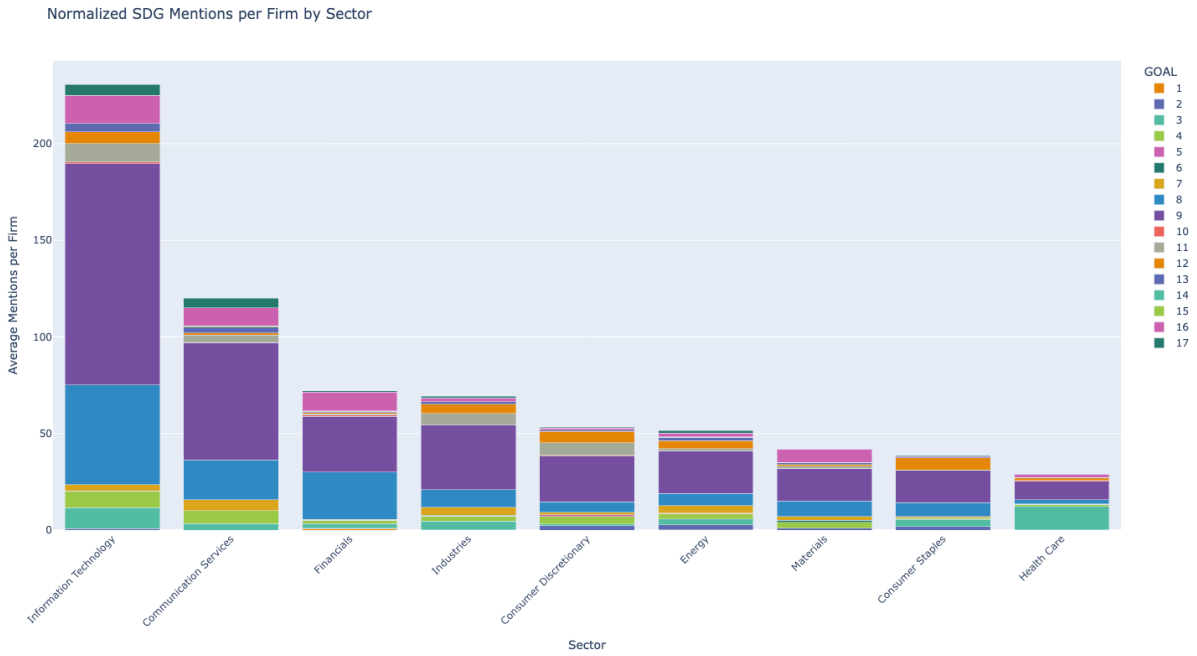

Figure 8: SDG mentions by sector

As for SDG mentions by country, we observed that the US leads in AI-mentions (Figure 9), followed by China, India and then Germany. This demonstrates the leading role of the US in the field of AI. Unfortunately, as a representative of Europe, Germany sits at the bottom of the ranking.

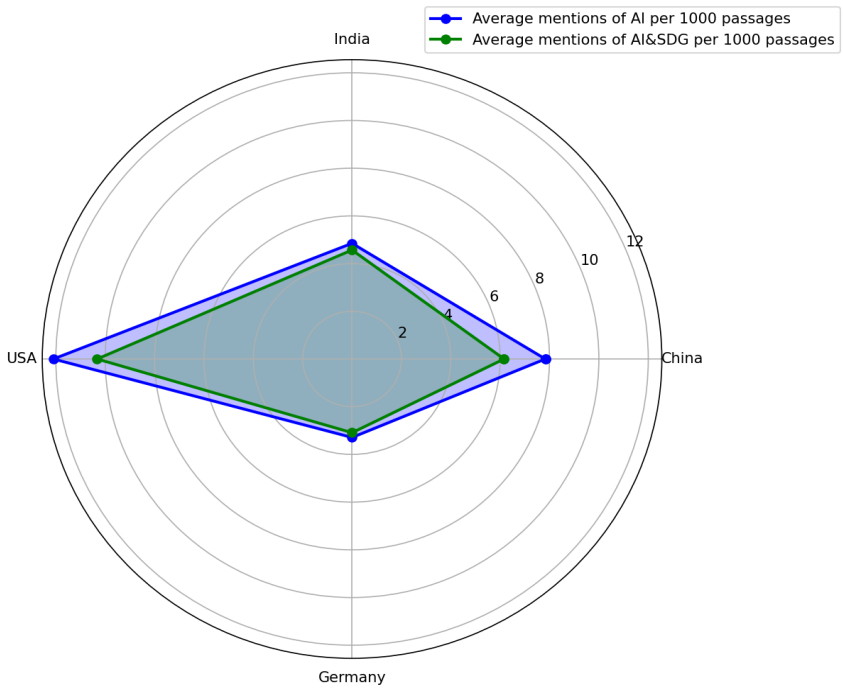

Figure 9: Comparison of AI mentions and AI & SDG mentions across the four countries

