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Electricity Deregulation in Japan

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A. Introduction

Japan is currently in the midst of radically reforming its electricity industry. As one of the very last OECD nations to attempt to deregulate, Japan will complete the deregulation of electricity retailers by April 2016, thereby allowing competition among companies that sell electricity to final consumers. Ultimately, Japanese regulators also seek to deregulate electricity generators in the future as well. An important issue that Japanese regulators must address is whether they will permit integration between vertical companies, specifically, vertically integration between: (1) generation companies that produce electricity, (2) retailer companies that sell electricity to final consumers, and (3) transmission companies that enable the transport of electricity between generators and retailers.

This paper studies the unique way that Japan's proposed deregulation strategy allows for some vertical integration between retail and transmission. Their approach diverges from other countries that only allow vertical integration between generation and retail as in UK, or only allow vertical integration between generation and transmission as in Germany. The paper provides a theoretical basis for these different vertical arrangements and predicts their impact on competition. That is, do we believe that vertical integration will likely benefit or harm consumers as deregulation proceeds and does this differ across the various types of vertical integration mentioned. To do this, I model these three scenarios to provide an analysis of whether Japan's vertical integration between transmission and retail is theoretically sound. The results show that prior to competitive entry, Japan's vertical integration strategy performs worst for final consumers compared with the alternate approaches, however, after competitive entry, Japan's vertical integration strategy performs the best. This said, Japan's vertical integration strategy creates asymmetry between retailers that could raise other potential anticompetitive concerns.

B. Background

All electricity industries are made up of three distinct markets. First, power generators create electricity and operate on the upstream. This market is characterized by high fixed costs and relatively low marginal costs. Although initially state-owned, this market tends to face the most change from competition because generators compete almost exclusively on price with no differentiation across competitors. The retail market operates on the downstream. These companies market and sell electricity to final consumers such as households and industries. Unlike generation, these retail companies face positive variable costs associated with marketing and advertising. Further, product differentiation is possible among retailers such that these companies may compete beyond just price competition. For example, improved quality, speed, and efficiency can allow retailers to distinguish themselves and establish some market power. Finally, the third market is transmission. Here, transmission companies provide the infrastructure for generators to transport their electricity to consumers through cable wiring. What is important is that transmission services are an input for generators in order for them to have access to consumers.[1] Universally, transmission is treated as a natural monopoly because infrastructure is costly to install for both producers and consumers so that it

[1] Electricity Transmission A Primer, NATIONAL COUNCIL ON ELECTRICITY POLICY, 23, 2004, available at http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/primer.pdf (Apr. 29, 2016)

would be inefficient to have competing infrastructure.[2] Further, transmission companies face the complex problem of managing the movement of electricity from generators to consumers in real time because storing electricity is not possible.[3] Because of this, even with privatization, transmission companies operate as monopolies and tend to be highly regulated. Regulators ensure that prices are not too high and that pricing is nondiscriminatory to prevent transmission companies from giving unfair advantage to some generators.

C. Why Deregulate

Through the mid-1970 onwards, most OECD countries faced a wave of deregulation across industries ranging from telecommunication and transport to banking.[4] Electricity market deregulations, however, markedly lagged other industries with efforts occurring in the late 1990s and early 2000s.[5] The US and Germany commenced their deregulation in 1998, and the UK stands as a pioneer being the first country to start deregulating their electricity industry in 1990. In contrast, Japan is late to engage in reform. Japan is part of a small minority of OECD countries that has not completed deregulation of the retail electricity market and has not even started deregulation of the generation market.[6] Interestingly, Japan faces relatively expensive retail electricity prices at about 26 US cents/kWh, which is higher than the average US prices of 12 cents/kWh and UK prices at 22 US cents/kWh, but still lower than German prices at 35 US cents/kWh.[7]

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[2] Al-Sunaidy, A., Green, R., Electricity deregulation in OECD countries. ENERGY 31 (2006) 769, 770.
[3] *Id.* at 8.
[4] Kwoka, John E., *Twenty-Five Years of Deregulation: Lessons for Electric Power*, 33 LOYOLA UNIVERSITY CHICAGO LAW JOURNAL 885, 885 (2002).
[5] Al-Sunaidy at 782 (Table 3).
[6] *Id.*
[7] Average electricity prices around the world: $/kWh, Ovo Energy. https://www.ovoenergy.com/guides/energy-guides/average-electricity-prices-kwh.html (Apr. 29, 2016)

Traditionally, the electricity market was treated as a quintessential case of a natural monopoly worthy of government regulation. Characterized by high fixed costs, close to zero marginal costs, and large economies of scale, power generation appeared to operate most efficiently when supplied by a single provider.[8] Further, transmitting power from the generators to consumers through power cables required installing extensive infrastructure as a public good. As a result, these state-owned monopolies were usually vertically integrated to control both the generation of energy as well as the transmission and retail of energy to the final consumer.[9] These large corporations were believed to be beneficial because they could operate most efficiently at the lowest average cost. To counteract the anticompetitive pricing tendencies of these monopolists, regulators typically imposed "rate of return" pricing that tied the sales price of electricity to a fixed rate of return on investment.[10]

A few realizations drove the wave of deregulation across OECD countries in the 1990s. First, improvements in electricity generation technology reduced costs and created the possibility that multiple firms could profitably operate in a sufficiently large market. However, in the face of these improving technologies, electricity prices still continued to rise, creating pressure to deregulate. These higher prices were attributed to inefficiencies driven by perverse incentives. Specifically, rate of return pricing perversely incentivized companies to artificially raise costs. By inflating costs through inefficient operations, regulated companies could raise their cost of capital and demand higher regulated prices.

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[8] *See* Coulson, Edward N., *The Effect of Electricity Deregulation on State Economies*, Pennsylvania State University. 1 http://grizzly.la.psu.edu/~ecoulson/electric_apr05.pdf (2005).
[9] Klitgaard, Thomas and Rekha Reddy, *Lowering Electricity Prices through Deregulation*, 6 CURRENT ISSUES IN ECONOMICS AND FINANCE 14, 1 (2000).
[10] Al-Sunaidy at 776.

Ultimately, the effect of deregulation on prices is mixed. Certainly cases exist, such as the failed deregulation of California's electricity market, where haphazard deregulation increased market power for incumbents resulting in higher unregulated supracompetitive prices.[11] However, studies attempting to measure the impact of deregulation across US states have found that deregulated states have lower electricity prices on average, particularly for residential consumers.[12] The UK stands as a success story where deregulation of both the generation industry in 1990 and retail industry in 1998 lead to entry and ultimately a 30% reduction in retail prices by 2002.[13] Further, looking at the extent of customer switching from incumbent retailers to other competitors retailers, the UK generally performed well with a 30%–50% switching rate.[14] Although the UK regulators initially required complete vertical separation of generation, transmission, and retail, by 1998, regulators allowed vertical integration between generators and retailers, but not transmission companies.[15]

At the other spectrum, German electricity deregulation was less smooth. Here, instead of complete ownership separation between generation, transmission, and retail, Germany allowed generators and transmission companies to integrate under common ownership.[16] In order to prevent transmission companies from charging higher prices to rival generators, regulators required nondiscriminatory prices so that all generators,

