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The Investor's Behavior in Competitive Korean Electricity Market

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Abstract

This paper describes the mechanism for new investment to appear in waves of boom and bust causing alternative periods of over and under supply of electricity in Korean market. A system dynamics model wasdeveloped to describe the dynamic behavior of new investment in Korean market. The simulation results show the boom and bust cycle in the new investments. When the market price is high, investors decide to build new power plants. However, it takes some delay time to complete new power plants. When the new power plants are being added into the grid, the supply increases and the wholesale price begins to decrease. This causes the cancellation of new power plant or delay the construction. This mechanism causes the boom and bust cycle in new investment.

Keywords: system dynamics model, boom and bust cycle, new investment

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Ⅰ. Introduction

The government of Korea had designed a multi-stage progression towards full restructuring of its electricity sector, which it intends to culminate in full wholesale and retail competition. The nation is currently in an early stage of this process, where generation facilities have been allocated to six firms and there is competitive bidding, albeit strictly on a cost basis. It was originally designed to implement a "two-way" bidding system between the six generation firms and the multiple distribution companies, where bidding will be market-based rather than cost-based. However, the California crisis along with the strong opposition of labor union caused the government to halt the further progress. At present time, there exist six generation companies and a single distribution firm, the Korea Electric Power Company (KEPCO).

Korea has several objectives in restructuring its electricity sector. These include increased efficiency, lower costs, incentives for private capital to finance the enormous increase in generation capacity that will be needed over the next decade, and competition itself, including enabling customer choice. In this respect, it is very significant to forecast the future wholesale price using quantitative model. We need to investigate whether it is possible to lower the price by restructuring in Korean market. The market price is determined by the various factors such as fuel mix, fuel price and load. When we designed the market, it is also important to test the market design at the extreme condition.

Chapter 2 describes a model designed to simulate the potential for cyclical behavior in the electricity markets in Korea. The model simulates the key feedback mechanisms that give rise to construction cycles. Chapter 3 presents simulations which reveal that cyclical behavior could emerge under a wide range of assumptions on demand, fuel cost, construction costs and investors' behavior. This paper concludes with some recommendations and further works.

Ⅱ. Model Description

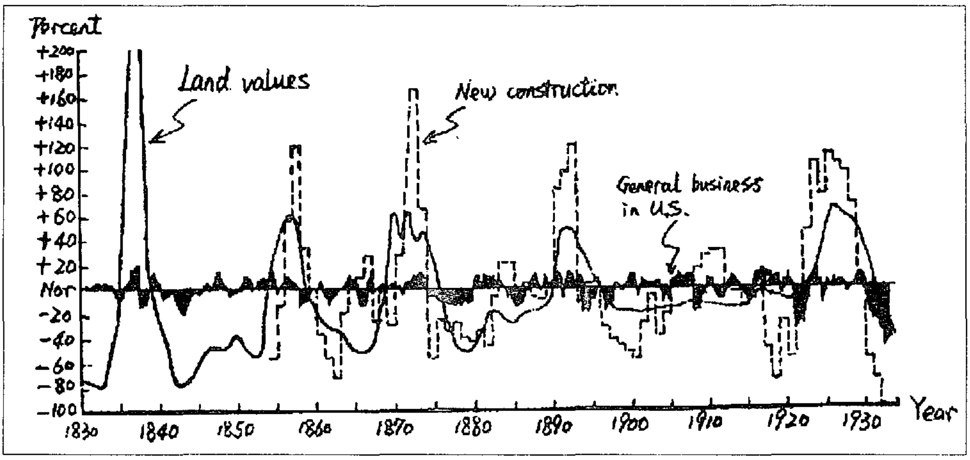
The Model uses the system dynamics approach described in books by Forester(1961), Ford(1999) and Sterman(2001). The approach is valued in a rapidly changing electricity industry with high risk (Dyner and Larsen 2001) and as a complement to traditional optimization methods(Bunn, Larsen and Vlahos 1993). Moreover, it has been used to warn the potential for volatile patterns of power plant construction arising from some of the market rules used in the UK shortly after privatization(Bunn and Larsen 1992).

