1 Introduction and Literature Review

1.1 Motivation

The purpose of this research is to use the repeated game model of collusion to analyze the day-ahead market premium in the electricity market. In the literature, large number of goods are traded in a sequential market setup, such as bonds, stock, futures. For a simple economics model, we used to predict that the price will converge in discounted value. However in the empirical observation, there are large inconsistent with this prediction. For example treasury bond market (Coutinho 2013) [1], mutual funds (Zitzewitz 2003) [2] and also electricity markets (Borenstein et al 2008) [3].

1.2 Sequential Market and Declining Price Anomaly

The canonical paper state that the price in the sequential market should converge (Milgorm and Weber 1982)[4]. However, some research documented the declining price anomaly in many sequential markets (McAfee and Vincent 1993) [5]. There are three branches of literature talked about sequential market. Three potential explanations are discussed. First is related to behavior of consumers who are not rational or impatient (Coase 1972) [6] or clearance sale (Nocke and Peitz 2007) [7]. Second is related to risk aversion (McAfee and Vincent 1993) [5] or asymmetric shocks (Bernhardt and Scoones 1994) [8]. But even with those two constrains, if there are arbitrage, then the price must converge, therefore a literature on why there limitations to arbitrage on energy market are discussed (Borenstein et al 2008 [3], Jha and Wolak 2014 [9]).

1.2.1 Risk Aversion of Consumer

If consumers are impatient, then they will make the offer in the first period of the market open. Thus in the first period, the price will be higher due to this impatient. Second, in the setting of typical clearance sale, the producer charge a higher price initially, then consumer with high-valuation will

purchase at the first stage, while the low-valuation consumer will wait until the price to drop. For producer to charge a higher price at the first stage and a lower price at second stage is a utility maximize strategy.

1.2.2 Risk Aversion and Asymmetric Shocks of Good

For consumers when the first period price is fixed it's a certain price, while he does not know the price of the second period, there are some uncertainty in the second stage, therefore he is willing to accept a higher price at the first stage with a certain price rather than a uncertain price with a lower expectation.

1.2.3 Lack of Arbitrage

If there are arbitrage, canonical (Milgorm and Weber 1982) [4] paper showed price will converge. Therefore we need to check how the arbitrage are constrained in the market setting. In electricity market, there are some evidence of lack of arbitrage (Borenstein et al 2008 [3], Jha and Wolak 2014 [9]).

1.3 Collusion

The collusion in energy market is documented in Fabra, Toro (2005) [10] using Spanish electricity market. There are two types of imperfect competition model. The first of it is the Cournot Nash Equilibrium with entry deterrence (Allaz and Vila 1993) [11]. The second is cooperative equilibrium in a repeated game.

1.3.1 Cournot Nash Equilibrium with Entry deterrence Models

The basic idea is that if there are limited number of firm, then the symmetric Nash equilibrium is a imperfect competition. Although this imperfect competition will converge to a perfect competition

as number of the firm goes to infinite. However if there are large fixed costs or/and some punishment threats to entry to the market, then it's possible that there are equilibrium that deters potential competitor in the market.

1.3.2 Cooperative Equilibrium in a repeated game

In a repeated game set up, the basic idea is that if some player does not act according to the designed strategies of cooperative equilibrium, then other players are going to min-max punish the deviator, then by Folk theorem, any outcome that are above threats points are attainable. Although the electricity market is imperfectly monitored, but under suitable conditions then there are still Folk theorem holds.

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