[11] *See* Borenstein, Soren (2002). "The Trouble with Electricity Markets: Understanding California's Restructuring Disaster," *Journal of Economic Perspectives*, 16, 191-211.
[12] Coulson, at 14–15.
[13] Analysis of DTI "Quarterly Energy Prices " Table 2.2.1 2 http://www.dti.gov.uk/energy/inform/energy_prices/tables.sht ml
[14] Al-Sunaidy at 782 (Table 3).
[15] Steve Thomas, *Regulation in a deregulated energy market: British experience*. PSIRU University of Greenwich. 3(2002).
[16] *Id.* at 777–78.

including those owned by transmission companies, were charged the same rate.[17] However, the results indicate that an increase in competition was not obvious in Germany. Instead of more market players, liberalization resulted in greater concentration. Originally, the eight major companies accounting for 79% of the generation market shrunk to four companies accounting for 96% of the market seven years after liberalization.[18] Similarly for retail, five companies accounting for 59% of the retail market shrunk to four companies accounting for 72.8% of the market.[19] Looking to electricity prices, the six years after liberalization has not seen a sustained reduction but rather just a stagnation of retails prices.[20] Finally, as expected, estimates on customer switching rate from incumbent retailers to competitors is only at 5%-10%.[21]

D. Japanese Electricity Deregulation

The Japanese situation has faced a similar general history. Originally established as a state-run entity, Japan privatized its energy market by forming ten regulated regional monopolies, each with ownership over power generation, cable transmission, and retailing energy to consumers.[22] Here, regulators set prices to allow these firms to earn about a 3% rate of return.[23] Japan's initial efforts at deregulation also arose under a similar concern of inefficiencies and pressures to reduce costs and prices. Among OECD countries, Japan has the eighth most expensive retail prices for households largely attributed to cost inflation.

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[17] *Id.* at 779.
[18] Brandt, Torsten, *Liberalization, privatization and regulation in the German electricity sector*, 5 Wirtschafts- und Sozialwissenschaftliches Institut (WSI) in der Hans-Böckler-Stiftung. (2006).
[19] *Id.*
[20] *Id.* at 16.
[21] Al-Sunaidy at 782 (Table 3).
[22] *Utilities have a Monopoly on Power*. The Japan Times available at http://www.japantimes.co.jp/news/2011/09/06/news/utilities-have-monopoly-on-power/#.Vx7LhBjGJbU (Apr. 29, 2016).
[23] *Id.*

For example, TEPCO's expenditure of ¥11.6 billion (approximately $109 million) on advertising was criticized because as a monopolist, such expenditures on advertising was unnecessary.[24] Most recently, Japan's electricity markets faced severe constraints following the Fukushima earthquake disaster that caused a crisis at Japanese nuclear plants. The subsequent shutdown of all nuclear plants, most of which are still closed today, eliminated 30% of Japan's power source leading to volatile electricity shortages and electricity bills rising much as 40%.[25] Finally, Japan's increasing reliance on imports to meets its energy needs has left it with an energy self-sufficiency rate at only 6%, the second lowest among OECD countries.[26] This concern over energy security has further pressured Japan's agencies to look to market mechanisms to improve energy efficiency.[27]

Nevertheless, Japan's deregulation process has been markedly gradual and incomplete. First, unlike retail deregulation among other OECD countries that have taken between one to nine years to complete, Japan's deregulation of retail began in 2000 and is set to finish sixteen years later by April 2016. Further, although entry into these previously closed markets has opened up for some 60% of the retail market, regulated price caps will not be removed until April 2020.[28] This gradual approach is influenced by a reaction to the British and Californian experience of large price spikes and volatility closely following

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[24] *Id.*

[25] Notes from meeting with the Ministry of Economy Trade and Industry on Electricity Market Reform in Japan on March 22nd 2016.

[26] Notes from meeting with the Ministry of Economy Trade and Industry on Electricity Market Reform in Japan on March 22nd 2016.

[27] Energy deregulation threatens to break up Japanese monopolies. The Financial Times. March 29, 2015 available at http://www.ft.com/intl/cms/s/2/ac713e7a-cbd1-11e4-beca-00144feab7de.html#axzz467AnmGHK (Apr. 29, 2016)

[28] Notes from meeting with the Ministry of Economy Trade and Industry on Electricity Market Reform in Japan on March 22nd 2016.

deregulation.[29] Second, Japan is unique in deciding to complete deregulation of the retail electricity market first, before commencing deregulation of the power generation market. Neither the UK, the US, nor Germany adopted this approach believing that energy inefficiencies primarily occurs in the generation market.

In terms of the specific deregulatory policy, there are two characteristics that make Japan's deregulation particularly novel: (1) greater product differentiation at the retail market, and (2) vertical integration allowed between retail and transmission. Typically, electricity markets operate completely independent from other utilities. However, Japanese regulators have made a concerted effort to attract a diverse array of potential entrants from other industries to enter the retail market.[30] Specifically, Japanese regulators have registered potential retail entrants across numerous other industries including: five companies operating in gas and oil, five companies operating in renewables, four companies operating in telecommunication and broadcast, and companies operating in other utilities such as railway.[31] The strategy is that these companies will bundle electricity services with other services such as heating, gas, or telecommunications to sell to final consumers. By doing so, product differentiation is now possible as firms not only compete on price, but can provide a unique bundle of products that compete on quality.

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[29] Notes from meeting with the Ministry of Economy Trade and Industry on Electricity Market Reform in Japan on March 22nd 2016.

[30] Notes from meeting with the Ministry of Economy Trade and Industry on Electricity Market Reform in Japan on March 22nd 2016; Ito, Koichiro., *Deregulation of Japan's Electricity Market: Key Factors Needed for Success*. Energy Policy Institute at the University of Chicago. March 1, 2016 available at https://epic.uchicago.edu/news-events/news/deregulation-japan%E2%80%99s-electricity-market-key-factors-needed-success.

[31] Notes from meeting with the Ministry of Economy Trade and Industry on Electricity Market Reform in Japan on March 22nd 2016.

This approach attempts to address concerns that the low marginal cost of electricity may results in unsustainably low electricity margins for retailers that hinder entry.

Japan's second major difference is the way it seeks to separate generation, transmission, and retail. Originally, generation, transmission, and retail operations were all vertically integrated and divided into regional monopolies. With the commencement of retail liberalization in 2000, entry came from both generators seeking vertical integration and new entrants from other industries. However, by 2020, regulators will require that generation be completely independent, such that a company that generates electricity can have no ownership rights of any transmission or retail company. The separation between generation and retail is justified given the concern that a generator with market power can engage in exclusionary conduct by discriminating across rival retailers. Conversely, the separation between generation and transmission is justified by the concern that transmission companies, which operates as a natural monopoly, may discriminate among competing generators once this market opens up. However, vertical integration between transmission and retailers will be allowed in Japan.[32] In doing so, Japanese regulators still require "legal unbundling" whereby transmission departments are prohibited from discriminatory pricing or treatment across any of the generators that they sell to. But since transmission companies do not sell directly to retailers and only impact retailers' prices via generators, this may alleviate concerns of discriminatory exclusion vis-à-vis retailers.

Japan's arrangement differs from the British and German approach as illustrated in Figure A. Recall that although the UK initially required disintegration across all three

[32] Notes from meeting with the Ministry of Economy Trade and Industry on Electricity Market Reform in Japan on March 22nd 2016.

markets, they eventually allowed integration between generators and retailers. Beyond possible efficiencies, one benefit for consumers is the elimination of a double margin from a merged generator and retailer entity because generators sell electricity directly to retailers. Similarly, vertical integration between transmission companies and generators, as found in Germany, may also benefits from eliminating double margins. This benefit of eliminating double margins may not exist in Japan's transmission-retail integration because transmission companies sells directly to generators and only impacts retailers' behavior via generators.

