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Feasibility of Wholesale Electricity Competition in a Developing Country: Insights from Simulating a Market in Maharashtra State, India

Amol Phadke *

Abstract

Conventional wisdom suggests that competitive wholesale electricity markets are not feasible in most developing countries. However, systematic analyses of the feasibility of wholesale competition in a specific developing country are rare. I model a potential wholesale electricity market in Maharashtra (MH) state, India in a Cournot framework to analyze the circumstances under which it could be competitive. I model the effect of certain characteristics of the MH state electricity sector that create unique opportunities for demand response. I also analyze the effect of publicly owned generation firms on the competitiveness of the market. Further, I model the effect of policies such as the divestiture of large firms and the requirement of long-term contracts. I find that demand response and the presence of publicly owned generation firms substantially increase the competitiveness of a potential wholesale electricity market in MH state. Further, the market would be robustly competitive even in a situation with a supply shortage of up to 5 percent, when opportunities for demand response are combined with policies such as divestiture and requiring long-term contracts. However, in the absence of policies to increase market competitiveness, the MH electricity market would exhibit significant market power. Many of the characteristics of the MH state electricity sector that this analysis shows can increase market competitiveness are common to other states in India and other developing countries. If the effect of these characteristics is taken into account, competitive wholesale electricity markets will be more feasible there than currently anticipated.

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1. Introduction

Over the last few years, many countries have been radically reforming their electricity sectors. Electricity sector reforms in the developed world include a transition from a regulated private or public monopoly to competitive wholesale and retail markets. This transition is based on a rationale that competition will improve efficiency and lower prices for consumers (Hirsh, 2002). Electricity sector reforms in developing countries commonly focus on privatizing the publicly owned electric utilities and establishing electricity regulatory commissions. In developing counties, these changes in the electricity sector are a part of a broader program of economic reforms involving privatization and liberalization of many parts of the economy (WRI, 2002). The rationale stated for reforms focused on privatization has been that public utilities are highly inefficient and cause a huge drain on government resources. It has also been argued that the public sector is not capable of meeting the rapidly growing future investment needs (World Bank, 1993).

In many developing countries, power sector reforms at their outset envisioned establishing wholesale markets and eventually establishing retail markets. It was argued that the main consumer benefits of privatization will come with competition (Bacon & Besant-Jones, 2002). However, reforms, in their early stages, were focused on private sector participation and little attention was paid to ensuring effective regulation or competition. The question of how, in the absence of effective regulation or competition, private sector participation would lead to benefits for consumers was not adequately addressed (Phadke & Rajan, 2003).

Recently a few developing countries have made some progress in establishing independent regulation in their electricity sectors. However, the regulatory capabilities in these countries are still quite limited (Wamukonya, 2004). In the context of weak regulation, competition could play an important role in forcing efficiency improvements and lowering prices for consumers in the electricity sectors of many developing countries. However, in the light of negative outcomes in the wholesale electricity markets of some developed countries (for example, the California Electricity Crisis), there has been rethinking about the feasibility of wholesale competition in most developing countries.

Some argue that wholesale competition is even more difficult to establish in developing countries compared to developed countries for the following reasons. First, as electricity sectors in developing countries tend to be relatively small, in many cases, a single generator owns a large share of the generation capacity. In these cases, the electricity market may not be large enough for effective wholesale competition. Second, developing countries tend to have smaller reserve margins and some face power shortages[1] which increases the potential for firms to exercise market power. Third, in many cases, the state-owned distribution utilities are bankrupt and do not have the ability to trade on commercial terms as required in a wholesale market (Besant-Jones & Tenenbaum, 2001). Hence it is commonly believed that wholesale electricity competition with spot markets would not feasible and desirable in the near future in most developing countries (see for example, Besant-Jones & Tenenbaum, 2001; Reddy, 2001; Dubash & Singh, 2005; and Thomas, 2005).

Although these concerns about the feasibility of wholesale electricity competition are valid for some developing countries, not all developing countries have characteristics that make competitive wholesale markets infeasible to establish. I argue in this paper that certain

[1] Reserve margin is defined as: (available capacity – peak demand)/available capacity. Reserve margin is an indicator of the extra generation capacity available when the peak demand occurs.

characteristics of electricity sectors in some developing countries could in fact increase the feasibility of wholesale electricity competition. The effect of these characteristics on the competitiveness of potential wholesale electricity markets is rarely considered by policymakers and researchers. By simulating a potential wholesale electricity market in Maharashtra (MH) state, India, I show that if the effect of these characteristics is taken into account, a competitive wholesale electricity market will be more feasible than currently thought. The following are some of these characteristics in the context of the Indian power sector:

1. The Availability of Large Quantities of Industrial Back-Up Generation

The Indian power sector has been facing increasing power shortages since 1998 and many industrial consumers have installed back-up generation to cope with them. The total back-up generation capacity in India is estimated to be at least 15,000 to 20,000 MW which is about 15% to 20% of the total installed generation capacity in India (CEA, 2005b). When the current power shortages are reduced, which I argue (later in this paper) is likely to be the case, this back-up generation capacity will be an additional capacity available in the system. Industrial consumers can use this capacity for demand response. If the wholesale price goes above a certain level, industrial consumers can generate from their back-up generators rather than buying power from the grid and in effect reduce their demand. This demand response ability will increase the competitiveness of a potential wholesale electricity market.

2. The Ability to Shift Large Quantities of Electricity Demand for Agricultural Pumping From Peak to Off-peak Periods [2]

In order to deal with the current power shortages, many state utilities in India are implementing schemes such as feeder separation, which enable them to shift large quantities of agricultural pumping load (for pumping water for irrigation) from a high demand (peak) period to a low demand (off-peak) period. Such load shifting may not be necessary in the long-run when power shortages are removed or reduced significantly. However, the distribution sector will continue to have the ability to shift the agricultural pumping load. This ability creates unique opportunities for demand response. Note that the agricultural pumping load need not shifted permanently to the off-peak periods to prevent the exercise of market power. A credible threat of shifting the agricultural pumping load if market power is exercised will reduce the exercise of market power.

3. The Feasibility of Interruptible Tariffs

Everyday living in developed countries is far more dependent on electricity than developing countries. In developed countries, the distribution utilities almost always have to buy power even if severe market power is exercised because load curtailment has enormous economic and political costs. The distribution utilities in developing countries can, however, curtail load under special circumstances without enormous economic and political costs. Hence they can credibly refuse to buy power if the price goes above a certain level. This credible threat will reduce the generators' ability to exercise market power.

4. Relatively Large Size of the Market

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[2] Electricity demand for agricultural pumping will be referred to as agricultural pumping load in the rest of this paper.

Unlike many developing countries, the Indian power sector is relatively large with an installed capacity of about 110,000 MW. Individual electricity markets in India will be smaller due to transmission constraints between various states. However, even a single state can be large enough to have effective competition. For example, MH has an installed capacity of about 15,000 MW and can be considered large enough to have effective competition.

5. The Likely Presence of Public Generation Firms Along With Private Generation Firms

Certain public generation utilities in India are not likely to be privatized in the near future and are likely to act as price-taking firms in a potential wholesale electricity market. As will be shown later in this paper, price-taking firms limit the ability of strategic firms to exercise market power.

6. The Ability to Trade on Commercial Terms

Unlike the state utilities in many other developing countries, state utilities in India are already trading power with each other in real time on commercial terms. Hence they can participate in a wholesale market.

7. Learning from the Past Experiences of Power Markets

We now understand power markets better than when some of the developed countries designed their markets. The importance of demand response, long-term contracts, and the divestiture of dominant firms in fostering effective competition is now relatively well understood and appreciated. The improved understanding of power markets will enable us to design policies that foster competition.

Analyzing the Feasibility of Competition

Traditionally, the analyses of the feasibility of wholesale competition (alternatively, the analyses of the potential for market power) in the electricity sector have utilized concentration measures such as the Hirschman-Herfindhal Index (HHI). Borenstein, Bushnell, & Knittel (1999) show that concentration measures can be misleading indicators of the feasibility of competition. Researchers have developed alternative approaches to analyzing the potential for market power which basically involve simulation of market outcomes using the available cost data and oligopoly equilibrium concepts. Their studies give far better insights into the potential for market power in electricity markets and also demonstrate the problems of using standard concentration measures like HHI.

I use one such approach to analyze the feasibility of competition in a potential wholesale electricity market in MH state. Application of this particular approach involves simulation of Cournot competition among the major suppliers of electricity in MH state. I use data on generators, transmission constraints, and electricity demand in MH state to simulate market prices. I analyze the effect of some the characteristics of the MH state electricity sector (similar to those mentioned earlier in this section), which are likely to increase the competitiveness of a potential wholesale electricity market there. I also analyze the effect of some of the main policies that are likely to increase competition: the divestiture of dominant generators and the requirement of long-term contracts.

In many electricity markets in developed countries, electricity is sold in different sub-markets such as the spot market, the day ahead market, the long term contracts market (physical or financial), and the ancillary services market. These sub-markets could emerge in a wholesale electricity market in MH state. If the system rules are appropriately designed and do not give an advantage to transactions in a particular sub-market, the price for electricity in each of these markets is likely to be the same. This is because any significant price difference in the price of electricity in these markets will be arbitraged away. I assume that this condition will exist in the MH state electricity market. In this case, the price of electricity essentially depends on the firms' costs and generation capacities and on the demand elasticity. I focus this analysis on the price of electricity as determined by these factors. Even though I do not expect any systematic price differences in the price of electricity in different sub-markets, this does not mean that allowing different sub-markets will not have any effect on the competitiveness of the market. As will be discussed later in this paper, empirical and theoretical research has shown that allowing long-term contracts increases the competitiveness of wholesale electricity markets. For the reasons described later in this paper, I model the effect of contracts in a static setting where the market outcomes are analyzed given the level of contracts.

Section 2 reviews various approaches used to analyze the feasibility of wholesale competition in the electricity sector. Section 3 describes the Cournot framework used in this analysis to simulate wholesale competition. This section also discusses how the potential electricity market is modeled in the Cournot framework by incorporating the different characteristics of the MH state electricity sector. Section 4 presents the results of the market simulations for various scenarios of market characteristics and policies. Section 5 concludes with a discussion of the circumstances under which competition is feasible in a potential wholesale electricity market in MH state. I also discuss the implications of my results for understanding the feasibility of wholesale competition in other states in India and in other developing countries.

The key findings of this research are:

1. Interruptible tariffs, the ability of the distribution sector in MH state to shift agricultural pumping load, and the availability of a large capacity of industrial back-up generation will substantially increase the demand response capacity in a potential wholesale electricity market in MH state and subsequently increase its competitiveness. The presence of government owned firms will also have a disciplining effect on market prices as these firms are likely to behave as price takers.

2. I find significant market power in the MH electricity market if demand response opportunities are not utilized and if the policies such as divestiture and requiring long-term contracts are not implemented.

3. A wholesale electricity market in MH state would be robustly competitive even in a situation with a supply shortage of up to 5 percent, when opportunities for demand response are utilized along with policies such as divestiture and requiring long-term contracts. This analysis indicates that no one policy implemented at a realistic level can ensure competition in the MH electricity market, but their combination implemented at easily attainable levels can achieve the goal. However, if the current situation of severe supply shortages (which are as large as 20% during peak times) continues, a competitive wholesale market will be impractical to establish in the MH state electricity sector. I argue in this paper that severe supply shortages are unlikely to continue indefinitely and are likely to be reduced significantly in the near future.

Most of the literature on wholesale electricity markets is on markets in developed countries. Hence the effects of certain characteristics, which are unique to electricity sectors in developing countries, on the market competitiveness are rarely analyzed. This research shows that some of these characteristics will increase the competitiveness of potential wholesale electricity markets and hence they are more feasible in some developing countries than currently thought. In the context of limited regulatory capacity in developing countries, rigorously assessing the option of introducing competition is all the more important. This research provides insights into the unique challenges and opportunities of introducing wholesale electricity competition in a developing country context.

2 Frameworks Used for Analyzing the Feasibility of Competition

Most recent academic studies analyzing the feasibility of competition in electricity markets use some form of oligopoly models. However, electricity regulators often use relatively primitive and indirect methods based on concentration measures. The analysis of the feasibility of competition in developing countries, in whatever limited form it exists, is mostly based on concentration measures.

In this section, I first describe in brief one of the most popular concentration measures and its limitations in analyzing the feasibility of competition in electricity markets. I then describe the two main oligopoly model approaches used to analyze electricity markets and discuss their relative merits.

2.1. Concentration Measures

Until recently, even in most developed countries, the screening of the potential for market power in the electricity sector was based on concentration indices such as the Hirschman Herfindahl Index (HHI). In some cases, the use of HHI continues even today. HHI measures the sum of the squared market shares of all the suppliers in the market.[3] Though HHI is a measure suitable for analyzing the competitiveness of many other markets, Borenstein et al. (1999) have shown that in the case of electricity markets, HHI is a poor measure of competitiveness. The main drawback of the HHI based analysis is the inadequate representation of demand and supply elasticities, which seriously undermines the ability to analyze the competitiveness of electricity markets. This is because the market outcomes are greatly influenced by supply and demand elasticities when supply and demand are relatively inelastic, which is believed to be the case in the electricity sector at least in the short-run. As mentioned earlier, in developing countries the analyses of the feasibility of competition is quite limited and is generally based on concentration measures like HHI. The analyses of the competitiveness of electricity markets conducted by the energy sector experts in multilateral donor agencies are generally based on HHI. For example, the discussion of the competitiveness of electricity sectors in developing countries in Bacon and Besant-Jones (2002) is based on HHI. In their discussion, it is argued that HHI is a simple measure to indicate the degree of the potential for market power. Table 1 is partially reproduced from Bacon and Besant-Jones (2002) and shows the HHI for electricity sectors in some developed as well as developing countries. Their discussion on the potential for market power in this paper indicates that firms in electricity sectors with lower values of HHI will have a lower potential for exercising market power.

