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ENDOGENOUS CAPACITY AND OPTIMAL GENERATION TECHNOLOGY MIX IN A COMPETITIVE ELECTRICITY MARKET

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Adequate generation capacity and technology mix in a competitive electricity market and the incentives to invest in new generation capacity are major concerns for policymakers. The incentives to under-invest in capacity are explained by the following phenomenon; building a new power plant is a slow process, requiring a long lead time, while daily and seasonal electricity demands fluctuate: day-time demands are higher than night-time demands, summer and winter demands exceed spring and autumn demands, and this seasonal and time-of-day demand variance is further exacerbated by extreme temperatures. When realized peak demand occasionally exceeds the level of all available capacity, the daily electricity price spikes, curtailing the excess demand. Hence, in a competitive electricity market, daily electricity prices tend to fluctuate wildly across the seasons and over the day. Nevertheless, a large share of the available capacity is frequently idle during many hours of the day and year (certainly during off-peak hours), making capacity investment, particularly in the expensive base-load technology, very costly. To avoid excessive generation costs, producers invest in a mix of generation technologies which includes, among other, coal-fired generators (CFGs) and combined cycle gas turbines (CCGTs).

To explore the connection between capacity expansion of heterogeneous generation units and price volatility in a competitive (oligopoly) electricity generating market, this paper develops a two-stage model to capture the lead time in capacity construction and the fact that short-term demands can only be met by installed capacity. In the first stage, when only the probability distribution function of future daily electricity demands is known, profit-seeking producers maximize their expected profits by determining the size and mix (CCGTs, CFGs) of capacity to be constructed. In the second stage, once daily demands become known, each producer selects its daily output level via the Cournot conjecture, thereby determining the equilibrium market prices.

This paper contributes to the literature by: (a) Analytically solving for and characterizing the *unique* (Nash) equilibrium solution of the optimal generation capacity and capacity mix, demonstrating that the two-stage model, which closely mimics the real-world decision process, yields highly volatile daily prices over the year, as we have so often observed in the real world. (b) Showing that the base-load technology may be underutilized at times; that is, peaking units may be employed even though base-load units are not fully utilized. (c) When the base-load technology is underutilized at the optimal solution, the number of CFG-using firms must be at least as large as the number of CCGT-using firms. (d) Showing how the number of CCGT-using and of CFG-using firms affects optimal capacity, capacity mix and energy use. (e) Showing that the short-term demand volatility and the very slow construction process make price spikes inevitable, unless there is reserve capacity that can absorb demand surges. Thus, the paper accentuates the interdependence among the endogenously determined generation capacity and generation technology mix, price level, price volatility and service reliability, a primary cause of concern in the continuing debate on electricity market reform.