The next section shall discuss the theoretical implications of the various vertical integration arrangements between Japan, the UK, and Germany. By taking into account product differentiation at the retail level in the Japanese market, the theory shall predict price effects under the various vertical arrangements.

E. Theory

In analyzing Japan's model, I make three simplifying assumptions. First, regulatory enforcement is perfect such that regulations that prohibit discriminatory pricing operate perfectly. Second, I assume there are no countervailing efficiencies to vertical integration beyond the elimination of double margins. Although regulators may operate imperfectly or countervailing efficiencies may exist, I ignore these because I am interested in the *prima facie* expectation of these vertical arrangements. Third, for simplicity, I assume there are no price-cap regulations before and after competitive entry. Although Japanese regulators will likely continue to limit transmission prices after deregulation, estimating prices effects without price regulation informs the pricing incentives of these companies. Seven models are analyzed consisting of: a status quo benchmark model with full integration and no competition, the three UK, German, and Japanese vertical arrangements prior to competitive entry, and then three UK, German, and Japanese vertical arrangement after competitive entry. Figure A and B presents an illustration of the six models and Appendix A presents the analytical model.

00. Status Quo No Deregulation (Full Integration and No Competition)

This is the status quo pre-deregulation scenario where one vertically integrated firm dominates the entire industry. It is not necessarily clear that this scenario is bad because the benefits of eliminating double or triple margins create efficiencies despite monopoly pricing. To account for cost inflations that exist in closed markets, I apply an inefficiency factor where costs under "No Competition" scenarios are *x* times the costs under competitive entry scenarios. There is no loss of generality in applying this factor.

A1. Generation-Retail Integration, No Competition (UK Model, pre-entry)

Because a generators-retailers entity is now separated from the transmission companies, the imposition of two margins on the retail price should raise prices compared with "00 Status Quo". A cost-inflation factor is applied to this scenario.

A2. Transmission-Generation Integration, No Competition (German Model, pre-entry)

Because a transmission-generation entity is now separated from retailers, the imposition of two margins on the retail price should raise prices compared with "00 Status Quo". A cost-inflation factor is applied to this scenario.

A3. Transmission-Retail Integration, No Competition (Japan Model, pre-entry)

Because a transmission-generation entity is now separated from retailers, the imposition of multiple margins on the retail price should raise prices. However, since a monopolistic generator may pass on some of the high transmission prices down to the retailer, transmission companies may have an incentive to lower their prices. The net effect compared to "00 Status Quo" is ambiguous. A cost-inflation factor is applied.

B1. Generation-Retail Integration, Full Competition (UK Model, post-entry)

A generator engaged in perfect competition with others integrates with one of the retailers. With competitive entry, competition among generators should push prices down to marginal cost. But since retailers are able to differentiate themselves by bundling their electricity services with other utilities, they should be able to maintain some supracompetitive retail price. This dynamic is modeled as a Bertrand product differentiation duopoly game between two retailers.[33] Finally, the transmission monopolist still charges monopoly prices. Overall, it is not clear whether integration creates any benefits since margins for generators are already at zero.

B2. Transmission-Generation Integration, Full Competition (German Model, post-entry)

A generator engaged in perfect competition with others integrates with the transmission monopolist. With competitive entry, competition among generators should push generation prices down to marginal cost, while the transmission company can still prices as a monopolist. Retailers price supracompetitively under a Bertrand product differentiation duopoly game.

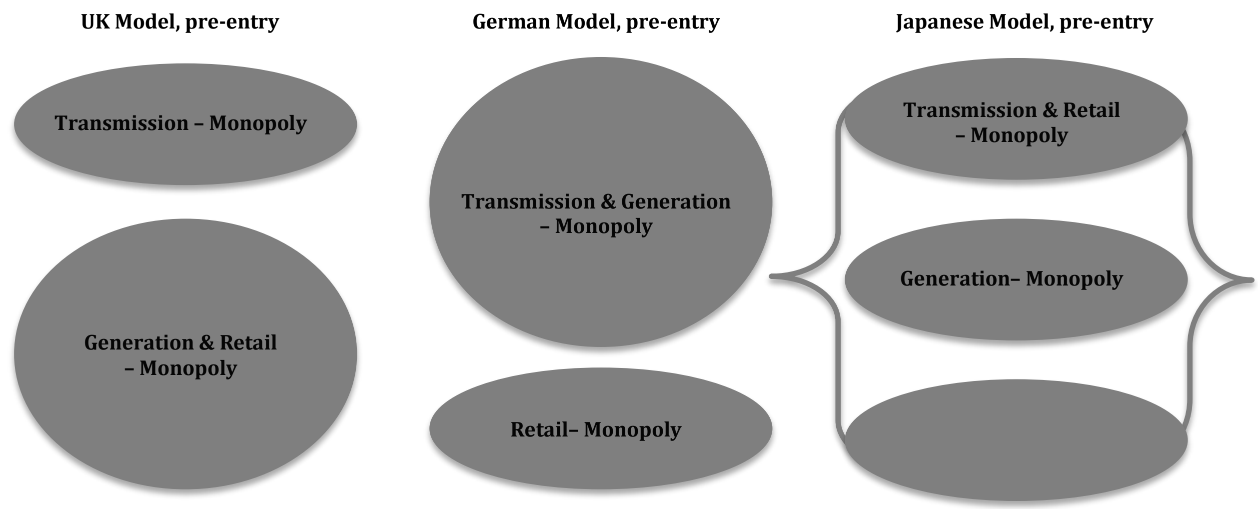
B3. Transmission-Generation Integration, Full Competition (Japan Model, post-entry)

One of the retailers competing in Bertrand duopoly integrated with the transmission monopolist. Bertrand competition at the retail market should drive prices down though

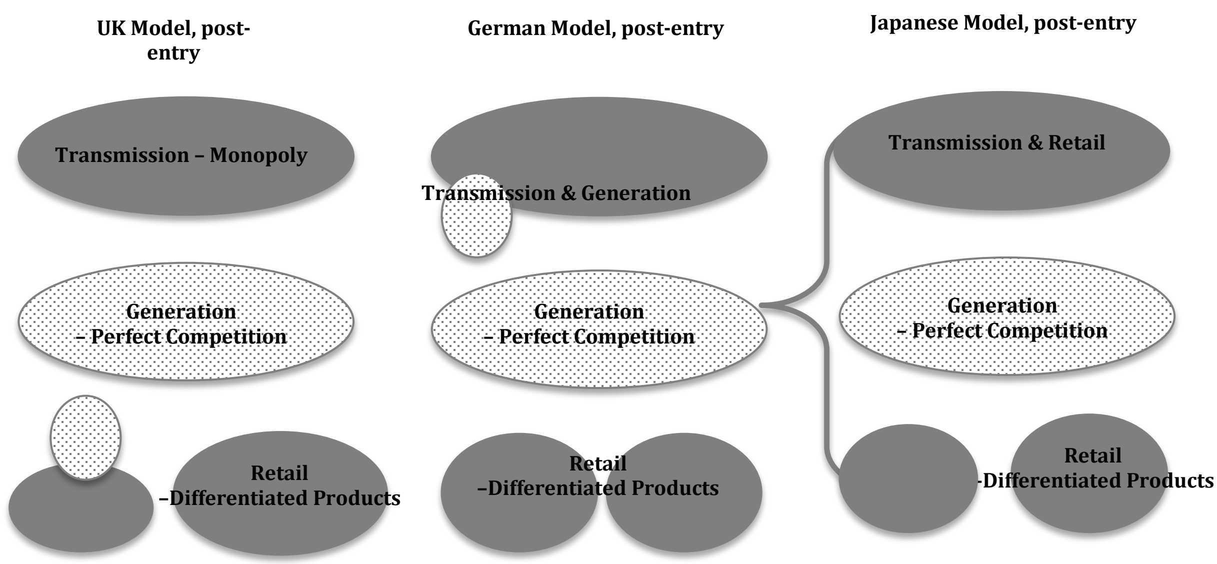
[33] Bertrand product differentiation models are a standard tools used to model mergers in antitrust. The model assumes that retailers are engaged in price (rather than quantity) competition and allows for some product differentiation so that a price increase on one retailer will lead some, but not all, consumers to switch to a competitor.