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[3] The convention is to multiply the resulting sum of squared market shares by 10,000. Thus, for example, a market with 5 equal sized producers would yield a HHI of 5 * 0.04 * 10,000 = 2,000.

Table 1: Index of Market Concentration for Power Sector Generation

Country/Region	No.of Frms	Share of the Largest Firm (%)	HHI	Equivalent No. of Equal Sized Firms
Argentina	38	14	0.06	16.7
California	40	23	0.11	9.1
Colombia	26	24	0.14	7.1
Brazil	14	25	0.15	6.7
Bolivia	6	26	0.19	5.2
Hungary	10	27	0.19	5.3
Peru (SICN)	8	35	0.23	4.3
Sweden	8	52	0.32	3.1
Chile (SING)	4	43	0.33	3.0
N. Ireland	4	48	0.33	3.0
Spain	8	46	0.34	2.9
Alberta	12	55	0.38	2.6
Chile (SIC)	4	60	0.43	2.3
Czech Rep.	6	75	0.6	1.7
Queensland	2	76	0.64	1.6
Portugal	3	93	0.86	1.2

Source: Bacon and Besant-Jones (2002)

However, note that even though the California electricity market had a low HHI value (lower than that of electricity sectors in most countries), the market was not competitive.

2.2 Oligopoly Models

Most recent academic studies analyzing the feasibility of competition in developed countries use oligopoly models as they account for the firms' profit maximizing strategies directly. In oligopoly models, the two main approaches used to analyze the competitiveness of electricity markets are the supply function equilibrium approach and the Cournot equilibrium approach. The Bertrand equilibrium approach, which is one of the basic approaches of modeling oligopolistic competition, is not commonly used in analyzing wholesale electricity markets. This approach is based on an assumption that a single firm can capture the entire market if it can offer the lowest price. In the electricity generation sector, unlike many other sectors, there are significant constraints in the short-run on the generation capacity of a firm. This is mainly because the storage of electricity is prohibitively expensive. Constructing new power plants takes considerable time (2 to 3 years at the minimum) which means that the short-run in the electricity sector is at least two to three years. Hence the assumption that a single firm can capture the entire market is not tenable. Therefore the models based on price competition, like the Bertrand model, are not suitable for analyzing the feasibility of competition in the electricity sector.

2.2.1 Supply Function Models

In supply function models, firms compete by bidding supply functions which state the relationship between the price and the supply offered by a firm at that price. At the equilibrium, each firm submits a supply function that allows the firm to maximize its profits given the supply function of the other firms. As supply function models incorporate the effect of the strategic behavior of firms, some studies have used them to analyze the competitiveness of electricity markets (see, for example, Green & Newbery, 1993 and Green, 1996). The other main attraction of supply function models is that they closely represent the manner in which bidding actually takes place in many electricity markets where the firms are required to bid a quantity and the price for that quantity. However, when there is no uncertainty in demand, supply function models yield multiple equilibria which are bounded above and below by the Cournot and the Bertrand equilibria respectively (Klemperer & Meyer, 1989). Although electricity demand is uncertain, the range of uncertainty is quite narrow in the demand for the next hour or day (Hobbs et al., 1997). When firms are bidding in the short-run electricity markets (day ahead or spot market), they face a relatively certain demand which would yield multiple equilibria if electricity markets are modeled in supply function models (Borenstein et al., 1999). A supply function model might find an equilibrium which is closer to the competitive equilibrium than what could actually happen and underestimate the potential for firms to exercise market power. This is one of the main drawbacks of supply function models if they are used as screens for market power.

2.2.2 The Suitability of the Cournot Framework for Analyzing the Feasibility of Competition in Electricity Markets

The Cournot framework assumes that firms compete by choosing the quantity they produce. Unlike the Bertrand framework, the Cournot framework need not assume that a single firm can capture the entire market. Hence the short-run constraints on the electricity generation capacity can be incorporated into the Cournot framework. The Cournot framework also addresses some of the drawbacks of analyzing the feasibility of competition in electricity markets using supply function models. Bolle (1992) shows that when demand is relatively certain (which is the case for electricity demand at least in the short-run), the most profitable supply function equilibrium, which is a Cournot equilibrium, is more plausible. Hence the use of a Cournot framework is more appropriate for analyzing electricity markets. Also the Cournot equilibrium represents the worst case scenario in terms of market power hence it is appropriate to use it as a screen for the potential for firms to exercise market power.

Many studies have used the Cournot framework to analyze the competitiveness of electricity markets and have incorporated the effect of some of the important characteristics of the electricity sector such as inelastic demand and short-run capacity constraints (see, for example, Gracia & Arbeláez, 2002; Borenstein & Bushnell, 1999; Hogan, 1997; Oren, 1997; and Anderson & Bergman, 1995). Bushnell, Mansur, & Saravia (2005) is the only study that I am aware of that tests the ability of a Cournot model to predict actual market outcomes. This study finds that a Cournot model can recreate the actual market outcomes reasonably well. This finding further supports the use of the Cournot framework in modeling wholesale electricity competition.

2.2.3 Limitations of the Static Cournot Framework Used in This Study

I use a static Cournot framework to simulate a potential wholesale electricity market in MH state and I do not model competition in a dynamic setting. The main reason for not modeling competition in a dynamic setting is that detailed empirical modeling of dynamic competition is extremely difficult and often gives indeterminate results. As a result, I do not take into account the effect of long-term entry and exit decisions. The threat of entry in the long-run is likely to discipline market prices. Since my analysis does not take into account this effect, it is likely to overestimate the extent of market power.

Many empirical and theoretical studies have analyzed the effect of long-term contracts on the competitiveness of wholesale electricity markets.[4] The general conclusion of these studies

[4] Theoretical studies on this topic include: Allaz and Vila (1988), Powell (1993), Newbery (1998), Green (1999), and Bushnell (2005). Some of the important empirical studies are: Wolak (2000) and Bushnell, Mansur, & Saravia (2005).

is that in most circumstances, the existence of or allowing long-term contracts can reduce the exercise of market power. These studies analyze the effect of long-term contracts in a static as well as in a dynamic setting. I want to analyze the effect of a policy of requiring the firms in the MH market to sign long-contracts for a portion of their generation. A dynamic model generally analyzes a situation in which firms are allowed to choose the level of contracts they sign. However, in our case, the level of contracts is prescribed by the policy. Hence I model the effect of contracts in a static setting where I analyze the behavior of firms given that they have signed a certain level of contracts. In the absence of a policy of requiring contracts, firms are likely to sign long-term contracts on their own. Firms also might sign more long-term contracts than required by the policy. However, my model implicitly assumes that the firms will sign long-term contracts only to the extent required by the policy. Hence my analysis will overestimate the exercise of market power in a situation where the firms would have signed more contracts than required by the policy.

The preceding discussion indicates why the approach of modeling competition in a static setting might represent a worst-case scenario in terms of market power. However, this static model does not capture the effect of repeated interaction amongst firms that could potentially make them compete less aggressively over time. In this case, my model could understate the extent of market power. Hence the results of this analysis should not be taken as exact predictions of the market outcomes but should be interpreted as an approximate indication of what might happen if a wholesale electricity market is set up in MH state.

This paper analyzes the effect of non-collusive market power and I do not model the collusion amongst firms directly. This is because the analysis of the factors which facilitate collusion is the beyond the scope of this analysis. The results of the scenario in which the firms are not divested can be interpreted as the results of a perfect collusion among firms when they are divested. Because firms face incentives to cheat on the collusion and there are legal barriers against explicit collusion, perfectly collusive outcomes are unlikely to occur.

3. Modeling the MH Electricity Market in the Cournot Framework

I use the Cournot modeling approach used by Borenstein & Bushnell (1999) as a starting point for developing a modeling approach used in this analysis and I adapt their approach to incorporate the essential characteristics of the MH state electricity sector. I simulate a potential wholesale electricity market in MH state in the financial year 2007-08[5]. I refer to this year as the simulation year. I use the financial year because all the data are available on a financial year basis. I choose 2007-08 as the year for market simulations because I believe that this year represents the conditions (in terms of the demand and supply balance) that are likely to prevail in the next 10 to 15 years in the MH state electricity sector. I discuss the basis for this assessment in Appendix I. In the following section, I discuss my approach to modeling the MH state market in the Cournot framework.

3.*1 Boundaries of the MH State Market*

India has four regional grids connected to the neighboring regional grids by High Voltage Direct Transmission (HVDC) lines. However, the inter-regional transmission capacity is

[5] The financial year begins in April and ends in March.

quite limited.[6] Each regional grid connects a few states. The electricity grid in MH state is a part of the Western Grid, which includes three other large states and one small union territory. The MH state grid is also connected to the neighboring state of Karnataka, which is part of the Southern Grid. Table 2 shows the transmission capacity between MH and its neighboring states.

Table 2: Transmission Capacity between MH and its Neighboring States

State	Transmission Capacity (MW)
Chattisgad	1,500
Gujarat	1,750
Madhya Pradesh	2,000
Southern Region HVDC	900
Total Capacity (MW)	**6,150**

Source: Power Map of the Western Region (Western Regional Load Dispatch Center, 2005).

I do not take into account the transmission capacity between Goa and MH state because it is not feasible to import a significant amount of power from Goa.[7] Each major state in India has been allocated a share of capacity in the central sector utilities (CSUs). The CSUs include the National Thermal Power Corporation (NTPC), the Nuclear Power Corporation (NPC), and the National Hydro Power Corporation (NHPC). These CSUs have power plants spread all across the country with NTPC having the largest capacity, which is almost 20% of the total installed capacity in the country. The majority of the MH state's share in the CSUs is in the plants outside of MH state. Currently, the power imports by MH state from the neighboring states are limited to the MH state's share in the generation by the CSUs' plants in the neighboring states. It is possible that if the price is high enough in MH state, the utilities in the neighboring states will export power to MH State. Currently all the states in the Western Grid are facing power shortages and it is unlikely that any state in the Western Grid will have substantially more spare capacity than MH state in the near future. The diurnal and the seasonal patterns of the electricity demand in all of the states in the Western Grid are quite similar. Hence possibilities of imports when a peak period in MH state coincides with an off-peak period in the neighboring states are rare. If the price is high enough, it is possible that utilities in neighboring states could curtail load of their own consumers and export power to MH state. However, the feasibility of this option depends upon load curtailment policies of utilities in neighboring states and the regulations guiding load curtailment in addition to political considerations. I assume that MH state's imports from its neighboring states in the Western Grid will be limited to MH state's share in CSUs' plants in the neighboring states. I assume that 500 MW of power will be available from the Southern Grid at a price of 4.5 cents/kWh based on the price and the amount of power currently imported from the Southern Grid (MSEB, 2005a).[8]

3.2 Generators in the MH Electricity Market

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[6] The total inter-regional transmission capacity is 4,800 MW compared to the total installed generation capacity in India of about 110,000 MW.

[7] The transmission capacity between MH State and the Union Territory of Goa is 440 MW and Goa is not connected to other states. The generation capacity in Goa is 220 MW, which is mostly utilized by Goa. Transmission capacity between Goa and MH cannot be utilized for importing power from states other than Goa. Hence it is not possible to import significant amount of power from Goa.

[8] For all the analysis and results presented in this paper, I use an exchange rate of Rs.43.5/$ which was the average exchange rate for the year 2005.

This section first discusses the procedure used to estimate the generation capacity available in the potential MH electricity market. I will then discuss and justify the assumptions made about the ownership of this generation capacity. I will also explain the basis for the estimation of marginal costs of generators in the potential MH electricity market in this section.

3.2.1 Generation Capacity

I estimate the generation capacity in the potential MH electricity market based on the current generation capacity and an estimate of the generation capacity additions that will take place in the future by the simulation year.

<u>Current Generation Capacity and Ownership</u>

Table 3 gives the generation capacity installed in MH state and MH state's share in the power plants of the CSUs outside of MH state for the financial year 2003-04.

Table 3: Generation Capacity for MH State (2003-2004)

	MW	% of Total
Capacity Installed in MH state		
MSEB	9,711	64%
TATA	1,774	12%
Reliance	500	3%
Dabhol	728	5%
NPC	190	1%
Total In State	**12,903**	**85%**
MH State's Share in Central Power Plants Outside MH State		
NPC	160	1%
NTPC	2,029	13%
Total Out of State	**2,189**	**15%**
Total Capacity for MH State		**15,092**
Capacity By Fuel		
Coal	9,561	63%
Gas	2,212	15%
Hydro	2,878	19%
Nuclear	350	2%

Source: MSEB Generation Statistics (MSEB, 2004a)

Since there have been no capacity additions in MH state since 2003-04, Table 3 states the current generation capacity available for MH state. MH State Electricity Board (MSEB), NTPC, and NPC are public utilities while TATA and Reliance are private utilities. Enron's Dabhol power plant is now owned by a joint venture of NTPC and the Gas Authority of India Ltd. (GAIL). Table 3 also shows that most (64%) of the generation capacity is coal based.