The model focuses on the dynamics of power plant construction. It can be used to study the possibility that construction will appear in waves of boom and bust in Korean market. The model assumes that developers will invest in gas burning power plants using the combined cycle technology. Investment in new CCs is simulated inside the model on the assumption that investors are following changes in spot market prices for electricity.

The model was developed based on the previous work by Ford (1999). The same algorithms for the price determination and investment decision as Ford are used in this model. The model is designed with parameters for the loads and resources in Korea.

1. Power plant Construction Cycle

Construction cycles have been observed in a variety of industries including automobile manufacturing, real estate construction and commodity production. Many commodities such as agricultural products, raw materials and forest products and real estate industry suffer from persistent cyclical instability in price, production, profitability and investment. In the real estate industry, several factors influence the construction of building. It requires long lead times for permitting and construction as a physical factor.



[Figure 1] Land Values and Real Estate Construction in Chicago traced from Hoyt (1933)

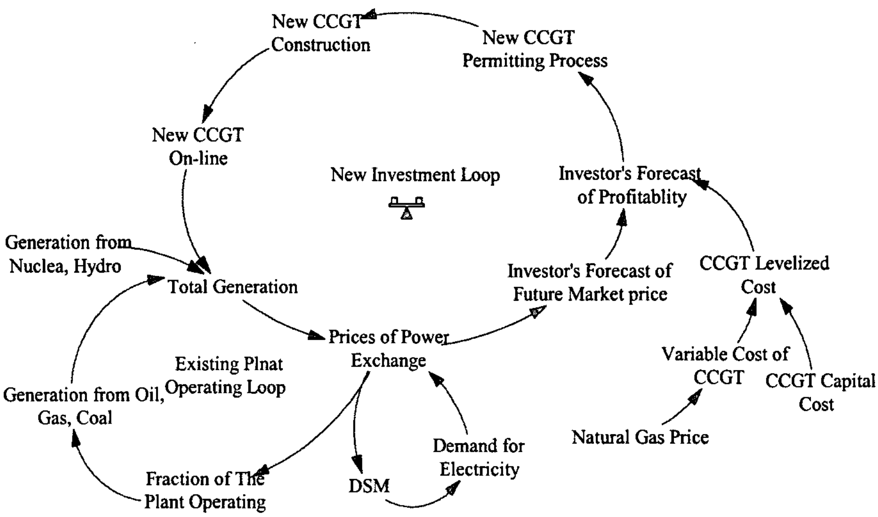
Many studies show that there also exist behavioral and psychological factors to influence the investment for construction. Investors tend to discount the construction in progress and show herd behavior during the boom and bust. Figure 1 shows the history of land value and construction in Chicago during 100 years. This figure show that there exist strong interrelationship among land value and construction along with economy growth.

This cycles has not been as prominent in the regulated electric industry because of the investor owned utilities clear obligation to build power plants needed to keep pace with demand. However, in the competitive market, the electricity industry will no longer rely on traditional rules. In the competitive market, utilities have no obligation to serve any or all of the demand. In other words, the generators would product the electricity or consider adding new power plants only if the market price exceeds the sum of capital cost and variable cost of the power plant and it is expected the profits. To add the new capacity needs time delay to complete the construction. This time delay combined with negative feedback loop cause the behavior of oscillation in new investment.

In this sense, the electric industry is similar to the real estate industry. Developers in both industries confront significant delays for permitting and construction. Both industries are similar in terms of capital intensive. Although we have learned to live with construction cycle in the real estate industry, it's not at all clear that we should tolerate construction cycles in the power industry. A fundamental difference in the two industries is the flexibility of the demand side. In electric power customers have little ability to react when reserve margins are low and prices are high. With the current market structure, our ultimate response to dangerously low reserve margins is to schedule rolling blackout to protect the integrity of the system.