prices should remain above marginal cost. Further, even if the transmission company operates as a monopoly, the impact of the transmission company's prices on retail, via pass-through from generators, should further place a downward pressure on price.

<u>Figure A – Vertical Integration without Competition</u>



<u>Figure B – Vertical Integration with Competition</u>



F. Analysis

Profit maximization models are calculated for each of the seven scenarios above. The model assumes linear demand of the form Q = $\alpha - \beta P$. For the Bertrand product differentiation duopoly model, the two retailers' demand functions are $q_1 = \frac{\alpha}{2} - \frac{3}{2}\beta P_{r1} + \beta P_{r2}$ and $q_2 = \frac{\alpha}{2} - \frac{3}{2}\beta P_{r2} + \beta P_{r1}$ such that q_1 + q_2 = Q when $p_1 = p_2$= P. Retailers #1 and #2 face marginal costs respectively c_{r1} and c_{r2} and generators face marginal cost c_g. Finally, these costs are subject to an x factor increase in the pre-entry models A1-A3. Profit maximizing equilibria are calculated for each entity in the model. This is done by first deriving the first order condition for each profit maximizing entity and then solving for the equilibrium retail price. Appendix A presents the profit maximizing functions and the derived formula for equilibrium retails prices. From here, equilibrium quantity, consumer, and producer surplus can be easily calculated.

To illustrate the competitive effects, an example where $\alpha = 100$, $\beta = 1$, $c_{r1} = c_{r2} = c_g$ =5 and $x = 4$ is calculated. Figure C and D show the price and surplus effects for each scenario normalized to the base case of "00 Status Quo". The direction of the price effects relative to the base case is general such that it does not depend on the magnitude of α, β, c, or x as proven in Appendix A.