Like many other states in India, MH state has initiated reforms in its electricity sector. The MH Electricity Regulatory Commission (MERC) was established in 1998. MERC has the authority to oversee investment decisions and to set tariffs. The recently passed Electricity Act 2003 that applies to all the states in India has de-licensed electricity generation, allowing any organization to set up a power plant without the permission of the government. The process of creating open-access to the transmission network has started. Regional power pools have been established where state utilities trade power with each other. In June 2005, the Government of MH (GOM) unbundled MSEB into three companies – MH State Power Generation Company, MH State Transmission Company, and MH State Distribution Company.

Generation Capacity Additions

Since I am simulating a potential MH electricity market in the year 2007-08, I need to estimate the capacity additions that will take place by the simulation year. I base my estimates on MSEB's estimates of capacity additions in the state.[9] However, I include only the projects that are finalized and are at an advanced state of equipment ordering or have begun construction.[10] For example, I do not include the proposed Uran power plant expansion since this project is not finalized yet. This project might come online in 2007-08 but I do not include this plant because I make a conservative estimate of the capacity additions. Table 4 shows the capacity of the new generation units that will come online by 2007-08.

Table 4: New Generation Capacity Planned to Come Online by 2007- 08

Entity	Capacity (MWs)
MSEB	900
Dabhol	2,210
Central Sector	2,092
Total	**5,202**

The capacity of all power plants in MH state is re-rated using an availability factor [11] that accounts for forced and maintenance outages of power plants as follows:

Plant availability factor = 1 – (forced outage rate + maintenance outage rate)

Plant's available capacity = installed capacity * availability factor.

3.2.2 Ownership of Generation Capacity in the MH Electricity Market

In the potential MH electricity market, I am making the following assumptions about the ownership of generation capacity available for MH state. I assume that all the thermal power plants owned by MSEB will be privatized and these plants will be owned by different firms. Privatization is not a prerequisite for establishing a wholesale market. I make this assumption as I want to analyze the effect of the profit-maximizing behavior, which is generally a characteristic of private ownership. The number of firms owning MSEB's plants varies across different scenarios. I assume that the plants owned by CSUs, including the Dabhol power plant, will continue to be under public ownership. NTPC, which is a CSU, owns all the central sector thermal power plants. NTPC is a professionally run public utility and is considered efficient by world standards (Tongia, 2004). Privatization of NTPC is not on the policy or the political agenda. Hence I assume that NTPC plants will continue to be under public ownership. I assume that each neighboring state has one public firm that owns the NTPC plants in that state and exports power to MH state. This artificial division of the NTPC power plants into different public firms, one for each state, is done to take into account the state specific transmission constraints and will not affect my results. I also assume that the generation capacity currently owned by the private utilities will continue to

[9] MSEB (2005b) states MSEB's estimate of the capacity additions in MH state in the near future.

[10] This assessment is based on a monthly report published by CEA (CEA, 2005a) on the status of various power projects in India.

[11] Estimates of the availability factors are obtained from MERC (2003 a). For the new plants planned to come online, MSEB claims an average availability factor of 80%. This availability factor appears to be too low for new plants. I estimate the availability factors for new plants based on the actual availability factors achieved by recently built power plants in India. As CEA (2005c) indicates, the average availability factor for new gas plants is 95% while that for the new coal plants is 90%.

be owned by them. It is unlikely that the hydro power projects in MH state will be privatized as they are also used for purposes other than power generation such as irrigation and flood control and hence it is complicated and politically difficult to privatize these projects.

3.2.3 Estimating Marginal Costs

MERC examines heat rate and fuel cost estimates provided by the utilities in MH state in a tariff case and approves certain fuel costs and heat rates based on their own estimates. I believe that the heat rates and the fuel costs approved by MERC are a better estimate than those provided by the utilities[12] and I use these estimates to calculate the marginal generation cost of power plants in MH state. Since the latest fuel cost estimates by MERC are for the financial year 2003-04, the fuel costs need to be forecasted for the simulation year (2007-08). The heat rate of a power plant is its design parameter and should not change significantly within a short period of time (in this case, four years). The forecast of fuel costs is based on the past trends in fuel prices as well as the future trends indicated by various government policy documents. I discuss the methodology and data used for forecasting fuel prices in Appendix II. Figure 1 shows the marginal cost estimates for various suppliers in MH state calculated from the forecasted fuel prices and MERC's estimates of the heat rates. Note that the suppliers are the suppliers assumed for the base case scenario.

<u>Accounting for Transmission Line Losses</u>

Transmission and distribution losses (T&D losses) in MH state are estimated to be 33%.[13] Since I am simulating wholesale competition, I need not account for losses in the distribution sector. I use MERC's estimates of the transmission losses between the load centers and various power plants.[14] To account for the transmission losses, I assume that the marginal cost of the delivered electricity, MC = marginal cost at the bus-bar[15]/(1-TL) where TL is the transmission loss as a fraction of total generation.

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[12] Heat rates and fuel costs stated by MSEB could be biased as MSEB faces an incentive to overstate their heat rates and fuel costs in order to have less stringent power plant performance requirements.

[13] The estimate of the transmission and distribution losses (T&D losses) is for the year 2003-04. T&D losses for MH State are estimated based on the estimates of T&D losses for MSEB obtained from MERC (2003) and on the estimates of T&D losses for Mumbai obtained from MERC (2004a) and MERC (2004b).

[14] MERC's estimate of the transmission losses is taken from MERC (2003b).

[15] Cost at the bus-bar is the marginal generation cost excluding any transmission costs.

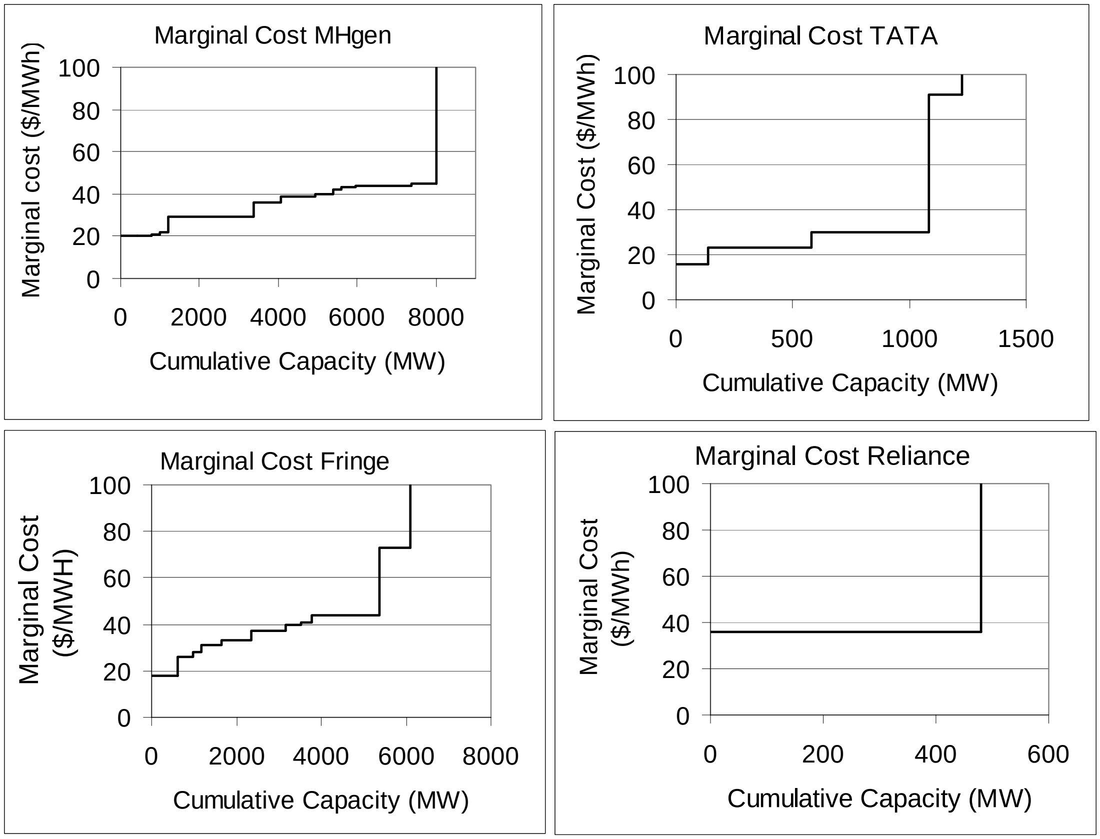

Figure 1: Marginal Cost of the Suppliers in MH State

3.3 Modeling the Behavior of Generators

In this section, I will discuss the approaches used to model the behavior of various types of generators in the MH electricity market. The generators are characterized by the fuel they use and their type of ownership (public or private).

3.3.1 Modeling Hydroelectric Generation

For thermal power plants, the input energy availability, which depends on the fuel availability, is generally not a constraint and thermal power plants are constrained only by their generation capacity.[16] Unlike thermal power plants, hydro power plants face a constraint on the total input energy availability over a certain period due to the limited availability of water during that period. Hence the firms owning hydro power plants (hydro firms) need to allocate their production to different times in a certain period. Besides the constraint on the total energy generation, hydro power plants often have to produce some minimum amount of electricity due to minimum flow constraints.[17] Like thermal power plants, hydro power plants face constraints on the maximum instantaneous power generation. Given these constraints on the total available energy, the maximum instantaneous generation capacity, and the minimum generation requirement, firms owning hydro face different incentives than

[16] Currently gas power plants in India are facing gas shortages. However, this situation is unlikely to continue as India has planned for major LNG imports.
[17] Minimum flow constraints are generally present for maintaining certain ecological conditions in the downstream flow of the river.

firms owning thermal generation in terms of their supply strategy in the market. A price-taking hydro firm will allocate all the possible hydro generation to a period in which the price is the highest until it reaches its maximum instantaneous generation capacity constraint in that period or until it is producing only the minimum required generation in the other periods. A price-taking hydro firm faces an incentive to shift its generation from a low price period to a high price period until the prices in all the periods are equalized. A Cournot hydro firm faces similar constraints and incentives but seeks to shift hydro production from a low price period to a high price period until its marginal revenue (not price) in all the periods is equalized. Given these incentives and constraints, it is possible to formulate the optimal hydro allocation for a Cournot and a price-taking hydro firm. However, it is difficult to solve this formulation and obtain values of the optimal allocation of hydro generation. Instead, a simple approximation used by Borenstein & Bushnell (1999), based upon a technique known as 'peak-shaving', can also be used to estimate the optimal allocation of hydro generation for a firm. The peak-shaving technique allocates hydro generation to the periods in which demand is the highest considering the maximum instantaneous generation capacity, the minimum generation requirements, and the total available energy.

The peak-shaving technique is more appropriate to approximate the optimal hydro generation allocation for a price-taking firm compared to a strategic Cournot firm for the following reason. The peak-shaving exercise attempts to equalize the residual demand across all the time periods considering various constraints on hydro generation. This approach will give optimal allocation of hydro generation for a firm if demand is a perfect indicator of the firm's marginal revenue. I argue that demand is likely to be a better indicator of a price-taking firm's marginal revenue than a Cournot firm's marginal revenue. A price-taking firm's marginal revenue is simply the market price. For a strategic Cournot firm, besides the market price, its marginal revenue depends on its infra-marginal production and the elasticity of demand. Both of these factors may not be directly linked to demand and hence demand may not be a perfect indicator of the marginal revenue of a Cournot (strategic) hydro firm.[18]In the potential MH electricity market, I assume that 87% of the hydro generation capacity will be owned by price-taking public firms for the reasons described earlier in this paper. Hence the peak-shaving exercise will not give substantially different allocation of hydro production than that obtained by actually solving for the optimal allocation.

