[*TECHNICAL CHANGE FROM FOSSIL-FUEL TO RENEWABLE INNOVATION: EVIDENCE FROM OFFSHORE ENERGY*]

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Overview

Recent research recognizes the importance of transitioning to clean technologies in reducing fossil fuel emissions and mitigating climate change.The technological challenge for many industries in transitioning to renewable is substantial, due to path dependency and switching cost(Acemoglu et al., 2016; Noily & Shestalova, 2017).However, firms can leverage their accumulated expertise in traditional "dirty" technologies, as knowledge may spill over into "clean" technologies, facilitating innovation in renewable energy sectors (Aghion et al., 2016; Ning & Guo, 2022). Among these technologies, offshore wind is of particular interest due to its potential for potentially limiting climate change and its connections to more established technologies like onshore wind and offshore oil and gas (O&G) (Noailly & Shestalova, 2017; Wang & Goldstein, 2024). This study examines the feasibility of transitioning from fossil fuel-based technologies to renewable energy, focusing on the innovation contributions of offshore oil and gas to the offshore wind sector.

Methods

We introduce the concept of **transferable technology** between offshore oil and gas and offshore wind, where transferable technology refers to offshore O&G patents that are backward cited by offshore wind patents. A patent is considered transferable if an offshore wind patent cites an offshore O&G patent. The data for this study is sourced from the PATSTAT Global database, covering patent applications from 2002 to 2022. Initial patent counts reveal 103,381 patent applications related to offshore wind (EPO & IRENA,2023) and 101,839 applications referencing offshore oil and gas platforms (Wang & Goldstein, 2024). To examine technological similarities across these sectors, we employ Natural Language Processing (NLP) methods, including tokenization, stop-word removal, and technical term extraction, followed by the conversion of textual data into numerical vectors using TF-IDF (Term Frequency-Inverse Document Frequency). We calculate both Jaccard similarity and cosine similarity to assess the overlap between the two industries.

We hypothesize that firms with a higher stock of transferable O&G technologies demonstrate greater innovation activity in offshore wind technologies. To empirically test this, we employ dynamic count data models, using a sample of 2090 firms with O&G patents. The patent stock is estimated using the perpetual inventory method, with a baseline depreciation rate of 20% and alternative rates (15%, 25%) for robustness checks. Control variables, including firm size and total patent quantity, are included to address potential endogeneity concerns. Empirical analysis focuses on how both intra- and inter-firm transferable patent stocks influence offshore wind innovation. Using dynamic count data models, we estimate the impact of these stocks on the number of offshore wind patents, controlling for firm characteristics such as size, overall patent stock, and R&D capacity, etc.

Results

Our analysis reveals a notable **technological relatedness** between the offshore O&G and offshore wind sectors. The text similarity analysis of patent documentation shows a steady increase in technological overlap, from 0.32 in 2002 to 0.52 in 2022, suggesting growing compatibility between the two sectors. The TF-IDF analysis highlights common technical domains in offshore environmental management, marine infrastructure, and logistical operations. Transferable O&G patents, which account for 5% of all offshore O&G patents, exhibit a significantly higher average similarity score (0.19 higher) compared to non-transferable patents, indicating substantial potential for cross-sector knowledge transfer.

The empirical analysis confirms that **firms with larger initial stocks of transferable O&G patents show greater innovative activity in offshore wind technologies**. Specifically, a one-unit increase in transferable O&G patent stock is associated with a 1.24% increase in offshore wind patent filings. Robustness checks, including the use of alternative patent identification methods and control variables, reaffirm the positive relationship between transferable O&G technologies and offshore wind innovation.Further analysis highlights that spillover effects occur not only within firms but also across firms. Specifically, we examine whether offshore wind patents owned by one

firm cite offshore O&G patents owned by another firm, indicating inter-firm knowledge transfer. The data reveals that approximately 18% of transferable offshore wind patents include citations to O&G patents from other firms, demonstrating the potential for cross-firm knowledge sharing. This spillover effect amplifies the overall knowledge stock available to the offshore wind sector and fosters collective innovation across the industry.

Additionally, heterogeneity analysis reveals that larger firms (top quartile by size) exhibit a 2.3% stronger response to transferable technologies compared to smaller firms. This suggests that economies of scale play a role in facilitating the transfer of technologies between sectors. Further analysis of non-transferable O&G patents shows a negative and statistically significant relationship with offshore wind innovation, highlighting the role of path dependency in hindering the transition to offshore wind energy.

Spillover effects occur both within and across firms. Firms with larger stocks of both intra- and inter-firm transferable O&G patents exhibit greater innovative output in offshore wind. A one-unit increase in inter-firm transferable patent stock is associated with a 0.76% increase in offshore wind patent filings, complementing the intra-firm spillover effect (1.24% increase per unit). These findings reinforce the importance of collaborative and competitive dynamics in accelerating the transition toward renewable energy technologies.

Conclusions

The concept of transferable technology bridges carbon-intensive and renewable sectors, providing firms in traditional industries a pathway to adapt existing knowledge to green technologies. Technological similarity analysis offers a formal assessment of cross-sector compatibility, advancing understanding of innovation convergence. This study highlights the strategic role of technological repositories in firms' renewable energy transitions and the importance of addressing path dependency in fostering green innovation. This study contributes to three key strands of literature. First, we introduce the concept of transferable technology, which bridges the gap between the carbon-intensive and clean energy sectors by leveraging existing technological assets in the transition to renewable energy. Second, we provide a quantitative assessment of technological similarity between "dirty" and "clean" technologies, using NLP methods to reveal an increasing convergence in technical domains, thereby highlighting the potential for cross-sector innovation. Third, we analyze how firms' prior technological stock influences their innovation in renewable energy, showing that firms with a larger initial stock of transferable technologies are more likely to lead in offshore wind innovation. Our findings offer valuable insights into how firms in traditional energy sectors can strategically repurpose their technological capabilities to contribute to the clean energy transition and mitigate transitional risks.

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