Figure C: Estimated Average Retail Price Effect

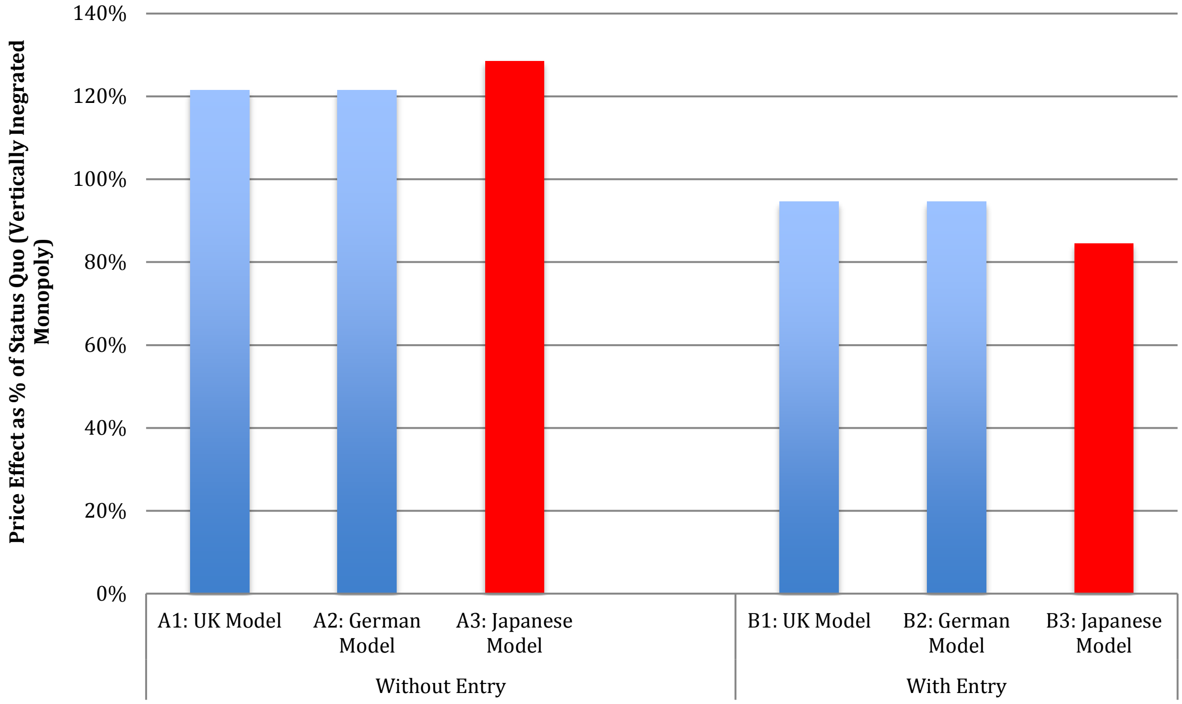


Figure D: Estimated Consumer and Producer Surplus Effects

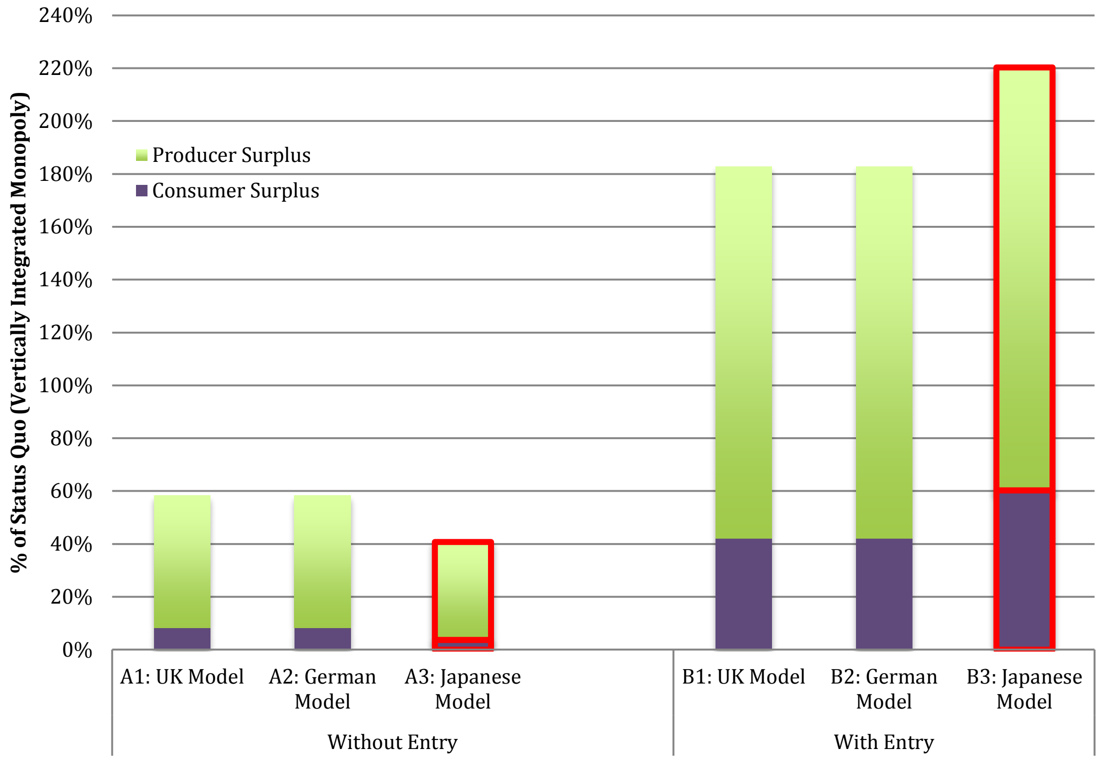


Figure C and D presents some interesting results. First, compared to the status quo of a fully vertically integrated monopoly, all three models show that vertical disintegration without competitive entry worsens price and surplus due to the imposition of multiple margins that disintegration creates. However, once entry is allowed such that generation becomes perfectly competitive and retail competes with product differentiation, then both price and surplus improve as expected.

What makes the analysis interesting is the asymmetry between the Japanese Model (allowing integration between transmission and retail) and the UK (allowing integration between generation and retail) and German Model (allowing integration between transmission and generation). Here we see that without competitive entry, the Japanese model performs worse than the UK and German Model with higher prices and lower surpluses. This is driven by the fact that integrating retailer and generators (UK) or transmission companies with generators (Germany) has the benefit of removing double margins. This benefit does not exist when integrating transmission and retail because transmission companies do not sell to retailers directly. As a result, any lower price that transmission companies sells to generators has a less than 100% pass-through benefit to retailers.

This said, when the generation and retail markets are liberalized to allow entry, then we see a reversal. Now, the Japanese model outperforms the UK and German model with lower prices and higher surpluses. This is because competition in the generation market eliminates their market power, driving prices to marginal cost. As a result, there are no benefits from eliminating double margins because generation margins are already zero. But the Japanese model has the added benefit that vertical integration between transmission and retail creates an incentive for the transmission-retailer to use its monopoly profit in transmission to subsidize its retail prices. The transmission-retailer entity can profitably maintain a high price of transmission as a costs imposed to generators and ultimately on all retailers including rival retailers. However, at the same time, the transmission-retailer entity can also use its transmission monopoly rents to subsidize the price of its own retailer. In doing so, the integrated entity can expand market share in the retail market to recoup the losses from the subsidization. Note that this result still maintains the nondiscriminatory transmission price that is constantly applied across all generators as required by Japanese regulation.

Ultimately, the net effect of competition of the Japanese model is still ambiguous. Although consumers benefit from the lower prices that transmission subsidizes, this creates an asymmetrical advantage for the integrated retailer over its rivals. If this advantage is maintained, the transmission-retail integrated entity could capture sufficient market share to exercise market power. This could lead to a return to concentrated markets and cost inflation that occurred in Germany. Take Figure E, which shows the trend of average retail prices as the rival retailer becomes more efficient relative to the transmission-retailer entity. In the situation of no integration at all, prices steadily fall as the rival firm becomes more efficient and gains market share. This is because a rival's cost advantage pressures all retailers to lower prices to compete. However, when there is transmission-retailer integration, average prices fails to fall as fast in reaction to lower rival costs. This can indicate a reduction in competitive pressure and inefficiency in the market. Similarly, Figure F shows the increase in the market share of a more efficient rival as the more efficient rival lowers its costs. Although the rival's market share increases with efficiency, the transmission-retailer firm is able to maintain a significant market share advantage in the face of the rival's increasing efficiency. If product differentiation is strong enough, this could lead to a result where more efficient retailers are hindered or even excluded from the market due to the subsidies that the transmission entity provides to their retailer.

Figure E: Average Retail Price as Rival Cost Efficiency Improves

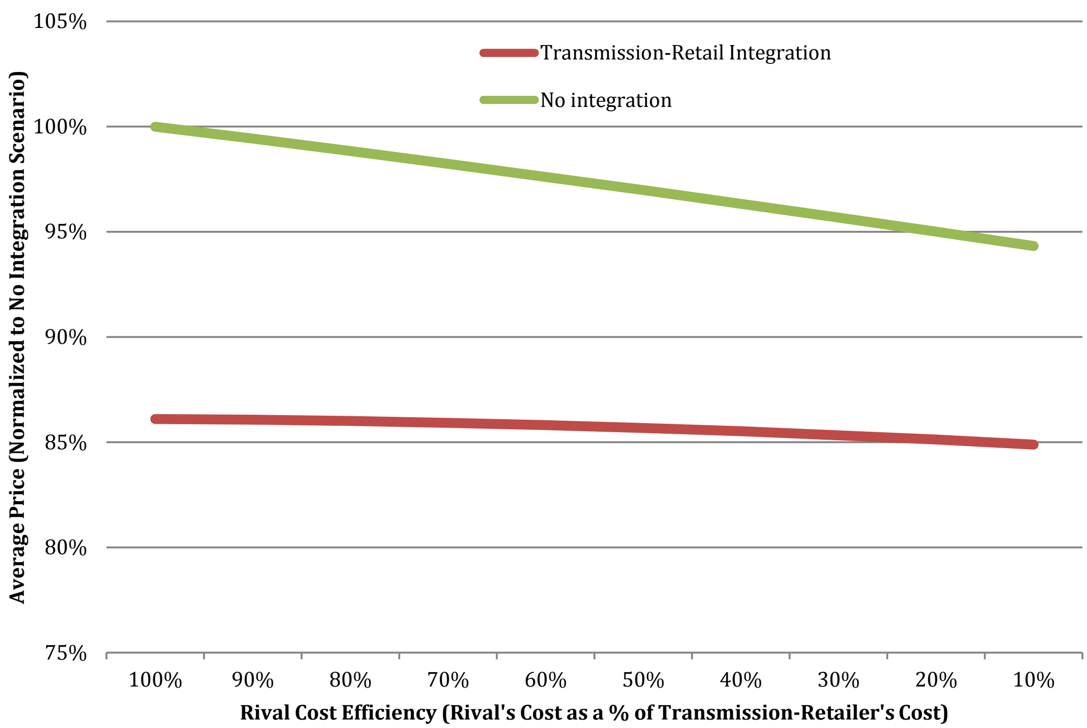
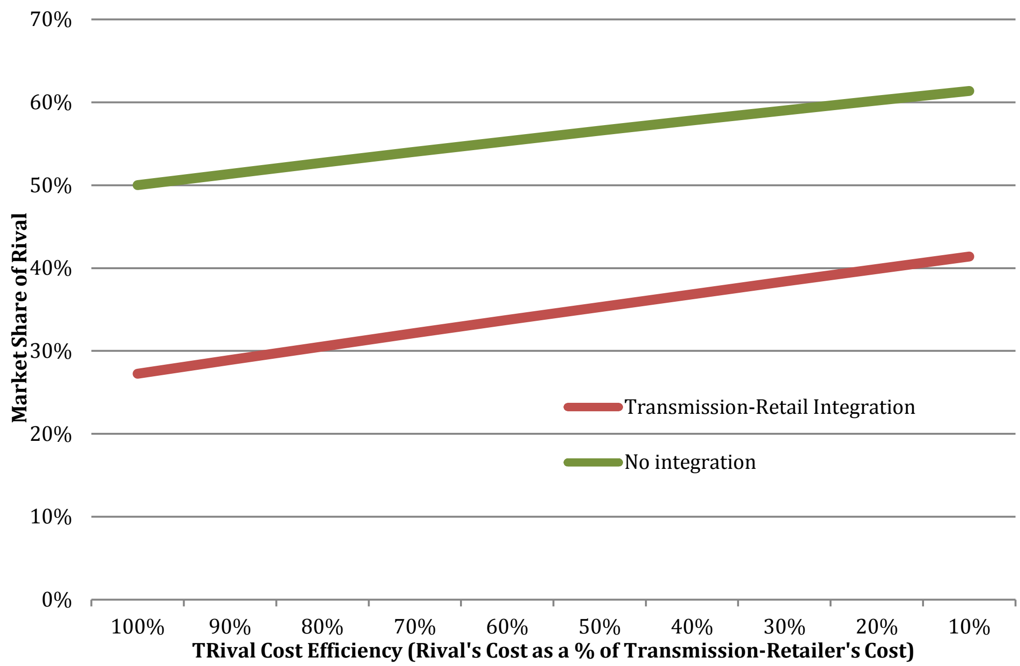