I undertake the peak-shaving exercise for each month of the simulation year which optimizes the allocation of hydro production to different hours each month given the total hydro generation in that month. This procedure does not allow for optimal allocation of hydro generation across months. I also conducted the peak-shaving exercise for the entire simulation year based on the hydro generation availability for that year. This procedure results in an allocation of more hydro generation to the months in which the demand is higher. However, the yearly peak-shaving does not take into account the many constraints on hydro generation such as irrigation requirements during certain months and constraints on storage. I do not know these system constraints in detail. Monthly hydro generation availability is likely to take into account the constraints on the hydro generation mentioned above. Hence I undertake the peak-shaving exercise on a monthly basis rather than on a

[18] Bushnell (1998) finds that a Cournot firm, under some circumstances, faces an incentive to shift production from a peak period to an off-peak period indicating that the Cournot firm's marginal revenue in the off-peak period is greater than its marginal revenue in the peak period. This suggests that the demand level may not be a perfect indicator of a Cournot firm's marginal revenue in every case.

yearly basis. I estimate the monthly hydro generation availability, the maximum instantaneous generation capacity, and the minimum flow constraints based on historical data and Table 5 shows the values of these parameters.[19]

Table 5: Monthly Hydro Generation Parameters

Month	1	2	3	4	5	6	7	8	9	10	11	12
MaxGen (MW)	2,634	2,606	2,521	2,800	2,288	2,292	2,424	2,561	2,695	2,718	2,719	2,700
MinGen (MW)	20	39	38	20	10	0	5	13	0	0	5	22
TotalEnergy (GWh)												
Base Case	528	454	501	589	497	301	563	494	555	539	453	475
Low Hydro	423	364	402	473	398	242	451	396	445	432	363	381

Figure 2 shows the load duration curve for December 2007 before and after the peak shaving exercise.[20]

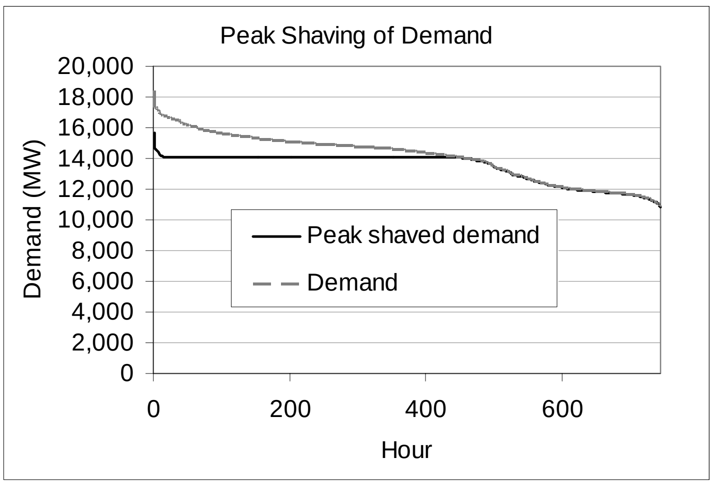

Figure 2: Peak Shaving of the Demand

Note that the peak-shaved demand is 14,115 MW for more than 50% of the hours in December. I refer to this residual demand level as the 'most common residual demand level' during that month. Note that the peak-shaved demand is above the most common residual demand only for a few hours (23 hours) in December and the situation is similar for all other months. Hence if the market is competitive for the most common residual demand level in a month, then it is competitive for most of the month. The area between the original demand curve and the peak-shaved residual demand curve is equal to the total hydro generation during December.

[19] I collected data on the total annual hydro generation in MH State for the last 15 years. Total hydro generation availability for the base case is the mean hydro generation of the last 15 years plus the estimated hydro generation from the Sardar Sarovar Project. I collected hourly hydro generation data for a two year period (2001-02 and 2002-03) for all hydro plants in MH State and estimated the average monthly hydro generation and the minimum and maximum hourly generation. The monthly hydro generation for the market simulation year (2007-08) was estimated by proportionally adjusting the average monthly generation for 2001-02 and 2002-03 so that the total hydro generation for the year is equal to the total hydro generation assumed for the base case. For the monthly peak-shaving exercise, I use the estimates of the maximum and the minimum hourly generation for each month based on the hourly hydro generation data for 2001-02 and 2002-03. I also analyze a scenario where the available hydro generation is two standard deviations below the mean. This scenario is discussed in detail in the results section.

[20] Estimation of hourly demand for the simulation year is explained in section 3.9

3.3.2 Modeling the Behavior of Public Firms Owning Thermal Generation

Profit maximization is generally not the objective of most public firms and hence I can assume that public firms will not act strategically to exercise market power. The model characterizes public firms owning thermal generation as non-strategic price-taking firms, which produce when their marginal cost is equal to or less than the market price.[21] I model the behavior of price-taking firms as follows. I first develop an aggregate supply curve of price-taking firms by adding the supply curves of individual price-taking firms. I account for transmission constraints by truncating the supply of curves of price-taking firms at the transmission constraint. I subtract the aggregate supply curve of price-taking firms from the market demand curve to obtain a residual market demand curve. I assume that the Cournot firms compete against each other given this residual demand curve. Equation 1 shows how the residual demand curve is obtained,

$$D_r(P) = D(P) - S^f_{Mh}(P) - Min(S^f_{Ch}(P), TR_{Ch}) - Min(S^f_{Mp}(P), TC_{Mp}) -$$

$$Min(S^f_{Gu}(P), TC_{Gu}) - Min(S^f_{Sr}(P), TC_{Sr}), \qquad (1)$$

where $D(P)$ is the market demand function, S^f_J represents fringe supply curve for the region J (Mh for MH, Ch for Chattisgad, MP for Madhya Pradesh, Gu for Gujarat, and Sr for the Southern Region), and TC_J represents transmission constraints between the region J and MH state. $D_r(P)$ represents the residual demand curve faced by the Cournot players.

3.3.3 Modeling the Behavior of Private Firms Owning Thermal Generation

I assume that private firms in the MH electricity market act as profit-maximizing firms. These firms are large enough to influence the market price. Hence I model them as Cournot firms. Cournot firms maximize their profits given the production from other firms. Unlike price-taking firms, Cournot firms take into account the effect of their production on the market price while making their production decision. The details of the strategy used to model the behavior Cournot firms are discussed in the section 3.5.

3.3.4 Modeling of Nuclear Generation

Unlike coal and gas plants, the output of nuclear plants can not be changed easily. Nuclear plants can not be shut down just for a few hours or days and restarted without difficulty. Hence it is unlikely that firms will withhold output from nuclear plants to exercise market power. Given the relatively low marginal costs of the nuclear plants in MH state and given the constraints on changing their output, I assume that nuclear plants will always run at their full capacity. I model them as plants with zero marginal costs to ensure that they are always running.

[21] One can not rule out the possibility of public firms exercising market power as there have been instances where some public firms might have exercised market power. For example, Los Angeles Department of Water &Power, a public utility, seems to have exercised market power during the California electricity crisis. However, such instances are likely to be rare because the broader objective of public firms is to maximize social welfare. Also public firms in India are subject to greater public scrutiny compared to private firms and politicians have some control over their behavior which makes it difficult for them to exercise market power. Public firms could also bid below their marginal costs to depress market prices if their objective is to maximize consumer welfare. Analyzing the effect of different objectives of public and private firms is beyond the scope of this paper and is a part of my ongoing research. In this paper, I model their behavior based on what seems most plausible.

3.4 Demand

I represent the demand for electricity in MH state with a constant elasticity demand function of the form $Q = C \times P^{-e}$. In this equation Q is demand, P is price and e is the market elasticity of demand. Electricity demand is believed to be relatively inelastic in the short-run. Hence, I assume a demand elasticity of 0.1.[22] In this analysis, I am analyzing the feasibility of competition in the short- run as I am most concerned about the exercise of market power in the short-run. If an electricity market is competitive in the short-run then it is also likely to be competitive in the long-run because supply and demand are believed to be more elastic in the long-run. The constant C was adjusted so that the demand function passes through the price-quantity pair from the average forecasted wholesale electricity price and demand for the simulation year (2007-08). For the simulation year, I estimate that the average wholesale price will be 4.7 cents/kWh and the average wholesale electricity demand will be 13,547 MW.[23] These values of quantity and price are used to anchor the constant elasticity demand curve. It is worth noting that the results that I obtain are not very sensitive to this anchor point. The 4.7 cents/kWh figure is only used to scale the demand functions at different hours. Since I will run market simulation for various demand levels in the financial year 2007-08, I will now forecast the demand levels in all the hours of the financial year 2007-08.

3.4.1 Forecasting Hourly Demand Levels for 2007-08

Estimating the Rate of Demand Growth

The Central Electricity Authority (CEA) is one of the main agencies forecasting demand in India. The CEA, in its 16th Electric Power Survey of India, estimates that the peak demand and the energy requirement in MH State will grow by 6% per year (CEA, 2003). Utilities in MH state and MERC also estimate electricity demand growth rates. They estimate that demand in MH state will grow at an average of 5% per annum.[24] The estimates by MERC and the utilities are considered more realistic as they are based on recent trends and data. Hence I assume a demand growth rate of 5%. Since there is uncertainty about the rate of demand growth, I test the sensitivity of my results to higher demand levels.

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[22] To my knowledge, there are no estimates of the short-run elasticity of electricity demand in MH state or in India. The estimates of short-run elasticity in other countries range from 0.1 to 0.4. I model a worst case scenario in terms of potential for exercising market power by assuming an elasticity of 0.1.

[23] The average wholesale price for the year 2007-08 is estimated as follows. The average retail electricity price for 2003-04 is estimated to be 7.5 cents/kWh. This estimate is based on the average retail price for MSEB consumers and consumers in Mumbai (MERC 2004, MERC 2005). Out of 7.5 cents/kWh, 3.75 cents/KWh is the cost of transmission and distribution. Transmission and distribution costs for utilities in MH state were estimated based on detailed cost data in their annual reports and tariff filings (MSEB 2003, MERC 2003, MERC 2004a, MERC 2004b). Hence the average wholesale price is estimated to be 3.8 cents/kWh. We use this price as the base year price. I assume a growth rate of 5% per year in electricity prices based on the growth of electricity prices in the last 5 years and estimate the average wholesale electricity price for 2007-08 (MOP, 2005). The average wholesale demand in MH state in 2002-03 is estimated to be 10,100 MW based on the hourly wholesale demand data for MH state. I assume a growth rate of 5% (basis for this growth rate is stated in the next section) to forecast an average demand of 13,547 MW in the year 2007-08.

[24] The estimate of demand growth in MH is based on an estimate of demand growth rate for MSEB consumers and consumers in Mumbai (MERC 2003, MERC 2004a, MERC 2004b)

Projecting Hourly Demand Levels

I obtained hourly demand data for all the three utilities in MH state and hourly data on the trade between these utilities for the financial year 2002-03.[25] Based on these data, I calculate the total hourly demand for MH state for all hours in 2002-03.[26] Demand for each hour in 2007-08 is forecasted by taking the demand in the corresponding hour in 2002-03 as a base and by assuming the estimated annual growth rate in demand. I use 2002-03 as the base year for projecting demand because demand data for later years are not available for some of the utilities. I assume no change in the load shape while projecting demand, which is consistent with the assumption by CEA, MSEB, and MERC.

3.5 The Cournot Algorithm

I use an algorithm based on the Cournot framework to simulate competition in a potential wholesale electricity market in MH state.[27] In this algorithm, the Cournot equilibrium is found interactively using a grid search method. First, the supply curve of price-taking firms is determined as follows: price-taking firms generate every unit of output possible as long as their marginal cost of generation is less than or equal to the market price. Hence the data on marginal costs of price-taking firms allow me to obtain relationships between the supply from price-taking firms and the market price which are supply curves of price-taking firms. A residual demand curve is obtained by subtracting the supply curves of price-taking firms from the market demand curve as shown in section 3.3.2. Each Cournot firm is facing a demand curve that is equal to the residual demand curve (as obtained in equation 1) minus the supply from all the other Cournot firms,

$$D_i(P) = D_r(P) - \sum q_j \quad where \quad i \neq j \qquad (2),$$

where $D_i(P)$ is the demand curve faced by a Cournot firm i, $D_r(P)$ is the residual demand curve obtained in equation (1), and $\sum q_j$ is the sum of the supply of all the other Cournot firms. Profit maximizing output for a Cournot firm is determined by considering the residual demand curve and the marginal cost curve of the Cournot firm, taking the output of the other Cournot firms as given. The process of finding the Cournot equilibrium starts by assuming that all the Cournot players have no output and the first Cournot player sets its output given that the other Cournot players have no output. The second Cournot player sets its output given the supply of the first Cournot player determined in the previous iteration. This process is repeated for all the Cournot firms until no firm can profit from changing its output given the output of the other firms. This state is the Cournot equilibrium where each firm is producing its profit-maximizing output.

Because the supply curves of price-taking firms have flat regions (since I assume that power plants have a constant marginal costs up to their capacity), the residual demand curve also has some flat regions which occasionally cause multiple equilibria. In such cases, I also find that one of the equilibria results in more total profits for firms compared to all the other equilibria. I choose to include this equilibrium in my analysis as it dominates, from the firms' perspective, all the other equilibria and represents a worst case scenario of market power.

3.7 Modeling Policy Scenarios

[25] See MSEB (2004 a) and MSEB (2004 b) for the source of this data.

[26] This demand includes the estimate of the demand not met due to the supply shortage.

[27] This algorithm was developed by Borenstein & Bushnell (1999).

As discussed earlier, the objective of this analysis is to understand the circumstances under which wholesale electricity competition is feasible in MH state. I analyze the effect of three main policies that are believed to increase the competitiveness of wholesale electricity markets. These policies include the divestiture of dominant firms, the requirement of long term contracts, and the implementation of demand response. I first simulate a scenario in which none of these policies are implemented: this forms the base case scenario. I then simulate various scenarios in which one or a combination of these policies is implemented to understand their effect on the competitiveness of the MH electricity market. I also analyze the effect of other important factors that might influence my results such as the hydro generation availability, the price at which demand response takes place, and the balance of demand and available supply. Further, I analyze the effect of public ownership on the competitiveness of the MH electricity market.