2. Causal loop diagram

We assumed for the model's simplification that investors in the competitive market invest only smaller, more efficient, cheaper gas-fired Combined Cycle plant in the model. Figure 2 shows the causal loop for modeling design.



[Figure 2] Causal Loop Diagram for New Power Plant Construction

• The existing plant loop represents the rapid adjustments in generation from existing power plants responding to changes in the power exchange price. This loop has no delay to keep the supply and demand in balance. The only existing plants whose variable cost does the lower than power exchange price can be operated.

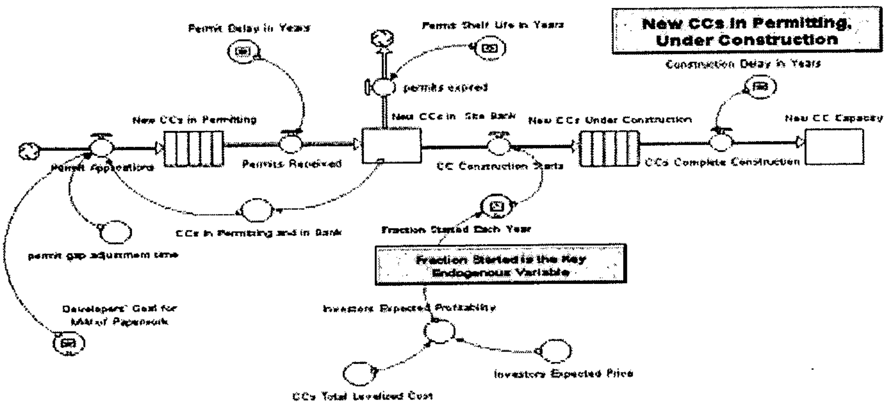
• The New Investment Loop describes how the new investment is decided in the market. Investors look beyond today's power exchange price in judging profitability. At this time, investors decide where they invest the new combined cycle gas turbine (CCGT) or not comparing levelized cost of CCGT with Expected Prices forecasted by investors. If it is expected the profitability, it leads to the increase in the number of CCGT process and construction Starting. The completed CCGT increase the electric supply and then affect the power exchanging price. This loop must consider the response of investor's behavior to price change and have a construction delay. So it is contained a possibility for excessive or insufficient supply.

• CCGT's levelized cost is affected heavily from the natural gas price variation in the real market. As we could not control this variable in our model we assumed that natural gas price is constant

• If the electric price is high, the government is undertaking positively the Demand-side Management (DSM) programs. These activities affect the power demands and power prices.

This loop is very important issue in aspect that DSM participants'behavior could not control and DSM Savings affect the future expecting profitability.

Stock and flows are the basic blocks of system dynamics. Figure 3 shows the stock and flow used to simulate investor decisions on permitting and construction.



[Figure 3] Construction Stock and Flow of New Power Plant

The Power plants proposed by investors are gas-fired combine cycle (CC) units. Investors must first apply for a construction permit. The model assumes that MW in permitting will experience a 12 month delay before the permit is granted and the approved site for the power plant enters a "site bank"with a self life of 24 months. This stock holds approved sites awaiting the investor's decision on starting construction. The Fraction of MW in the site bank that actually starts construction is a key, endogenous variable in the model.

The "Profitability" is the ratio of the expected price over a year to the total levelized cost. If the ratio is 1, the investors would expect to meet their profitability goals. If the ratio is 0.95, the price is 5% short of the value needed to meet their profitability goals.

3. Korea Wholesale Electricity Market Model

The Korean market model was developed based on causal loop diagram described in Figure 2. It consist two major feedback loops: investment loop and existing plant operating loop. It considered the real delay time effect of endogenous construction. The decision for the delay or the cancellation of new capacity is made depending on the change of market condition endogenously.