Figure F: Rival's Market Share as Rival Cost Efficiency Improves



G. Conclusion

These unique results are driven by the interaction between transmission-retailer integration and product differentiation at the retail market. Japanese regulators have a sound understanding of each of these effects independently. Transmission-retailer integration on its own is beneficial as it creates incentives to lower retail prices with no price discrimination. Further, product differentiation grants retailers some market power to induce diverse entry and allows for quality competition, rather than pure price competition. But when these two dynamics interact, the overall competitive effect is more complex and ambiguous.

From a consumer perspective, prices are lower and both producer and consumer surplus are higher under the Japanese Model. However, these lower prices come with a dominant retailer that may have sufficient market power to hinder entry and increase concentration. Modern economic theory rejects predatory pricing as anticompetitive because a dominant firm could not profitably drive out rivals through below-cost pricing and expect to recoup. However, this situation is different because the transmission-retailer can subsidize retail prices above costs to expand their retail market share in a way that is profitable.[34] What is important is that this type of vertical integration, even with aggressive regulation, forces the integrated entity to take account of the effect of its transmission prices its own retail sales. This said, a possible counterargument is that the transmission-retailer advantage is needed to counteract the market power that diverse rivals exercise when they bundles electricity services with others utilities. These rivals could use the market power in their other utilities markets to subsidize electricity retail prices similar to what the transmission-retailer does.

Ultimately, this paper is unable to provide a conclusive result on the competitive impact of Japan's model because there are crosscutting effects that depend on antitrust goals and empirical facts. Rather, this paper raises some unique issues that have not been addressed in prior deregulations efforts and are not necessarily obvious to Japanese regulators.

Nevertheless, there is one clear policy implication. Recall that the Japanese model performs worse than the UK and German model under closed markets, but performs better than the UK and German model once competition opens up. This makes Japan's slow and gradual deregulation process problematic. Retail market liberalization took sixteen to complete, vertical integration regulation will not be imposed until 2020, and only afterwards shall deregulating the generation market commence. This delay is likely to be harmful because Japan's model is especially harmful to consumers without competition.

[34] The simulation in Figure D predicts that the transmission-retailer entity has 14% high profits with vertical integration than without.

The benefits of vertical integration only accrue after competition opens up and entry is allowed. Such gradualism may also exacerbate the asymmetric effects that transmission-retail integration creates in the retail market. As a result, Japanese regulators should seek faster reforms that open up competition earlier. From discussion with the regulators, it is likely that the hesitance to deregulate generation is more of a political problem due to entrenched interests, rather than a purposeful strategy. Nevertheless, with an established commitment to deregulate generation, sooner is better than later.

Appendix A

This appendix presents the theoretical analysis for the seven models presented in the paper. Each model assumes the same linear demand function for retail electricity of form Q = $\alpha - \beta P$, applies the relevant vertical integration and competition structure, and then calculates the profit maximizing equilibria for each participant. For each model, this appendix will: (a) identify the participants and the type of vertical integration, (b) present the profit maximization problem for each participant, (c) present the first-order conditions for each participant, (d) solve for the equilibrium retail price.

Assumed Inputs	
α	x-intercept of the linear demand function when P = 0
β	Slope of the linear demand function as P increases
c_g	Marginal cost of generators
c_r	Marginal cost of retailers
c_{r1}	Marginal cost of retailer #1
c_{r2}	Marginal cost of retailer #2
x	Cost-inflation factor that applied to all costs with no-competition
Calculated Variables	
π_t	Profit function of an independent transmission company
π_g	Profit function of an independent generator
π_r	Profit function of an independent retailer
π_{r1}	Profit function of an independent retailer #1
π_{r2}	Profit function of an independent retailer #2
π_{gr}	Profit function of a generator-retailer integrated company
π_{tg}	Profit function of a transmission-generator integrated company
π_{tr}	Profit function of a transmission-retailer integrated company
π_{tgr}	Profit function of a transmission-generator-retailer integrated company
P_t	Price that an independent transmission company sells.
P_g	Price that an independent generator sells.
P_r	Price that an independent retailer.
P_{r1}	Price that an independent retailer #1 sells.
P_{r2}	Price that an independent retailer #2 sells.

<u>Scenario 00: Status Quo of Full Integration and No Competition</u>

This scenario involves one vertically integrated profit-maximizing firm that assumes all generation and retailing costs and sells directly to the final consumer. The firm's profit function is:

$$\pi_{tgr} = P_r(\alpha - \beta P_r) - xc_g(\alpha - \beta P_r) - xc_r(\alpha - \beta P_r)$$

The firm is a monopolist, so it sets P_r such that:

$$\alpha - 2\beta P_r + xc_g\beta + xc_r\beta = 0$$

The equilibrium retail price is:

$$P_r^* = \frac{\alpha}{2\beta} + \frac{xc_g}{2} + \frac{xc_r}{2}$$

Scenario A1: Generation-Retailer Integration, No Competition

This scenario involves two entities. A transmission monopolist that sells transmission services to a vertically integrated generator-retailer monopolist that sells directly to the final consumer. The profit functions of the two entities are:

$$\pi_{gr} = P_r\left(\alpha - \beta P_{gr}\right) - xc_r(\alpha - \beta P_r) - xc_g(\alpha - \beta P_r) - P_t(\alpha - \beta P_r)$$
$$\pi_t = P_t\left(\alpha - \beta P_{gr}\right)$$

The respective first order conditions are:

$$P_r = \frac{\alpha}{2\beta} + \frac{xc_g}{2} + \frac{xc_r}{2} + \frac{P_t}{2}$$
$$P_t = \frac{\alpha}{2\beta} - \frac{xc_g}{2} - \frac{xc_r}{2}$$

The equilibrium retail price is:

$$P_r^* = \frac{3\alpha}{4\beta} + \frac{xc_g}{4} + \frac{xc_r}{4}$$

Scenario A2: Transmission-Generation Integration, No Competition

This scenario involves two entities. A vertically integrated transmission-generation monopolist that sells transmission services to a retailer monopolist that sells directly to the final consumer. The profit functions of the two entities are:

$$\pi_r = P_t(\alpha - \beta P_r) - xc_r(\alpha - \beta P_r) - P_g(\alpha - \beta P_r)$$
$$\pi_{tg} = P_g(\alpha - \beta P_r) - xc_g(\alpha - \beta P_r)$$