In the MH electricity market, the wholesale price is unlikely to be allowed to rise without any limit. Hence I assume a price cap of $500/MWh based on expert opinion.[28] The residual demand obtained after subtracting hydro production (estimated with the peak-shaving exercise) from the original demand varies between 8,000 to 16,000 MW. Appendix IV presents the results of the peak-shaving exercise and shows the seasonal variation in the residual demand. I calculate Cournot equilibria for demand levels from 8,000 MW to 16,000 MW at 500 MW intervals. This exercise gives us an idea of the demand level at which the market starts to deviate from being perfectly competitive. I also calculate Cournot equilibria at specific demand levels in December, June, and April. These months were selected to account for the seasonal variation in demand and the availability of agricultural pumping load that could be shifted as a demand response strategy. For each month, I calculate Cournot equilibrium prices at five representative demand levels: the residual peak demand, the most commonly observed residual demand (see section 3.3.1 for the definition of the most commonly observed residual demand level), and the 174Th, 354th, and 534th highest residual demand of the month. Note that the most commonly observed residual demand and the 174th highest residual demand is the same for all the months in 2007-08. I also calculate the price that will occur if all the firms acted as competitive price-taking firms as a benchmark equilibrium. As a result of the peak-shaving exercise, the number of hours in which the residual demand is higher than the most commonly observed residual demand is quite small (about 5% of the hours). Hence the market will be competitive about 95% of the time if it is competitive at the most commonly observed residual demand. In the next section I present the results of various scenarios starting with the base case. The results are also summarized in section 4.4.

4. Results

4.1 Base Case

For this scenario, I assume that a single private firm, MHgen, owns a large share of the thermal generation capacity in the MH electricity sector.[29] Table 6 shows the market structure for the base case scenario. I assume that generation firms do not sign any long-term contracts and distribution utilities and consumers do not have any demand response capacity. Because I am simulating market outcomes for the residual demand levels after accounting for hydro generation, hydro capacity is not included in this table.

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[28] Based on an interview with Dr. S. K. Soonee, Director Power Grid Corporation of India (17th August, 2005).

[29] I assume that MHgen owns all the generation capacity currently owned by MSEB.

Table 6: Market Structure with No Divestiture

Name	Ownership	Firm Type	Capacity (MW)	% of total
MHgen	Private	Cournot	7,999	52%
TATA	Private	Cournot	1,224	8%
BSES	Private	Cournot	480	3%
CH Import	Public	Price-Taking	984	6%
MP Import	Public	Price-Taking	1,501	10%
GU Import	Public	Price-Taking	665	4%
SR Import	Public	Price-Taking	500	3%
Dabhol	Public	Price-Taking	2,076	13%
Total Cournot			**9,523**	**63%**
Total Price-Taking			**6,021**	**37%**
Total			**15,544**	

The series 'Base PM' in Figure 3 shows the simulation results for various demand levels from 8,000 MW to 18,000 MW. The X-axis shows the demand level for which the simulation was carried out and the Y-axis shows the Cournot equilibrium price and the competitive price (the series 'PC') for the corresponding demand level. Figure 3 shows that the Cournot equilibrium price is substantially higher than the competitive price even at a demand level of 8,000 MW because at this demand level, the dominant firm MHgen is able to withhold enough capacity to exhaust all the price-taking firms' supply so that it sets the price. The column 'No –Divest' in Table 12 (on page 30) shows that the Cournot equilibrium prices for a few selected demand levels in December, April, and June are at the price cap.

As discussed in section 3.3.2, Cournot firms face a residual demand curve that is obtained by subtracting price-taking firms' supply curves from the market demand curve. Since I assume inelastic market demand, most of the elasticity of the residual demand is due to price-taking firms' supply. Once the price-taking firms' capacity is exhausted, the residual demand is inelastic and Cournot firms can raise prices substantially above competitive levels. The point at which price-taking firms' supply is exhausted depends upon the demand level and the ability of Cournot players to withhold capacity. At higher demand levels, a part of the price taking firms' supply is already exhausted and hence Cournot players need to withhold less capacity to exhaust all the inexpensive supply of price-taking firms and raise prices. If the Cournot players have the ability to withhold more supply, price-taking firm's supply could be exhausted at lower demand levels. In this scenario, firms are able to exercise extensive market power for all the demand levels that would occur in 2007-08 which indicates that MH electricity market would not be competitive unless some policies to increase competitiveness are implemented.

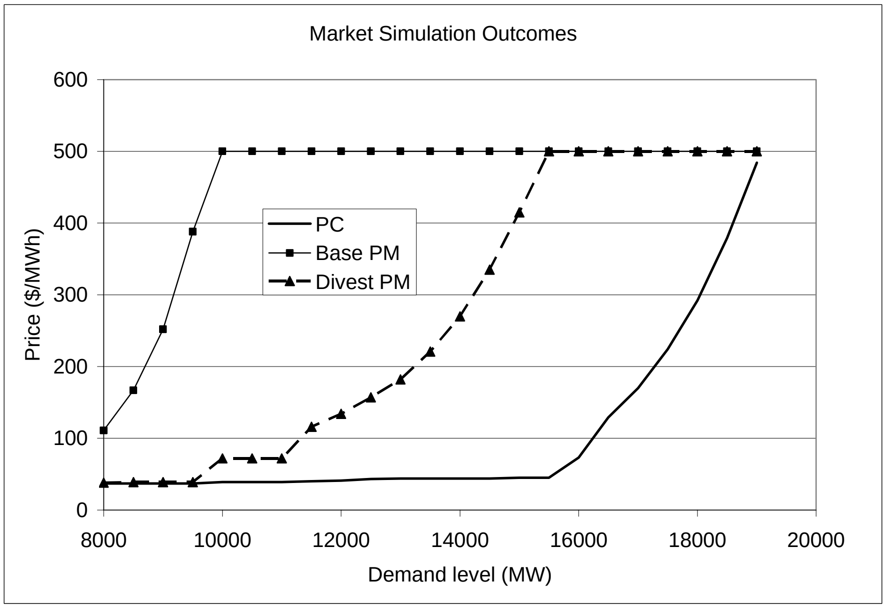

Figure 3: Cournot Prices Before and After Divestiture

4.2 Divestiture of Thermal Generation (Divestiture Scenario)

Divesting (dividing) large firms into a number of smaller firms is considered one of the main policies for reducing the ability of large firms to exercise market power. I assume that MHgen is divested into four generation companies – MHcoal1, MHcoal2, MHcoal3, and MHgas. Table 7 gives the market structure after this divestiture. Based on expert opinion[30], further divestiture is theoretically possible but it is not practically feasible as only a limited number of private players are likely to be interested in purchasing power plants in the MH electricity sector.

Table 7: Market Structure with Divestiture

Name	Ownership	Firm Type	Capacity (MW)	% of total
MHcoal1	Private	Cournot	2,542	16%
MHcoal2	Private	Cournot	2,140	14%
MHcoal3	Private	Cournot	2,508	16%
Mhgas	Private	Cournot	809	5%
TATA	Private	Cournot	1,224	8%
BSES	Private	Cournot	480	3%
CH Import	Public	Price-Taking	984	6%
MP Import	Public	Price-Taking	1,501	10%
GU Import	Public	Price-Taking	665	4%
SR Import	Public	Price-Taking	500	3%
Dabhol	Public	Price-Taking	2,076	13%
Total Cournot			9,523	63%
Total Price-Taking			6,021	37%
Total			15,544	100%

The series 'Divest PM' in Figure 5 (on page 30) shows the Cournot equilibrium prices at different demand levels and the column 'Divest' in Table 12 (on page 30) shows the Cournot

[30] Based on interviews conducted with senior power sector officials in MH state (August 13, 2005)

equilibrium prices at selected demand levels in June, April, and December. As expected, divestiture reduces Cournot equilibrium prices. Note that the Cournot equilibrium price deviates from the competitive price at a higher demand level compared to the case with no divestiture. However, Table 12 (on page 30) shows that even with this divestiture, the MH electricity market is not competitive for the most common demand levels in June, December, and April indicating that this level of divestiture will not make the market competitive.

I define the industry Lerner index as (P-C)/P where P is the Cournot price and C is the industry marginal cost for the Cournot quantity if that quantity was produced at the least cost by the industry. This is the markup over the price expressed as a fraction of the Cournot price, which would yield the same output in a perfectly competitive market. Table 13 (on page 31) shows the Lerner index for the selected demand levels in June, April, and December. For the most common demand level in December, the Lerner index drops from 91% to 83% with divestiture.

I simulate a limit case of divestiture where every plant is owned by a different firm. In this case, the largest firm owns 2,140 MW of capacity since the largest plant in MH state is 2,140 MW. In this scenario, the market is competitive for most of the demand levels except during the peak and most commonly observed demand levels in December. However, such extensive divestiture is not plausible in MH state as only a limited number of players are likely to be present in the MH electricity market.[31]

4.3 Demand Side Participation

Demand-side participation is believed to increase the competitiveness of wholesale electricity markets and could happen primarily in two ways. First, the end-use consumers could respond to the wholesale price by adjusting their demand if they are exposed to the wholesale price. Since the wholesale price usually changes within a small interval of time, end-use consumers need to be on real-time pricing to face the right incentives and have the right information to respond to the wholesale price. Hence real-time pricing is necessary to increase the short-run responsiveness of demand. Other forms of time varying pricing such as time-of-use pricing may lead to the flattening of the demand curve as consumers shift consumption from high demand periods to low demand periods. However, such pricing schemes will not increase the responsiveness of demand in the very short- run (for the demand in the next hour or day) which is critical for controlling market power.

The second way in which demand could participate in a wholesale electricity market is by having interruptible tariffs for consumers. The consumers on interruptible tariffs get a discounted electricity price and in return the distribution utility has the right to curtail the demand (interrupt) of these consumers. A distribution utility could respond to wholesale prices by adjusting its demand by curtailing or reconnecting the demand of consumers on interruptible tariffs. Interruptible tariffs are a crude method of demand response and could lead to a loss in economic efficiency.[32] If a distribution utility has some share of its

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[31] Based on interviews conducted with senior power sector officials in MH state (August 13, 2005)

[32] This will be the case if a consumer's marginal value of consumption varies a lot with the consumer's consumption level. Because load curtailment can not be easily done for just a part of a consumer's load, consumers participating in interruptible tariffs base their decision to subscribe for interruptible tariffs based on the average value of their consumption and not on the marginal value of their consumption leading to some inefficiency.

consumers on interruptible tariffs, it can credibly threaten to reduce its demand if market power is exercised and the price goes above a certain level which controls the exercise of market power. Implementing interruptible tariffs does not mean that the demand of consumers on interruptible tariffs will be curtailed all the time to reduce the exercise of market power because a credible threat of demand reduction is sufficient to reduce its exercise.

4.3.1 The Possibilities of Demand-Side Participation in the MH State Market

This section describes the possibilities for demand response in various consumer categories in MH state. Table 8 shows the distribution of the total electricity consumption in MH state among the categories of consumers.

Table 8: Consumer Category-Wise Consumption in 2002-2003

Consumer Category	Consumption (GWh)	% of Total Consumption	Average Demand (07-08)
Residential	12,267	25%	3,327
Commercial	4,659	9%	1,264
Industrial	18,156	36%	4,925
Agriculture	10,642	21%	2,887
Other	4,221	8%	1,145
Total	49,945		13,547

Source: Economic Survey of MH State 2003-04 (Government of Maharashtra, 2003).

Note: Agricultural consumption is the energy consumed by irrigation pumps.

Industrial Consumers

As shown in Table 8, industrial users consume the largest share of electricity. Like many other states in India, MH state has faced increasing power shortages since 1998. In the last two to three years, power shortages have grown as large as 20% of the peak demand. Many industrial consumers in MH state have installed back-up generation as a response to the power cuts and the poor quality of power. This back-up generation capacity could act as reserve capacity when power shortages are reduced significantly which I argue (later in this paper) is quite likely to happen in the near future. The availability of a large back-up generation capacity creates opportunities for demand side participation from industrial consumers. The distinction between what counts as generation and what counts as demand response is quite arbitrary. I consider generation from back-up generators of industrial consumers as demand response because industrial consumers are reducing their net demand in the market when they use their back-up generation. I estimate that the total capacity of relatively large back-up generators (above 0.5 MW) could be as high as 4,000 MW and the marginal cost of these back-up generators is about 18 cents/kWh. The basis of this estimation is discussed in Appendix III. Since there is uncertainty about the available capacity of back-up generation, I make a conservative assumption that only 1,500 MW of the industrial back up generation will be available for demand-side participation. I assume that industrial consumers will generate from their back-up generation capacity if the wholesale price goes above the marginal cost of back-up generation. It is worth noting that about 10,000 large industrial consumers (which is .07% of the total number of consumers) constitute about 30% of the total electricity demand in MH state. Almost all of the relatively large back-up generation capacity is available from these 10,000 industrial consumers. Since a small number of industrial consumers constitute a large share of the demand, having a real-time pricing program just for these consumers would put about 30% of the demand in MH state on real-time pricing for a relatively low cost. I discuss in detail the options for implementing demand response programs for the large industrial consumers in Appendix III.