This model simulates the wholesale market as a single market place on an hour-by-hour basis. It simulates the spot price over the 24 hours in a typical day, with one day for each quarter. It produces chronological price data so the user can see prices in "real time".

It assumes that the power plants for new investment is limited to new combined cycle power plant only. Investment in new combined cycle capacity is simulated based on an endogenous theory of investor behavior. Theses investors are treated as "merchant investors" looking for profitable returns in the spot market. The model includes the delays for permitting and construction that could cause construction to lag behind the growth in demand. The investors look into the future to anticipate the growth in demand, the amount of generating capacity and the system reserve margin. From this information, they prepare an estimate of the average market price over the course of the year shortly after a new CC would enter operation. The investors watch current generating capacity. As soon as units are retired, they adjust their forecast downward. The "weight" is used to represent how the investors account for the CCs under construction in forming their estimates of future market prices. Set the weight to 1if you believe the vast majority of investors will count the CCs in their forecasts while they are still under construction. Set the weight to zero if you believe the vast majority of the investors are not inclined to count these units in their forecasting. If you set the weight to zero, you are assuming that the investors will wait to see the units enter operation before they believe they are "for real." The base case value is 0.5, an intermediate position. This assumption provides a good match against historical benchmarks.

Cogeneration, hydro and nuclear are treated as must run units. Nuclear generation capacity increases during the simulation. One flow keeps track of nuclear capacity that is under construction at the start of simulation. This flow uses PULSE function to bring additional units into operation in each planned years of the simulation. The addition time and size of new nuclear are transported from the government long term nuclear development plan.

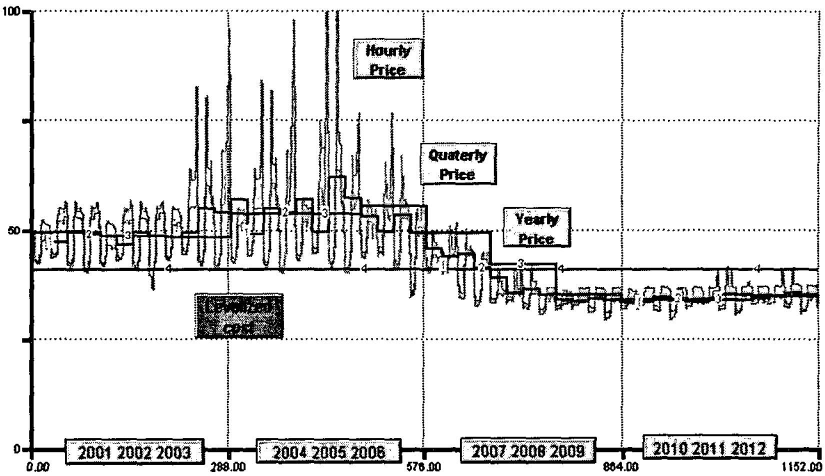
The model simulates the loads, resources, operation and spot market prices for a whole sales electricity market in Korea from the year of 2001 to 2012, this is sufficient time to show the simulate response of privet investor who may be building new gas-fueled combined cycle power plant and forecasting electric price variations.

The base case begins with gas priced at $4.2/million BTU and Demand growth at 5% per year. The price of natural gas remains constant in the simulation. With natural priced at $4.2

per million BTU, investors expect the full, levelized cost of a new CC power plant to be $44.5 per mwh.

Ⅲ. Simulation results

The simulation result for base case is described in Figure 4. The hourly prices are shown in lightly gray (Line 1) the quarterly prices in red (Line2); and the annual prices in black. The simulation was conducted from 2001 to 2012.