The respective first order conditions are:

$$P_r = \frac{\alpha}{2\beta} + \frac{xc_r}{2} + \frac{P_g}{2}$$
$$P_g = \frac{\alpha}{2\beta} + \frac{xc_g}{2} - \frac{xc_r}{2}$$

The equilibrium retail price is:

$$P_r^* = \frac{3\alpha}{4\beta} + \frac{xc_g}{4} + \frac{xc_r}{4}$$

Scenario A3: Transmission-Retail Integration, No Competition

This scenario involves two entities, a vertically integrated transmission-retail monopolist and a generator monopolist. Here, the transmission-retailer monopolist both sells transmission services to the generator monopolist but also purchases power from the generator that they sell directly to the final consumer. As a result, the transmission-retailer monopolist maximizes profits by setting two prices, P_t and P_r. The profit functions of the two entities are:

$$\pi_{tr} = P_r(\alpha - \beta P_r) - xc_r(\alpha - \beta P_r) - P_g(\alpha - \beta P_r) + P_t(\alpha - \beta P_r)$$
$$\pi_g = P_g(\alpha - \beta P_r) - xc_g(\alpha - \beta P_r) - P_t(\alpha - \beta P_r)$$

The transmission-retailer's first order condition when setting the retail price, P_r is:

$$P_r = \frac{\alpha}{2\beta} + \frac{xc_r\beta}{2} + \frac{P_g}{2}$$

The generator's sets its price, taking the transmission-retailer's first order condition as given, such that:

$$P_g = \frac{\alpha}{2\beta} + \frac{xc_g}{2} - \frac{xc_r}{2} + \frac{P_t}{2}$$

The transmission-retailer maximizes profit by setting P_t taking the P_g and P_r functions as given such that:

$$P_t = \frac{\alpha}{3\beta} - \frac{xc_g}{3} - \frac{xc_r}{3}$$

Solving for the equilibrium retail price gives:

$$P_r^* = \frac{5\alpha}{6\beta} + \frac{xc_g}{6} + \frac{xc_r}{6}$$

Scenario B1: Generation-Retailer Integration, With Competition

This scenario involves a transmission company monopolist, multiple generators engaged in perfect competition, and two retailers engaged in Betrand product differentiation competition. However, one of the generators competing perfectly is vertically integrated with one of the retailers. Thus, this scenario models the profit maximizing behavior of three entities: the transmission company monopolist, retailer #1 that is integrated with a generator, and retailer #2 that operates independently and competes with retailer #1. The demand equations for retailer #1 and #2 respectively are $q_{r1} = \frac{\alpha}{2} - \frac{3}{2}\beta P_{r1} + \beta P_{r2}$ and $q_{r2} = \frac{\alpha}{2} - \frac{3}{2}\beta P_{r2} + \beta P_{r1}$ so that $q_{r1} + q_{r1} = \alpha - \frac{1}{2}\beta P_{r1} - \frac{1}{2}\beta P_{r2} = Q$ when $P_{r1} = P_{r2}$. The profit function for the transmission company monopolist:

$$\pi_t = P_t(q_{r1} + q_{r1}) = P_t(\alpha - \frac{1}{2}\beta P_{r1} - \frac{1}{2}\beta P_{r2})$$

Profit function for the retailer #1 integrated with a generator.

$$\pi_{r1} = P_{r1}(q_{r1}) - c_{r1}(q_{r1}) + P_g(q_{r1}) - P_g(q_{r1}) - c_g(q_{r1}) - P_t(q_{r1}) + P_g(q_{r2}) - c_g(q_{r2}) - P_t(q_{r2})$$

Retailer #2's profit function is:

$$\pi_{r2} = P_{r2}(q_{r2}) - c_{r2}(q_{r2}) - P_g(q_{r2})$$

All generators operate in perfect competition such that:

$$P_g = c_g + P_t$$

Retailer #1's profit function simplifies to:

$$\pi_{r1} = P_{r1}(q_{r1}) - c_{r1}(q_{r1}) - c_g(q_{r1}) - P_t(q_{r1})$$

Retailer #2's profit function simplifies to:

$$\pi_{r2} = P_{r2}(q_{r2}) - c_{r2}(q_{r2}) - c_g(q_{r2}) - P_t(q_{r2})$$

The reaction functions for the two retailers are:

$$P_{r1} = \frac{\alpha}{6\beta} + \frac{c_g}{2} + \frac{c_{r1}}{2} + \frac{P_{r2}}{3} + \frac{P_t}{2}$$
$$P_{r1} = \frac{\alpha}{6\beta} + \frac{c_g}{2} + \frac{c_{r2}}{2} + \frac{P_{r2}}{3} + \frac{P_t}{2}$$

The retailers' first order conditions with respect to P_t are:

$$P_{r1} = \frac{\alpha}{4\beta} + \frac{9c_{r1}}{16} + \frac{3c_{r2}}{16} + \frac{3c_g}{4} + \frac{3P_t}{4}$$
$$P_{r2} = \frac{\alpha}{4\beta} + \frac{9c_{r2}}{16} + \frac{3c_{r1}}{16} + \frac{3c_g}{4} + \frac{3P_t}{4}$$

The transmission company's first order conditions taking the retailers' reaction functions as given is:

$$P_t = \frac{\alpha}{2\beta} + \frac{c_{r1}}{4} + \frac{c_{r2}}{4} + \frac{c_g}{2}$$

Solving for the equilibrium retail price is:

$$P_{r1}^* = \frac{5\alpha}{8\beta} + \frac{3c_{r1}}{8} + \frac{3c_g}{8}$$
$$P_{r2}^* = \frac{5\alpha}{8\beta} + \frac{3c_{r2}}{8} + \frac{3c_g}{8}$$

<u>Scenario B2: Transmission-Generation Integration, With Competition</u>

This scenario involves a transmission company monopolist that is integrated with a generator engaged in perfect competition. The generators sell electricity to two retailers engaged in Betrand product differentiation competition. The demand equations for retailer #1 and #2 respectively are $q_{r1} = \frac{\alpha}{2} - \frac{3}{2}\beta P_{r1} + \beta P_{r2}$ and $q_{r2} = \frac{\alpha}{2} - \frac{3}{2}\beta P_{r2} + \beta P_{r1}$ so that $q_{r1} + q_{r1} = \alpha - \frac{1}{2}\beta P_{r1} - \frac{1}{2}\beta P_{r2} = Q$ when $P_{r1} = P_{r2}$.