Agricultural Consumers

The distribution sector in MH state is likely to have the ability to shift large quantities of agricultural pumping load from peak to off-peak periods. To deal with the current power shortages in MH state, MSEB sheds significant amount of load in rural areas during peak demand periods. This load shedding is primarily done to curtail power to the agricultural pumping load which constitutes about 25% of the system demand during peak periods. It is argued that farmers in MH state run agricultural pumps for 4 to 6 hours a day on average and they could potentially run the pumps at any time during the day. Because the agricultural pumping load and rural residential load are on the same feeder (electricity line), rural households are deprived of electricity during peak periods. To address this problem, MSEB is implementing schemes which allow MSEB to selectively curtail power to agricultural pumps while providing power to rural households.[33]

Peak coincident agricultural load in MH state is estimated to be 4,500 MW (MERC, 2005). MSEB estimates that its single phasing scheme will give them the ability to shift about 1,900 MW of agricultural pumping load from peak to off-peak periods. MSEB has also shown interest in other technical and institutional measures to separate the agricultural pumping load from the rural residential load. Since there is uncertainty about the extent to which these schemes will be implemented in practice, I make a conservative assumption that the distribution sector in MH state will have the ability to shift only one third (1,500 MW out of 4,500 MW) of the peak-coincident agricultural pumping load from peak to off-peak periods. I assume that during the low demand months (May to September), the distribution utilities will not have the ability to shift agricultural pumping load as there is little agricultural pumping load in the system. When the power shortages are removed or reduced significantly in the future, shifting of the agricultural pumping load may not be necessary. However, the ability to shift agricultural pumping load to another period will still be there as the distribution network changes made for schemes like single-phasing and feeder separation are permanent. This ability to shift agricultural pumping load creates opportunities for demand response in the agricultural sector.

The cost associated with curtailing power to agricultural pumping during peak times to force agricultural consumption to occur only during the off-peak time is the inconvenience faced by farmers as they are required to pump water during the off-peak time which is usually the night. It is hard to measure this inconvenience cost. However, if the agricultural pumping load is shifted form the evening super-peak period to other parts of the day (load is not

[33] These include technical as well as institutional measures. In institutional measures such as 'Akshay Prakash Yojana' (Continuous Light Program), a village manages its demand and does not allow pumping during the peak periods and in return that village's electricity is not cut during the peak hours (MERC, 2005c). Technical solutions include feeder separation and single phasing. In feeder separation, the lines, which supply power to rural households, are separated from lines that supply power to agricultural pumps. Many states in India have made significant investments in feeder separation. Single phasing allows utilities to selectively shut of three phase loads (like agricultural pumping) while continuing to provide power to single phase loads (like residential lighting and appliances). Many objections have been raised about the single-phasing scheme related to its cost effectiveness, safety, and consumer discrimination (MERC, 2005). However, MSEB is implementing a single phasing scheme with funds and approval from the government of MH (GOM). MSEB also has expressed interest in implementing other options such as feeder separation.

shifted to the night)[34], the inconvenience cost is likely to be negligible. Most likely the inconvenience cost will be lower than the cost of running expensive peak-load plants. A utility could have various approaches to decide the price above which the agricultural pumping load is curtailed. For example, a utility could have a policy where it will cut supply to agricultural consumers only when the capacity of all power plants except the expensive peak-load plants is utilized. In a competitive market, given the marginal cost of various plants, this will happen at a price of $45/MWh. In the long-run, if agricultural load will be shed only when the power is generated from expensive peak-load plants (such as diesel generators), then the price at which the agricultural load is shed should be equal to the long range marginal cost (LRMC) of an intermediate load plant. I estimate that the LRMC of an intermediate load plant, a combined cycle gas turbine plant (CCGT), is $46/MWh.[35] For the base case scenario, I assume that the distribution utilities will curtail agricultural load when the price goes above $46/MWh.

Residential and Commercial Consumers

As mentioned earlier, life in developing countries is less dependant on a constant, uninterrupted supply of electricity as compared to developed countries which makes interruptible tariffs more feasible in developing countries. However, it is hard to estimate the extent to which consumers will subscribe to interruptible tariffs. I make a conservative assumption that 500 MW of commercial and residential load will be on interruptible tariffs which is about 6% to 7% of the total residential and commercial demand during the peak times. I assume that these consumers do not want to pay for the high cost electricity during the super-peak hours when the demand is met by expensive peak-load plants. The distribution utility curtails power to these consumers as well as agricultural consumers if the price goes above $46/MWh. I test the sensitivity of my results to the amount of load on interruptible tariffs and to the price at which the load is curtailed.

4.3.2 Modeling Demand Response

I assume that demand side participation in the MH electricity market comes primarily from the distribution utilities who curtail a certain quantity of load at a certain price that reflects the marginal cost of curtailing load. This is equivalent to generation from a price-taking firm, which produces when its marginal cost is less than or equal to the market price. Hence I model demand response as generation from a price-taking demand-reducing firm. Because the distribution utilities have control over their demand, they could also act as monopsonists and depress market prices by curtailing load even when the marginal cost of curtailment is more than the wholesale market price. However, this strategy is unlikely to be politically

[34] Electricity demand in MH state is the highest during the evening (6 p.m. to 9 p.m.). This period is known as the super-peak period.

[35] If a new CCGT plant enters the MH electricity market, its marginal cost is going to be comparable to the marginal cost of old coal power plants in the system and hence it is likely to operate 80 to 90% of the time during the year. If I assume that only the top 10% of the load in a year is served by expensive peak-load plants (diesel generators or open cycle gas turbines), a CCGT plant will operate only 10% of the time at the end of its lifetime as the newer CCGT plants are likely to have lower heat rates and will be dispatched before this plant. Hence the average utilization of a CCGT plant during its lifetime will be 45% to 50%. We estimate the LRMC of a CCGT plant operating 50% of the time over its lifetime to be $46/MWh. LRMC is estimated assuming a capital cost of $550/kW, life of 20 years, discount rate of 10%, plant utilization factor of 50%, and natural gas price of $4.5/MMBtu.

feasible as it requires the utilities to curtail power to some of their consumers even when relatively cheap power is available.

Figure 4 shows the marginal cost curve of this price-taking demand-reducing firm for high demand months, which includes demand response from agricultural consumers. For low demand months, the capacity of this price-taking firm available at the marginal cost of $46/MWh is reduced by 1,500 MW because it does not include demand response from agricultural consumers. As mentioned earlier, I make conservative assumptions about the demand response capacity in the MH state electricity sector as there is uncertainty about how much demand response could actually be achieved. For example, I assume that only 1,500 MW of industrial back up-generation capacity is available in MH state where the actual back-up generation capacity available could be as high as 4,000 MW. Similarly, I assume that the distribution sector in MH state will have an ability to shift 1,500 MW of agricultural pumping load when the peak-coincident agricultural pumping demand is about 4,500 MW and it is possible shift almost all of this demand to the other periods of the day.

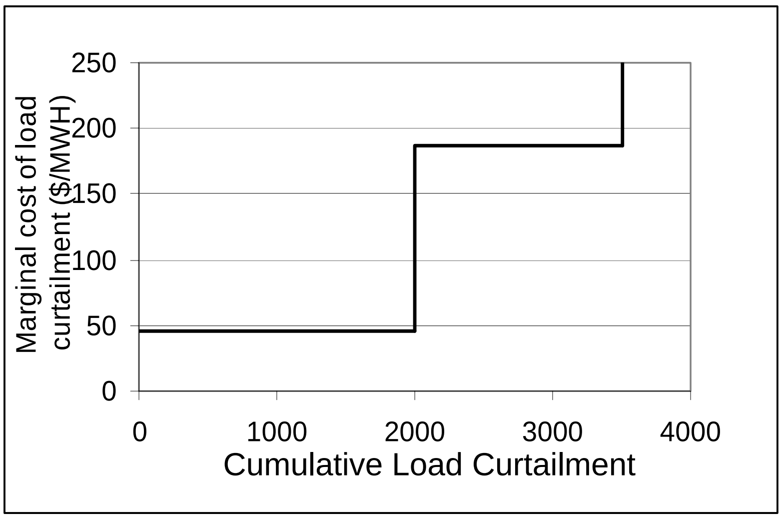

Figure 4: Marginal Cost Curve of the Demand Firm

If the demand response capacity is more than that assumed for this analysis, the MH electricity market will be more competitive than indicated by this analysis.

4.3.3 The Effect of Demand Response (Divestiture & Demand Response [DR] Scenario)

Table 9 shows the reserve margins with and without considering demand response.[36]

Table 2: Reserve Margins With and Without Demand Response

Available Capacity (MW)	Supply side	15,544
	Demand response	3,500
	Total	19,044
Peak demand (MW)		15,680
Reserve Margin	With only supply side capacity	-1%
	With demand response included	23%

[36] Reserve margin = (peak demand – total available supply)/peak demand

Without considering demand response, the available generation capacity is little less than the peak demand resulting in a reserve margin of -1%. Adding the demand response capacity to the portfolio reveals a reserve margin of 23%. Higher reserve margins increase the competitiveness of electricity markets in most cases.

The marginal cost curve of this price-taking demand firm is shown in Figure 4. I add this price-taking demand firm to the market to understand the effect of demand-side participation. I assume that MHgen is divested into four companies as assumed for the Divestiture scenario. The series 'Divest & DR' in Figure 5 (on page 30) shows the Cournot equilibrium prices at various demand levels for the high demand months. The column 'Divest & DR' in Table 12 (on page 30) shows the Cournot equilibrium prices for the selected hours in June, April, and December. As Table 12 and Figure 5 (on page 30) show, demand response substantially reduces the Cournot equilibrium prices. However, the Lerner index for the most commonly observed demand levels in December and June (shown in the 'Divest & DR' column in Table 13) indicates that there is substantial market power at these demand levels. The market is competitive for the most commonly observed demand level in April indicating that it will be competitive in the low demand months.

In the Divestiture and DR scenario, the Cournot equilibrium price starts deviating from the competitive price at a demand level that is about 3,500 MW higher that it did with divestiture alone. This is the effect of the 2,000 MW of demand response available at $46/kWh. Table 10 shows the production of price-taking and Cournot firms at the demand levels where the Cournot equilibrium price starts to deviate from competitive levels.

Table 10: Production by Cournot and Fringe Firms

	Divest			Divest & DR		
	Demand Level (MW)			Demand Level (MW)		
	9500	9600		12900	13000	
	Generation (MW)		Difference	Generation (MW)		Difference
MHcoal1	2,542	611	(1,931)	2,542	957	(1,585)
Rest Cournot	2,722	2,525	(197)	4,440	3,526	(914)
Cournot Production	5,264	3,136	(2,128)	6,982	4,483	(2,499)
Fringe Production	4,292	5,947	1,655	5,947	7,947	2,000
Q Cournot (MW)	9556	9083		19,911	12,430	
P Cournot ($/MWh)	39	72		44	72	

In the divestiture scenario, when demand increases from 9,500 MW to 9600 MW, Cournot players find it profitable to withhold capacity so that all the inexpensive capacity of price-taking firms is exhausted and the price is set by an expensive price-taking generator. Table 10 shows that at demand of 9,600 MW, Cournot players are withholding 2,128 MW and the inexpensive (efficient base-load and mid-merit) capacity of price-taking firms (which is 5,947 MW) is exhausted. Demand response increases the inexpensive capacity of price-taking firms from 5,947 MW to 7,947 MW. The demand level needs to increase to use this additional capacity up-to a point where Cournot players can exhaust the remaining inexpensive capacity of the price-taking firms by withholding some of their own capacity. In the Divest and Demand Response Scenario this happens when the demand reaches 12,900 MW. When demand increases from 12,900 MW to 13,000 MW, Cournot players withhold 2,499 MW to exhaust the additional 2,000 MW of the inexpensive capacity of price-taking firms and the price is set by an expensive price-taking generator. If the inexpensive capacity of price-taking firms is large enough, Cournot players are unlikely to withhold capacity because it will not increase the price very much as the price will be set by an inexpensive price-taking generator.

I find that if the inexpensive demand response capacity increases to 4200 MW, the MH electricity market will be competitive for all of the selected demand levels in December, April, and June. Doubling the number of residential and commercial consumers on interruptible tariffs (from 7% to 15% of the total residential and commercial consumption) and doubling the ability to shift agricultural load (from 30% to 60% of the total agricultural pumping load) would increase the demand response capacity to 4,200 MW. This level of demand response is difficult but not impossible to achieve.

4.4 The Effect of Long-Term Contracts (Divestiture & Contracts Scenario)

As discussed in Section 2.2, theoretical and empirical research shows that allowing or the existence of long-term contracts, under most circumstances, increases the competitiveness of wholesale electricity markets. I want to analyze the effect of the policy of requiring firms to sign long-term contracts for a certain portion of their generation. Hence I analyze the effect of contracts on equilibrium prices in a static setting where the contract quantity is exogenously determined.

I model contracts signed by a firm by subtracting the contract quantity from that firm's supply curve and form the demand level for which I am calculating the Cournot equilibrium price. This approach will correctly model the effect of contracts as long as the production for the contracts quantity is infra-marginal for that firm. If a high-cost firm has signed contracts for a large portion of its generation then there could be instances when the firm will find it cheaper to buy electricity in the market rather than generating from its own plants to meet its contractual obligations. In this case, my approach will misstate the supply and demand curves. I assume that firms only sign contract to produce infra-marginal power for the demand levels at which I am calculating equilibrium prices which leads to about 40 % of the total capacity of Cournot firms under contracts. Table 11 shows the contracting level assumed for these firms.