However, when further counting the mentions of both AI and SGDs, the US and China exhibited significant declines, whereas Germany's count remained virtually unchanged. This suggests that AI discourse in Germany is more closely connected to sustainability-

related objectives, while firms in US and China may have higher potential to further integrate AI with SDGs. Interestingly, the decrease in India's mentions is marginal. A possible explanation is that Indian firms are more prone to include sustainability-related texts in their annual reports. Sensharma et al. (2022), for example, find that 54% of Indian companies have been identified as greenwashers.

Discussion

The analysis reveals a nuanced and asymmetric integration of AI into firms' sustainability strategies. Interpreting these patterns, several key findings emerge:

- **Corporate AI adoption is guided by proximity to economic value.**
  AI is predominantly linked to economic-oriented SDGs. Firms appear to deploy and communicate AI efforts that support core business efficiency rather than sustainability at large. This reveals a structural preference for short-term return over broader ESG transformation.

- **Environmental SDGs are still largely neglected.**
  The low association between AI and goals suggests that these areas are neither perceived as urgent nor as AI-addressable by most firms, despite growing scientific evidence to the contrary.

- **AI's impact on the SDGs varies significantly across industries and countries.**
  Sectors such as information technology and communication services lead in linking AI to sustainability goals, while traditional sectors like energy, healthcare, and consumer goods lag behind. While U.S. firms discuss AI most frequently, German firms are more likely to associate it with sustainability. This underscores the need for context-specific strategies that reflect each sector's capacity and each country's regulatory and cultural environment.

Based on these interpretations, several concrete actions can be proposed.

- **Corporate leaders** should systematically conduct AI-SDG mapping exercises to identify which SDGs remain underserved within their organizations. These exercises can help firms better understand the scope and limitations of their current AI initiatives in relation to broader sustainability objectives. In addition, companies could establish internal benchmarks that ensure their AI applications are not limited to economic efficiency alone, but are also designed to address environmental and social priorities. Importantly, this effort will require investment in cross-functional collaborations to explore AI use cases that go beyond traditional industrial applications.
- **Policymakers and regulators** could introduce incentives for applications targeting underrepresented goals to encourage more balanced AI adoption across all SDGs. These incentives may include targeted subsidies, preferential tax schemes, or certification programs for "green AI" initiatives. Regulatory frameworks can further support responsible innovation by making explicit the expectation that digital transformation contributes to sustainability outcomes, not just operational performance, thereby fostering greater transparency and accountability. Of course, these regulations need to consider country-specific situations.
- **ESG raters** could refine their evaluation frameworks to assess not only whether companies adopt AI technologies, but also how comprehensively these technologies are aligned with the various SDGs. Current ESG ratings are sometimes criticized for significant subjectivity, leading to considerable discrepancies across different rating agencies. Could the United Nations' Sustainable Development Goals serve as a more standardized and goal-oriented framework for evaluating corporate sustainability efforts? In addition, to

support AI's alignment with SDGs, analysts could place greater value on firms that demonstrate a holistic and balanced integration of AI across economic, environmental, and social domains.

Conclusion

The main contribution of this study is the presentation of a relatively straightforward yet novel method to quantitatively analyze firms' use of AI in achieving various Sustainable Development Goals. Drawing on 814 annual reports from 85 listed companies in China, Germany, India, and the United States (2014–2023), our firm-level, cross-country, longitudinal approach is the first to track the mapping between AI and all 17 SDGs over the past decade. Our study quantitatively reveals its evolution across firms, industries, and national contexts.

The findings provide a practical foundation for more informed decision-making, policy formulation, and corporate reporting. This study supports managers, policymakers and ESG analysts in identifying both opportunities and gaps in AI-driven sustainability strategies.

It would be interesting to extend this research with more data or data from other countries.

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Appendix

The United Nations' 17 Sustainable Development Goals