Environmental Investment, Productivity, and Energy Efficiency

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Overview

Investment in new and more ‘green’ means of production serves as one way for firms to reduce energy use and pollution emissions, often in response to more stringent environmental standards. As the continued debate surrounding the Porter Hypothesis (Porter and van der Linde, 1995) highlights, this may even lead to innovations that drive productivity growth and the potential for increased firm profits. Research and development is cited as one of the primary sources of technological change, both directly through design improvements, as well as indirectly through spillover effects (Clark et al., 2006).

This study examines the role of investment in environmental production practices for productivity change over time. We employ a network modelling approach that links successive production technologies through inter-temporal investment decisions. This allows us to estimate productivity change and its associated decompositions into efficiency change and technology change, accounting for long-term environmental investment, annual environmental management expenditures, and energy use. We apply this framework to detailed production data from a panel of Swedish manufacturing firms in the pulp and paper industry for the years 2002-2008.

Methods

We introduce firm-level investments, both environmental and production-oriented, into a network production model to better understand their effects on productivity. We model the production technology for a given time period, t, as

$T^t = \{(x^t, i^{t-1}, y^t, u^t)$: x^t and i^{t-1} can produce y^t and $u^t\}$,

where x^t denotes the vector of current period resource inputs, i^{t-1} total investment from the previous period, y^t the vector of current period production output and u^t the vector of associated pollution emissions. Following Bogetoft et al. (2009), we decompose investment into production investment, *pi*, and environmental investment, *ei*, where $pi^t + ei^t = i^t$. We decompuse output into final output, fy^t, and investment purchases, so that $y^t = fy^t + i^t$. We also decompose inputs into energy inputs, *ex*, and all other inputs, *ox*, so that $x^t = ex^t + ox^t$. The network diagram below illustrates the technology linkage through investment for three time periods, *t-1*, *t*, and *t+1*.

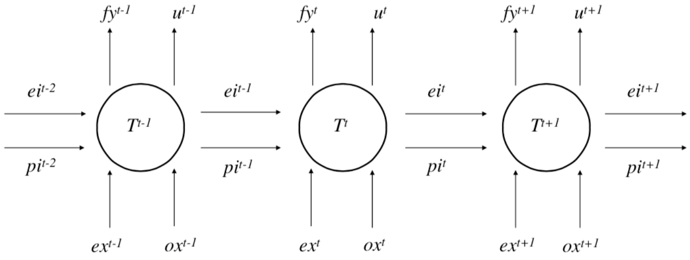

Figure 1: The Network Technology

We use Data Envelopment Analysis (DEA) (Charnes et al., 1978) to estimate the network technology depicted in Figure 1, and the resulting productivity measures to construct Malmquist indexes of Productivity Change (Färe et al., 1994) for the study period. In addition, use the estimated network technology to construct index measures for environmental performance (Färe et al., 2004; 2010) and develop a new index measure for energy efficiency.

Results

At the industry level, we find negligible productivity change over the study period, with annual geometric mean values ranging from 0.960 to 1.039. Efficiency change ranges from 0.901 to 1.038 and technology change from 0.970 to 1.119. Overall efficiency gains in the early part of our study period (2003-2004) appear to outweigh slight technology losses, while efficiency losses mostly outweigh technology gains in the latter half of the study period (2005-2008). Our resultas indicate general decreases to both energy efficiency and environmental performance, due in part to falling production efficiency, coupled with increasing pollution emissions.

However, average values conceal considerable variation in productivity change, both across manufacturing plants and across time. For instance, annual productivity change estimates at the firm level range from 0.327 to 4.442, or a roughly 70% decrease versus more than a 400% increase. Efficiency change and technology change measures vary similarly. Over time, geometric mean values for productivity change at the firm level range from 0.736 to 1.983, still reflecting significan variation among firms.

We also examine the relationship between each of our index measures. We find some evidence that producitivty and environmental performance are positively related (Spearman's $\rho = 0.31$), as well as energy efficiency and environmental performance ($\rho = 0.23$) and energy efficiency and productivity ($\rho = 0.28$). Each of these rank-order correlation coefficiencts is significant below the 0.001 level.

Conclusions

To our knowledge, this is the first study to incorporate environemtnal investments into a network production technology in order to estimate productivity change, environmental performance and energy eficiency. In evaluating environmental production decisions, it is important to distinguish annual management practices from longer tern investments in in new means of production. We plan to extend our use of network modelling to the dynamic case, in order to estimate optimal investment time paths in light of both production and environmental objectives. We are also interested in integrating our environmental investment network technlolgy to an abatement technology, to more explicitly model the relationship between investments, energy use, production and pollution.

References

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