NATURAL GAS: RENEWABLES SUPPORTER OR OPPONENT?

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Overview

Constantly available electricity at a low cost is part of the bedrock of developed economies. It also has to reconcile purposes that are at odds with each other, given the technology that is currently available. Such a dichotomy of purpose exists between renewable energy and conventional fossil fuel generation. Renewable energy generation technology is a tool to reduce the carbon intensity of the electricity sector, but is intermittent and costly. Fossil fuel generators have a much higher carbon footprint, but can be called upon to produce electricity at any time within certain technical constraints.

This paper focuses on the interaction between wind, natural gas and coal generation, particularly how this interaction is affected by the intermittent nature of wind power, and the carbon footprint of natural gas and coal power. Each of these technologies has attributes which currently make them part of a typical power generation portfolio.

Using a concise theoretical micro-economic model inspired by Ambec & Crampes (2012), I describe the interaction between intermittent renewable energy, natural gas and coal. The question being asked, is natural gas a substitute or a complement to intermittent renewables?

This paper contributes to the literature examining the interaction of different generation technologies, first summarized by Crew et al. (1995). Policies seeking to reduce carbon dioxide emissions in the electricity sector focus on the generation of electrical energy, an issue that the literature has long engaged with: examinations of how to support wind power by Garcia et al. (2012), the problems arising due to the differing cost structure of conventional and renewable generation by Ambec & Crampes (2012), or the importance of natural gas in this process described in Knittel et al. (2016).

Methods

I posit a model comprising of three technologies, coal (c), natural gas (g) and intermittent wind (i). Each is characterized by an installation (r_t) and a running cost (c_t), continuous increasing concave functions in the quantity of each technology installed K_t and dispatched q_t^s. The model exists in a world that is either in a windy state, or a windless state with a certain probability; the two fossil fuel technologies can operate in both states, whilst wind can only operate in the windy. All three technologies have a certain carbon intensity factor, coal's being the highest and wind's the lowest. The problem's program is a constrained maximization of the consumer surplus:

$$\max_{K_t, q_t^s} \left\{ \sum_s Pr(s) \left[S\left(\sum_t q_t^s \right) - \sum_t c_t(q_t^s) \right] - \sum_t r_t(K_t) \right\}$$

Such that:

$$q_s^t \geq 0 \qquad K_t \geq 0 \qquad \sum_s Pr(s) \left(\sum_t q_t^s \theta_t \right) \leq \overline{e}$$

The ability of the technologies to be dispatched depends on the state of nature s, whose probability of occurrence is given by $Pr(s)$. I solve the centralized equilibrium, which is then subjected to an emission cap and natural gas price shock.

Results

In a world where the interaction of natural gas, coal and wind power is dominated by the key characteristics of installation & operation cost, and the intermittent character of renewable energy, I show that natural gas, coal and wind are all substitutes for each other. Three propositions describe the effects of an emission cap policy, a natural gas price shock, as well as their joint effect.

Proposition 1 (effect of an emission limit). The application of a binding emission limit reduces the quantity of fossil fuels – both gas and coal – installed and causes an increase in the amount of intermittent wind capacity installed.

Proposition 2 (effect of a gas boom). A decrease in the cost of generating a unit of natural gas based power results in increased use of this fuel. More capacity is installed overall and more of it is dispatched in both states of the environment. This increase occurs at the expense of coal and intermittent energy capacity installed and then generated.

Proposition 3 (joint effect of an emission limit and gas boom). The imposition of an emissions cap under a gas boom shifts the burden of adjustment to the coal power sector. Natural gas output can be shown to increase by virtue of its falling operating cost and lower unit emissions. Intermittent wind capacity also increases by virtue of its zero emissions.

Conclusions

This stylized model of the electricity sector can be used to clarify the forces at play in the electricity sector. By making the defensible assumption that the installation and generation decisions are made primarily on a basis of cost, I show the following:

- Without policy intervention, natural gas and wind power are substitutes not complements; the cheaper technology will be preferred.
- An emission cap favors renewables; the adjustment burden is on carbon intensive sources.
- A natural gas boom displaces renewable energy; as the cost of generating electricity using this technology falls, intermittent wind power capacity decreases.

References

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