NATURAL GAS COMBINED CYCLE INNOVATIONS IN THE US: THE IMPACT OF THE ADVANCED TURBINE SYSTEM PROGRAM

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Overview

Developments over the past thirty years have contributed to increased natural gas generation in the US electricity sector, which surpassed coal for the first time in history on an annual basis in 2016. In addition to low natural gas prices, developments with the natural gas-fired combined cycle generator (NGCC) have contributed to the rise of natural gas. In the 1990s, technological innovations led to substantial efficiency gains for NGCC, rendering these generators cleaner and more efficient than other fossil-fuel fired sources of power generation during this period. The improved NGCC generators were rapidly deployed in the early 2000s during the largest short-term increase in generation capacity in history. Since then, NGCC is increasingly being used to provide baseload power, due in part to the efficiency innovations that took place in the 1990s.

In this study, I evaluate the impact of a government-sponsored research program on NGCC efficiency innovations in the 1990s called the Advanced Turbine System program (DOE-ATS). DOE-ATS was a public-private partnership between the Department of Energy and two US turbine manufacturers, General Electric (GE) and Siemens Westinghouse Power Corporation (SWPC). Using data from the European Patent Office's worldwide patent database (PATSTAT), I use econometric models to evaluate the impact of DOE-ATS on advanced turbine patenting activity. Next, I consider how the program resulted in the observed changes in patenting activity by the program participants during the program and in the years that followed. I draw conclusions about government-sponsored research and development (R&D) program design for NGCC innovation, and apply these findings to future interests in NGCC innovation for increased ramp speeds to better complement intermittent renewable generation.

Methods

In the first part of this study I quantitatively evaluate advanced turbine system innovations for NGCC efficiency from 1980-2008 using global patent data. Using International Patent Classification (IPC) codes associated with NGCC efficiency, I extract approximately fourteen thousand unique patents from PATSTAT sorted by application date and inventor company (Figure 1). I use a negative binomial model on patent counts and patent citation counts to determine the impact of the DOE-ATS program on patent volume and patent impact by program participants relative to their competitors before, during, and after the DOE-ATS program. In addition to the global sample, I also evaluate patents that were authorized in the US to determine the impact of the program on domestic patenting.

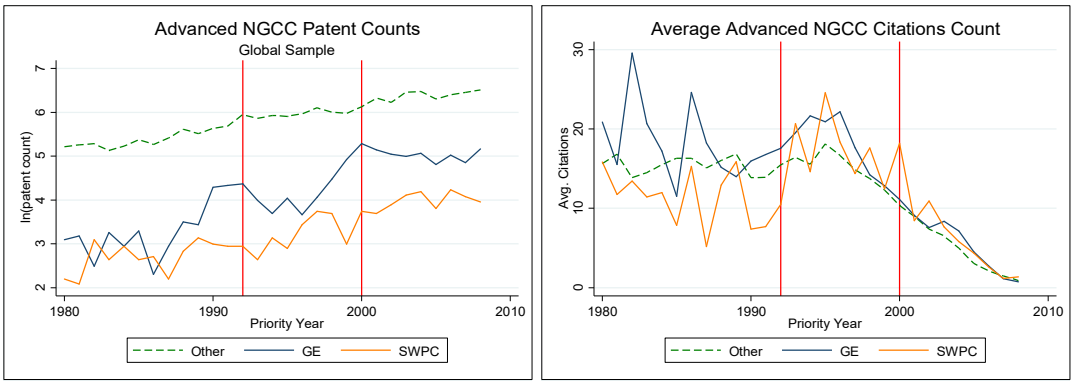

Figure 1: Global sample of advanced NGCC patent counts (left) and average patent citations (right) by the two DOE-ATS program participants (GE and SWPC), before, during (1992-2000), and after the program.

In the second half of this study, I use qualitative information from patent content and citations to verify the impact of the DOE-ATS program on changes in patenting activity by the program participants. Patent content analysis provides more detailed information about the nature and applicability of the innovation. The citation data contain information on knowledge flow to determine the impact of the program on knowledge diffusion between competitors, licensees, and merged companies. I plan to use the results from the content analysis and citation analysis to determine: 1.) how the program impacted changes in patenting activity by GE and SWPC, 2.) how the program patents translated into commercialized technologies for GE and SWPC, and 3.) if the program led to transformational changes for turbine manufacturers worldwide.

Results

The econometric analysis on advanced NGCC innovations shows the DOE-ATS program had different impacts on the two program participants during and after the program. After removing company and year fixed-effects, I find GE had higher patent volume relative to competitors for several years before the program started, indicating there was not a lack of this type of research being done before the government-sponsored program began. After a dip in patenting activity in the early years of the program, GE increased the volume of their patents towards the end of the DOE-ATS program and afterwards, patenting nearly three times as much as their competitors in this field. This increase in patenting activity was higher than the pre-program patenting increase, and suggests the program led to higher patent volumes for GE towards the end of the program. SWPC did not experience a statistically significant change in global patenting volume during the program, but did have higher patent citations for patents filed during the program relative to competitors. This indicates the patents produced by SWPC during the program had a higher impact than competitor's patents and earlier patents issued by SWPC. Meanwhile, GE had no statistically significant changes in patent citations during the program. In the qualitative portion of this study, I plan to further evaluate why the program had a different impact on each of the program participants, and how these innovations translated into commercialized technologies.

Conclusions

This study adds to the existing literature regarding the impact of a government-sponsored cost-sharing program on advanced turbine innovations for NGCC generators. The results of a quantitative patent analysis reveal that advanced NGCC patent counts and citations changed for the two participants in different ways during the program and in the years that followed. Qualitative analysis of patent content will provide further information on why the program impacted the two participants differently, and how the program influenced the observed changes in patenting activity.

As NGCC is increasingly used to complement intermittent renewable generation, there is renewed interest in NGCC R&D funding to further improve NGCC ramp speeds to better complement growing intermittent renewable capacity. The results from this study provide recommendations to future NGCC R&D program designers and turbine manufacturers on how to improve innovative outcomes that result in better performing technology.