Table 11: Contract Quantities

Firm	Total Capacity (MW)	Contract Quantity (MW)	Net Position (MW)
MHcoal1	2,542	1,700	842
MHcoal2	2,140	1,300	840
MHcoal3	2,508	1,000	1,508
Total	7,190	4,000	3,190

The series 'Divest & Contracts' in Figure 5 shows the Cournot equilibrium prices at different demand levels. As the column 'Divestiture & Contracts' in Table 11 shows, the Cournot equilibrium prices for the selected demand levels in June, April, and December have dropped significantly compared to the Divestiture scenario. Prices are competitive except in the month of December. The Lerner index (shown in the column 'Divest and Contracts' in Table 13) for the selected demand levels in December indicates that the market will not be competitive in December. As the contract obligation of Cournot firms increases, their net position in the spot market decreases which reduces their incentive to exercise market power in the spot market. If all the capacity of a Cournot firm is under contracts, it does not face any incentive to exercise market power in the spot market. Wolak (2004) argues for a similar approach in which only a forward market for long-term contracts is established and the real time imbalances are priced at the system marginal cost estimated from actual cost data. Wolak also argues that his approach could be an intermediate step before wholesale competition with spot markets is implemented India. A similar market already exits in India where state utilities engage in bilateral forward contracts and the imbalances are priced at the system marginal cost.[37]

Table 12: Summary of Results

Demand Level	Price ($/MWH)					
	Pcomp	PCournot				
		No Divest	Divest	Divest & Contracts	Divest & DR	Divest & DR & Contracts
June						
Highest	43	500	500	43	141	43
Most common	41	500	134	41	122	41
372th	39	500	116	41	72	41
534th	39	500	72	41	72	41
April						
Highest	44	500	182	44	72	44
Most common	43	500	157	43	45	43
352th	43	500	157	43	45	43
554th	41	500	134	41	43	41
December						
Highest	45	500	500	136	167	72
Most common	45	500	270	72	110	45
352th	45	500	270	72	110	45
554th	43	500	157	43	45	43

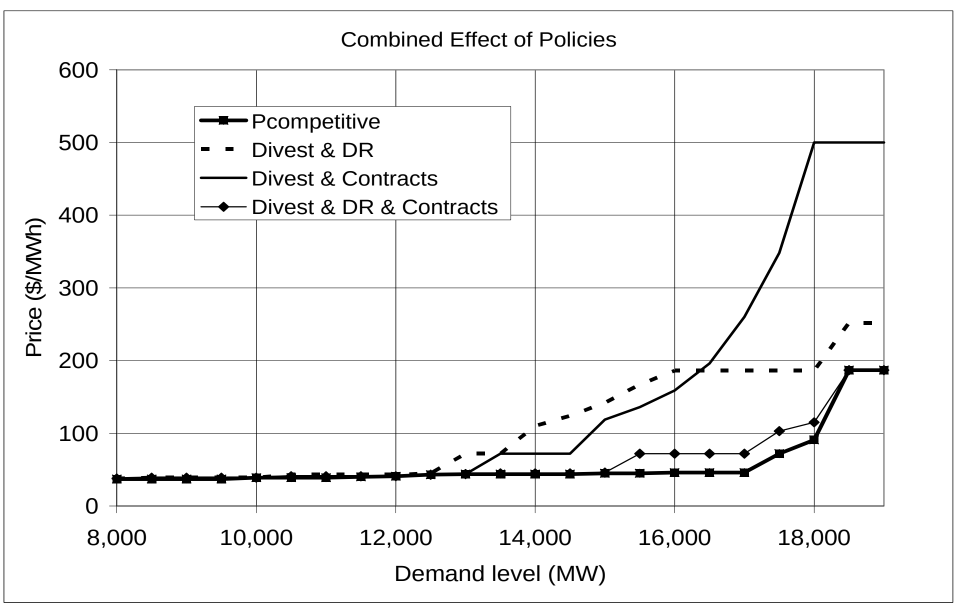

Figure 5: Combined Effect of Policies

[37] The price for imbalances is based on the system frequency which is allowed to float within a narrow band. This imbalance pricing mechanism is set up in a way that the imbalance price represents the system marginal cost (Khosla & Plummer, 2004)

Table 13: Summary of the Lerner Index

Demand Level	Lerner index				
	No Divest	Divest	Divest & DR	Divest &Contracts	Divest & DR & Contracts
June					
Highest	91%	91%	70%	< 1 %	< 1 %
Most common	92%	69%	66%	< 1 %	< 1 %
372th	92%	66%	46%	< 1 %	< 1 %
534th	92%	46%	46%	< 1 %	< 1 %
April					
Highest	91%	76%	39%	< 1 %	< 1 %
Most common	91%	73%	4%	< 1 %	< 1 %
352th	91%	73%	4%	< 1 %	< 1 %
554th	92%	69%	5%	< 1 %	< 1 %
December					
Highest	91%	91%	73%	67%	38%
Most common	91%	83%	59%	38%	< 1 %
352th	91%	83%	59%	38%	< 1 %
554th	91%	73%	4%	< 1 %	< 1 %

4.5 Combined Effect of Divestiture, Demand Response, and Contracts (Divestiture, Demand Response (DR), and Contracts Scenario)

As shown in the previous sections, any one of the policies of divestiture, demand response, and contract requirements, if implemented to the maximum extent attainable, could make the MH electricity market almost perfectly competitive. Pursuing any one of these policies to the maximum extent attainable will be difficult and in some cases impractical. Instead, all these policies could be simultaneously implemented at levels easily attainable. I simulate a scenario where I assume that MHgen will be divested into four companies. The three coal companies will have contracts for a total of 4,000 MW of capacity and distribution utilities will have a demand response capability of 3,500 MW. The series 'Divest & DR & Contracts' in Figure 5 shows the Cournot equilibrium prices for this scenario at various demand levels. The column 'Divestiture & DR & Contracts' in Table 12 shows the Cournot equilibrium prices at the selected hours in June, April, and December. The MH electricity market is perfectly competitive in every hour in the year, except for 14 hours when the demand is above 15,000 MW, so for all practical purposes the market can be considered nearly perfectly competitive. This scenario indicates that appropriate policies can foster effective competition in the MH state power sector. This analysis indicates that no one policy implemented at a realistic level can ensure competition in the MH electricity market, but their combination implemented at easily attainable levels can achieve the goal. In the next section, I analyze the sensitivity of this result to various factors.

4.5.1 Robustness of the Results

<u>Higher Demand</u>

If I use a demand growth rate assumed by CEA, which is 20% higher than the growth rate I have used based on MERC's estimate, the demand level in every hour will be about 700 MW more than assumed for the base case. Table 14 shows that there is no difference in the Cournot equilibrium prices in the selected hours in December between the base case and high demand scenarios.

Table 14: The Effect of Higher Demand

Demand Level	Pcomp	Pcournot	
		Base Demand	High Demand
Highest	45	72	72
Most common	45	45	45
372th	45	45	45
534th	43	43	43

Figure 5 shows that as long as the most commonly observed residual demand is below 15,000 MW, market power is limited to a small number of hours. I calculate the Lerner index for all hours in the year for the scenarios in which demand in all hours is 1,000 MW, 1,500 MW, 2000 MW, and 3,000MW more than the base case. I also calculate the average monthly Lerner index and the results are shown in Table 15. When demand is 1,000 MW higher in all hours, the reserve margin is negative 5 percent and the MH state market is close to being perfectly competitive.

Table 15: Average Monthly Lerner Index at the Higher Demand Levels

Month	1000 MW +	1500 MW +	2000 MW +	3000 MW +
1	< 1 %	0%	25%	27%
2	< 1 %	0%	25%	29%
3	< 1 %	0%	22%	28%
4	< 1 %	0%	0%	26%
5	2%	29%	32%	37%
6	< 1 %	1%	18%	28%
7	< 1 %	1%	26%	33%
8	< 1 %	0%	0%	26%
9	< 1 %	23%	26%	33%
10	< 1 %	0%	25%	31%
11	< 1 %	21%	24%	29%
12	< 1 %	24%	25%	28%
Mean	< 1%	8%	21%	30%

If demand is 3,000 MW higher in every hour of the year compared to the base case, the MH electricity market exhibits significant market power. This case is similar to the current situation in which there are severe power shortages. Power shortages need to be reduced to a level below 5 percent in order to have a competitive wholesale electricity market in MH state.

Hydro Generation Availability

Total hydro generation availability for a year varies primarily with rainfall. I estimate the standard deviation of the total annual hydro generation based on the last 15 years data. I simulate a scenario in which the hydro generation availability is two standard deviations below the mean (which is 22% below the mean). For this low hydro scenario, I assume the same maximum and minimum hourly generation constraints as these constraints are likely to be the design characteristics of hydro power plants and will not change when the total hydro generation availability changes. Table 16 compares residual demand levels for the base case scenario and the low hydro generation scenario for December.

Table 16: The Effect of Lower Hydro Generation

Demand Level	Residual Demand	
	Low Hydro	Base Hydro
Highest	15,680	15,680
Most common	14,307	14,116
372th	14,307	14,116
534th	12,496	12,349

Lower hydro generation availability increases the most commonly observed residual demand by 200 MW and has no effect on the Cournot equilibrium prices for the selected hours in December, April, and June.

The Effect of Price at which Demand Response Takes Place

A utility could have a policy (although it is unlikely) of not curtailing power to the agricultural pumping load even if power is generated from expensive peak-load plants. I simulate a scenario in which the utility curtails power to its interruptible consumers only when the price goes above $92/MWh (which is the LRMC of a peak-load plant). The series 'HIGH IT' in Figure 6 shows the effect of this policy on equilibrium prices at various demand levels.

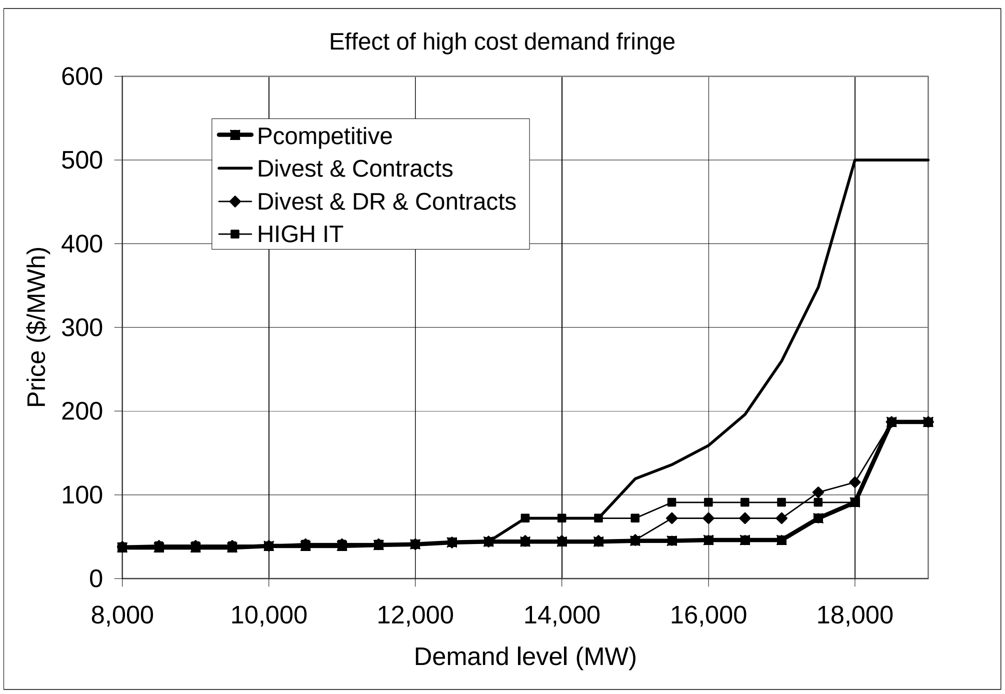

Figure 6: The Effect of High Cost Fringe.

In this scenario, demand response does not reduce the exercise of market power because the exercise of market power results in a price ($72/MWh) which is lower than the price ($92/MWh) at which demand response takes place. However, for demand levels above 14,500 MW, demand response reduces the extent of market power substantially compared to the Divest & Contracts scenario.

The Effect of Government Ownership

As discussed earlier in this paper, public firms are likely to behave as non-strategic price-taking firms. Price-taking firms increase competition in the market by making the residual demand curve faced by the strategic Cournot firms more elastic. This effect can be intuitively explained as follows. If price-taking firms own enough inexpensive generation capacity then even if Cournot firms withhold capacity to raise prices, the low cost price-taking firms will generate and set the market price making withholding less attractive for Cournot firms. Cournot firms anticipate this response from price-taking firms which reduces their incentive to exercise market power.