The profit function for the transmission-generator company is:

$$\pi_{tg} = P_t(q_{r1} + q_{r2}) + P_g(q_{r1} + q_{r2}) - P_g(q_{r1} + q_{r2}) - c_g(q_{r1} + q_{r2})$$

The profit function for two retailers, #1 and #2, are:

$$\pi_{r1} = P_{r1}(q_{r1}) - c_{r1}(q_{r1}) - P_g(q_{r1})$$
$$\pi_{r2} = P_{r2}(q_{r2}) - c_{r2}(q_{r2}) - P_g(q_{r2})$$

Since all generators operate in perfect competition such that $P_g = c_g + P_t$, the retailers' profits functions simplify to:

$$\pi_{r1} = P_{r1}(q_{r1}) - c_{r1}(q_{r1}) - c_g(q_{r1}) - P_t(q_{r1})$$
$$\pi_{r2} = P_{r2}(q_{r2}) - c_{r2}(q_{r2}) - c_g(q_{r2}) - P_t(q_{r2})$$

The reaction functions for the two retailers are:

$$P_{r1} = \frac{\alpha}{6\beta} + \frac{c_g}{2} + \frac{c_{r1}}{2} + \frac{P_{r2}}{3} + \frac{P_t}{2}$$
$$P_{r1} = \frac{\alpha}{6\beta} + \frac{c_g}{2} + \frac{c_{r2}}{2} + \frac{P_{r2}}{3} + \frac{P_t}{2}$$

T

he retailers' first order conditions with respect to P_t and P_r are:

$$P_{r1} = \frac{\alpha}{4\beta} + \frac{9c_{r1}}{16} + \frac{3c_{r2}}{16} + \frac{3c_g}{4} + \frac{3P_t}{4}$$
$$P_{r2} = \frac{\alpha}{4\beta} + \frac{9c_{r2}}{16} + \frac{3c_{r1}}{16} + \frac{3c_g}{4} + \frac{3P_t}{4}$$

The transmission company maximizes profit taking the retailers' reaction functions so that:

$$P_t = \frac{\alpha}{2\beta} + \frac{c_{r1}}{4} + \frac{c_{r2}}{4} + \frac{c_g}{2}$$

Solving for the equilibrium retail price is:

$$P^*_{r1} = \frac{5\alpha}{8\beta} + \frac{3c_{r1}}{8} + \frac{3c_g}{8}$$
$$P^*_{r2} = \frac{5\alpha}{8\beta} + \frac{3c_{r2}}{8} + \frac{3c_g}{8}$$

Scenario B3: Transmission-Retailer Integration, With Competition

This scenario involves a transmission company monopolist that is integrated one of the retailers engaged in Betrand product differentiation competition with another retailer. The demand equations for retailer #1 and #2 respectively are $q_{r1} = \frac{\alpha}{2} - \frac{3}{2}\beta P_{r1} + \beta P_{r2}$ and $q_{r2} = \frac{\alpha}{2} - \frac{3}{2}\beta P_{r2} + \beta P_{r1}$ so that $q_{r1} + q_{r1} = \alpha - \frac{1}{2}\beta P_{r1} - \frac{1}{2}\beta P_{r2} = Q$ when $P_{r1} = P_{r2}$. All generators operate independently and are engaged in perfect competition.
The profit function for the transmission-retailer company (retailer #1) is:

$$\pi_{r1} = P_{r1}(q_{r1}) - c_{r1}(q_{r1}) - P_g(q_{r1}) + P_t(q_{r1} + q_{r2}),$$

The profit function for the other retailers #2 is:

$$\pi_{r2} = P_{r2}(q_{r2}) - c_{r2}(q_{r2}) - P_g(q_{r2})$$

Since generators compete perfectly such that $P_g = c_g + P_t$ the profit function simplifies to:

$$\pi_{r1} = P_{r1}(q_{r1}) - c_{r1}(q_{r1}) - c_g(q_{r1}) + P_t(q_{r2}),$$
$$\pi_{r2} = P_{r2}(q_{r2}) - c_{r2}(q_{r2}) - c_g(q_{r2}) - P_t(q_{r2})$$

The reaction functions for the two retailers are (note that they are not symmetric):

$$P_{r1} = \frac{\alpha}{6\beta} + \frac{c_g}{2} + \frac{c_{r1}}{2} + \frac{P_{r2}}{3} + \frac{P_t}{3}$$
$$P_{r2} = \frac{\alpha}{6\beta} + \frac{c_g}{2} + \frac{c_{r2}}{2} + \frac{P_{r2}}{3} + \frac{P_t}{2}$$

The retailers' first order conditions with respect to P_t are:

$$P_{r1} = \frac{\alpha}{4\beta} + \frac{9c_{r1}}{16} + \frac{3c_{r2}}{16} + \frac{3c_g}{4} + \frac{9P_t}{16}$$
$$P_{r2} = \frac{\alpha}{4\beta} + \frac{9c_{r2}}{16} + \frac{3c_{r1}}{16} + \frac{3c_g}{4} + \frac{11P_t}{16}$$

Retailer #1 choose P_t to maximizes profit by taking the two reaction functions as given so that:

$$P_t = \frac{28\alpha}{57\beta} - \frac{c_{r1}}{57} - \frac{27c_{r2}}{57} - \frac{28c_g}{57}$$

Solving for the equilibrium retail price is:

$$P_{r1}^* = \frac{20\alpha}{38\beta} + \frac{21c_{r1}}{38} - \frac{3c_{r2}}{38} + \frac{18c_g}{38}$$
$$P_{r2}^* = \frac{67\alpha}{114\beta} + \frac{27c_{r2}}{114} - \frac{20c_{r1}}{114} + \frac{47c_g}{114}$$

<u>Conclusions</u>

From comparing equilibrium retails prices across the various scenarios, two analytical conclusions can be made.

First, from comparing the retail price equilibrium across the no competition scenarios, (Scenario A1, A2, A3), it is clear that:

$$P_r\,(A1) = P_r\,(A2) < P_r\,(A3)$$

because

$$P_{A1}^* = \frac{3\alpha}{4\beta} + \frac{xc_g}{4} + \frac{xc_r}{4} = P_{A2}^* = \frac{3\alpha}{4\beta} + \frac{xc_g}{4} + \frac{xc_r}{4} < P_{A3}^* = \frac{5\alpha}{6\beta} + \frac{xc_g}{6} + \frac{xc_r}{6}$$

when the marginal cost of retail, c_r, and marginal cost of generation, c_g, are sufficiently small relative to the size of the market, α. This assumption seems reasonable in the electricity industry where fixed capital costs are high and marginal costs are low. Therefore, when there is vertical integration between a transmission and retail monopolist, retail prices will likely be higher than the other types of vertical integration.

Second, from comparing the retail price equilibrium across the with competition scenarios, (Scenario B1, B2, B3), it is clear that:

$$P_r\,(B1) = P_r\,(B2) > P_r\,(B3)$$

because

$$P_{r1(B1)}^* = \frac{5\alpha}{8\beta} + \frac{3c_{r1}}{8} + \frac{3c_g}{8} = P_{r1(B2)}^* = \frac{5\alpha}{8\beta} + \frac{3c_{r1}}{8} + \frac{3c_g}{8} > P_{r1(B3)}^* = \frac{20\alpha}{38\beta} + \frac{21c_{r1}}{38} - \frac{3c_{r2}}{38} + \frac{18c_g}{38}$$

and

$$P^*_{r2(B1)} = \frac{5\alpha}{8\beta} + \frac{3c_{r2}}{8} + \frac{3c_g}{8} = P^*_{r2(B2)} = \frac{5\alpha}{8\beta} + \frac{3c_{r2}}{8} + \frac{3c_g}{8} > P^*_{r2(B3)} = \frac{67\alpha}{114\beta} + \frac{27c_{r2}}{114} - \frac{20c_{r1}}{114} + \frac{47c_g}{114}$$

when the marginal cost of retail, c_r, and marginal cost of generation, c_g, are sufficiently small relative to the size of the market, α. This assumption seems reasonable in the electricity industry where fixed capital costs are high and marginal costs are low. Therefore, when there is vertical integration between a transmission monopolist and retailer with product differentiation, average retail prices will likely be lower than the other types of vertical integration.