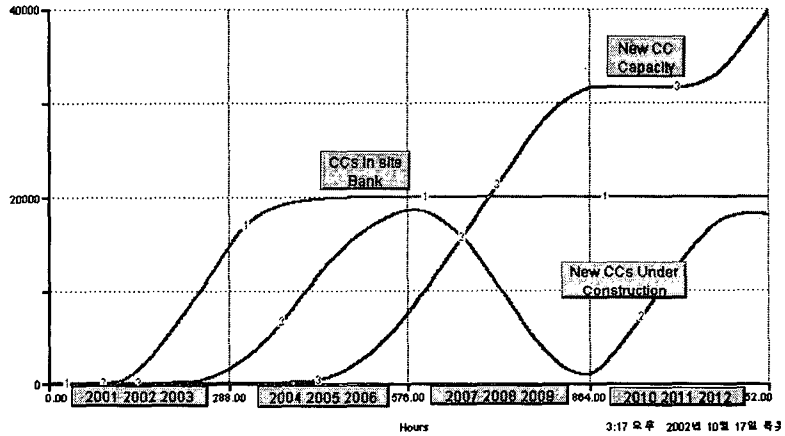


[Figure 4] Wholesale Market Price in Korean market from 2001 to 2012

Simulated hourly prices are around $50/mwh in the first few years but they rise to around $78/Mwh by summer of 2002 and exceed around $100/mwh by 2005. During the summer time, the marginal unit is LNG power plant, which forces the market price to go higher. These higher prices appear when the investment in new generating capacity does not keep pace with the growth in demand. When the market price exceeds the proper level for profitability, investors decide to invest in new combined cycle power plant. During the first half of this simulation, there was a boom for construction. However, the boom of construction was not reflected in the first half because it takes 2-3 years to complete construction.

The second half of Figure 4 shows market prices declining after the year 2007. This decline is caused by a large building boom in CCs. The building boom causes the supply exceed to demand, which causes the average annual price to fall lower than value of the full cost of a new CC. After the market price fall below the levelized cost, the new investment drops sharply.

Figure 5 shows the pattern of new CC investment in Korean market. It shows the typical boom and bust cycle cited in Chapter 2.



[Figure 5] Investment for New Construction of New CCs

The red curve (Line2) shows CCs under construction. The construction boom peaks in the end of 2006 and 2007 with over 18,600MW under construction. The second boom appears around 2011-2012. The blue curve (Line3) shows installed CC capacity growing to just over 32,000MW by the end of the first building boom.

Figure 5 show that New CCs investments have a cyclical pattern of construction. There is major over-building in this simulation and the large amount of new CC capacity causes the "bust" after 2007. During the bust period, investors cancel or delay the construction of new CC power plants. This simulation result coincide with the theory suggested in Chapter 2.

This simulation was selected to provide an example of market price's variations that might appear in the Korea electricity market if private investment does not occur in timely manner after competitive market would begin. The electricity market in California experienced "crisis"conditions during the year 2000-2001 due, in part, to the several factors including the lack of resource adequacy. During the year of 2000 -2001, there was an over investments in generation. When the constructions are completed around 2002-2003, the supply exceeds the demand, which leads to the market price lower. It caused the bankruptcy of merchant power producers. In Korean market, we may not have the same experience as California even though our grid is isolated. In Korean market, enough transmission lines are installed and the new investments by nuclear or large coal power plants are encouraged by the government. The portion of new CCs in Korean market is relatively small compared to California market.

Ⅳ. Conclusion and future researches

The system dynamics model for Korean market works well as expected. This model generated the waves of boom and bust cycle in new investment. Although the new investment mechanism used in this model is very realistic, the feedback effect of investment decision mechanism turned out relatively small since the large portion of nuclear and coal power plants are specified by user.

There remain many improvements in this model. The base case is very simple with many assumptions. In a real market, various mechanisms to control demand are being implemented such as DSM, Real Time Pricing. Market power exercise is another important mechanism to consider when the market is designed and tested. Transmission congestion is another area to improve in this model. To forecast the market price in the wholesale market, transmission congestion causes a significant price increase.

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