All the scenarios considered in this analysis assume that some of the firms which are currently under public ownership will continue to be under public ownership in a potential MH wholesale electricity market. This is because I know with reasonable certainty that these firms will not be privatized even if a wholesale electricity market is established in MH state. I analyze the effect of government ownership on the competitiveness of the MH electricity market in two ways. First, I analyze the effect of privatizing some of the firms that I have assumed to be under public ownership. The Series '75% Private' in Figure 7 shows the Cournot equilibrium prices at various demand levels when one of the large publicly owned firms is privatized increasing the private ownership in the market from 62% to 75%. Figure 7 shows that the privatization of this large generator increases the Cournot equilibrium prices substantially. Compared to the base case, the demand level at which the Cournot equilibrium price is substantially higher than the perfectly competitive price drops by 1,500 MW. This means that the market will not be competitive at lower demand levels which occur more frequently in the simulation year. The series '100% Private' shows that the demand level at which the Cournot equilibrium price is substantially higher than the competitive price drops even further and the Cournot equilibrium prices increase even more when all the government owned firms are privatized. In this case, the market is not competitive during most hours in the simulation year. This analysis shows that the presence of price-taking public firms plays a critical role in fostering competition in the MH electricity market.

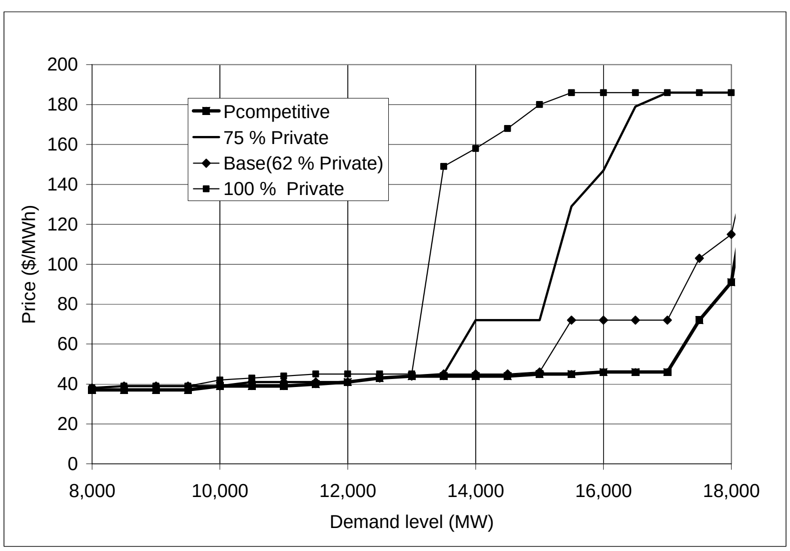

Figure 7: The Effect of Privatizing Government Owned Firms

I also compare the effect of generation capacity addition by private (Cournot) firms and public (price-taking) firms on market prices. In both cases, I assume that all the firms add equal amounts of base-load capacity and this new capacity increases the thermal generation capacity in the market by 15%.

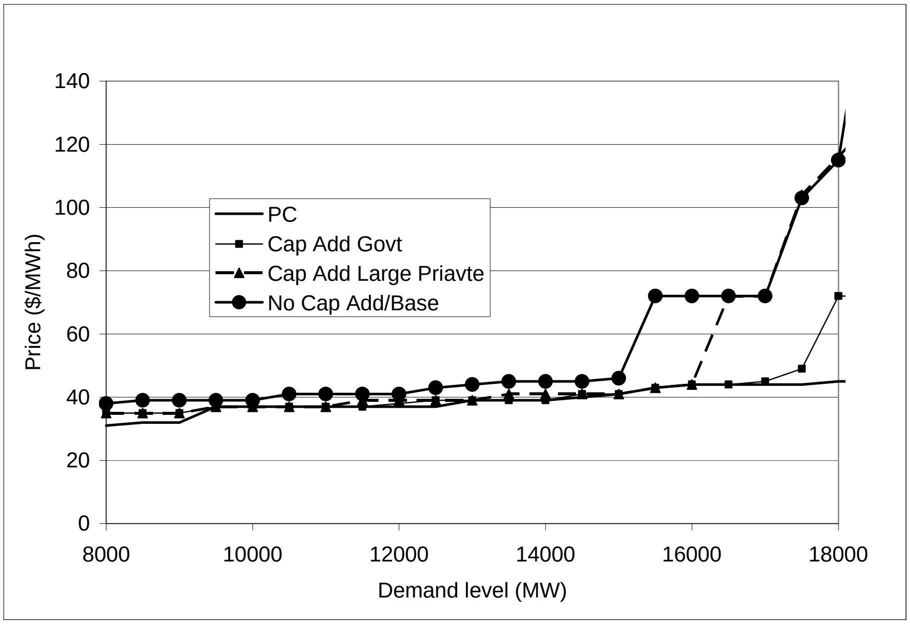

Figure 8: Comparing Capacity Addition by Public and Private Firms

The series 'Cap Add Govt.' in Figure 8 shows that compared to the base case, the expansion of government owned capacity increases the demand level at which the Cournot equilibrium price is substantially higher than the perfectly competitive price by 2,500 MW. The same amount of capacity additions by private firms increases this demand level only by 1,000 MW. Compared to capacity additions by private firms, capacity additions by public firms makes the market competitive for higher demand levels reducing the instances in which market power is exercised. It is generally believed that capacity additions (with demand being the same) increase the competitiveness of electricity markets. This analysis shows that the type of capacity addition (public or private) is an important determinant of how much capacity expansion affects the competitiveness of the market.

4.6 Summary of the Results

I have modeled the effect of three policies namely divestiture, demand response, and the requirement of long-term contracts on the competitiveness of a potential wholesale electricity market in MH state. Table 17 summarizes the effect of these policies when they are implemented at levels that are easily attainable. The MH electricity market is competitive when all the three policies are implemented simultaneously at levels easily attainable.

Table 17: Policies and Market Competitiveness

Policy	Scenarios			
	Base Case	D & DR	D & C	D & DR & C
Divestiture [D]	No	Yes	Yes	Yes
Contracts [C]	No	No	Yes	Yes
Demand Response [DR]	No	Yes	No	Yes
Market Outcome	High Market Power	Partially Competitive	Partially Competitive	Competitive

High Market Power: substantial market power is exercised in all the months in the simulation year.
Partially Competitive: substantial market power is exercised only in the high demand months (October to February)

I analyze the robustness of the results of the scenario in which all the three policies are simultaneously implemented resulting in a competitive MH electricity market. The results of this exercise are summarized in Table 18.

Table 18: Sensitivity Analysis of the Competitive Scenario

High Demand			
Shortage Level	~ 5 %	~10 %	~20 %
Average Price Cost Margin	< 1 %	8%	30%
Lower Hydro Generation			
Hydro Generation	Two Standard Deviations Below the Mean		
Average Price Cost Margin	< 1 %		
More Private (Cournot) Ownership [64 % Private in the Base Case]			
Increase in Private Ownership	21%	61 % [All Private]	
Average Price Cost Margin	9%	34%	

Note: Price Cost Margin is expressed as a Lerner index

The MH electricity market is competitive in a situation of small supply shortages; however, it is not competitive when the supply shortages are severe. The lower availability of hydro generation at the levels analyzed in this paper does not have any effect on the competitiveness of the market. An increase in private (Cournot) ownership of the generation capacity in the MH electricity market compared to the base case reduces its competitiveness and the market exhibits a high degree of market power when all the capacity is owned by private (Cournot) players.

5. Conclusions

It is generally believed that competitive wholesale electricity markets are not feasible in most developing countries because the power sectors in these countries are small, have small or negative (in the case of a supply shortage) reserve margins, and have distribution utilities that are unable to trade on commercial terms. Although these concerns about the feasibility of wholesale electricity competition are valid for some developing countries, not all developing countries have power sectors that exhibit characteristics which make competitive wholesale electricity markets difficult to establish. I argue in this paper that certain characteristics of electricity sectors in some developing countries could in fact increase the competitiveness of potential wholesale electricity markets there. I analyze the effect of such characteristics of the MH state electricity sector on the competitiveness of a potential wholesale electricity market there.

Some characteristics of the MH state electricity sector create unique opportunities for demand response which could potentially increase the competitiveness of a wholesale electricity market there. They include: the feasibility of interruptible tariffs, the availability of large quantities of industrial back-up generation, and the ability of the distribution utilities to shift large quantities of agricultural pumping load from one period of the day to another. If the distribution utilities have a demand response capacity, they can exert a credible threat to reduce their demand if market power is exercised which limits market power. I find that if these demand response opportunities are utilized, the competitiveness of a potential wholesale electricity market in MH state can be increased substantially. Note that in most developed countries, distribution utilities can not credibly threaten to reduce their demand even if severe market power is exercised because they have little demand response capacity (unless they have real time pricing, or critical peak pricing programs). Part of the reason why developed country utilities lack this capacity is that their customers are far more dependent on uninterrupted electricity supplies than customers are in developing countries. The results about the effect of demand response on the competitiveness of the MH electricity market are sensitive to the price at which demand response takes place. The distribution utilities in MH state will have to rely on other policies to control market power if the price resulting from the exercise of market power is below the price at which the demand response takes place.

It is increasingly believed that both public and private firms will play important roles in the electricity sectors in developing countries (World Bank, 2005). This is different from the mainstream view in the early nineties that the private sector should completely replace the public sector. Hence it is important to analyze the effect of mixed ownership (when public and private firms operate in the sector at the same time) on wholesale electricity competition. I model the effect of the presence of publicly owned firms on the competitiveness of a potential wholesale electricity market in MH state. I find that publicly-owned firms increase market competitiveness because they are likely to behave as non-strategic price-taking firms.

I also model the effect of two well known policies that increase the competitiveness of wholesale electricity markets: the requirement of long-term contracts and the divestiture of the dominant firms. I find that in the absence of policies to increase market competitiveness, the MH electricity market exhibits substantial market power. Further, I find that any one of the policies of demand response, divestiture, and contract requirements, if implemented at the maximum extent attainable, could make the MH electricity market almost perfectly competitive. Implementing any one of these policies at the maximum extent attainable will be difficult and in some cases impractical. Instead, if all these policies are simultaneously implemented at easily attainable levels, the MH electricity market would be almost perfectly competitive even in situations of up to 5% supply shortages. This analysis indicates that no one policy implemented at a realistic level can ensure competition in the MH electricity market, but their combination implemented at easily attainable levels can achieve the goal. However, if the current situation of severe supply shortages (shortages are about 25% of the peak demand) continues, a potential wholesale electricity market in MH state will not be competitive even if all of the policies discussed above are implemented simultaneously. I argue that severe supply shortages are unlikely to continue indefinitely. Even if I make a conservative estimate of the planned generation capacity additions, the supply shortages will be reduced significantly. However, small supply shortages may still continue and this analysis shows that the MH electricity market can be competitive even with small supply shortages.

Many of the characteristics of the MH state electricity sector that this analysis shows can increase market competitiveness are common to other states in India and other developing countries. For example, the state of Gujarat, like MH state, has significant industrial generation capacity (PESD, 2004) and pubic generation firms are common in developing countries. To my knowledge, this is one of the first attempts to analyze the effect of these characteristics on the competitiveness of a potential wholesale electricity market in a developing country. If the effects of these characteristics are taken into account, a competitive wholesale electricity market will be more feasible in some developing countries than currently thought. In the context of limited regulatory capacity in developing countries, rigorously assessing the option of introducing competition is all the more important. This research provides insights into the unique challenges and opportunities of introducing wholesale electricity competition in a developing country context.

I do not model collusion among firms directly because the analysis of the factors which facilitate collusion is beyond the scope of this analysis. Collusion among firms reduces the competition facilitating effect of divestiture and in this case other policies which increase competition would need to be implemented more extensively for competitive markets. The scope of this research is limited to analyzing the feasibility of wholesale competition from an industrial organization point of view. I do not analyze the infrastructural, institutional, and regulatory requirements for implementing wholesale competition in MH state. I plan to explore those questions in my future research. I also do not make any claims about the desirability of wholesale competition. Wholesale competition is one method to force efficiency improvements and lower prices for consumers. The form of competition or regulation suitable for MH state is beyond the scope of this analysis. This analysis indicates that wholesale competition could be one of the options at the disposal of policymakers under certain circumstances described in this paper.

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Appendix I: The Demand-Supply Position in MH State: Analysis of Trends

MH state has been facing increasing power shortages since 1998. Table AI 1 shows the total electricity curtailed during a financial year and the average power shortage during the evening peak hours in January for the last 10 years. Prior to 1998, supply shortages were limited to a relatively small percentage of the installed capacity.

Table AI 1: The Load Shedding in MH state

	Load Shedding		
Year	GWh	MW	% of Peak Demand
93-94	68	-	0.0%
94-95	137	108	1.0%
95-96	235	225	1.9%
96-97	220	70	0.6%
97-98	262	382	3.2%
98-99	307	335	2.6%
99-2000	1,121	793	6.2%
2000-2001	1,603	718	5.2%
2001-2002	1,014	921	6.3%
2002-2003	2,530	1,802	12.4%
2003-2004	2,000	1,246	8.6%

The main reason for energy and power shortages in the last few years is that the capacity additions have significantly lagged behind the growth in demand. Table AI 2 shows the compound annual average growth rates of peak demand and installed capacity for the last four decades.[38]

Table AI 2: The Growth in Installed Capacity and Peak Demand

	Compund Annual Growth Rate		
Years	Peak Demand	Installed Capacity	Ratio
1964-1974	9.4%	8.6%	91%
1974-1984	7.5%	10.1%	135%
1984-1994	7.5%	6.3%	84%
1994-2004	6.1%	2.6%	43%

In the last decade, generation capacity was added at a rate that is less than half of the rate of the peak demand growth. In the three decades prior to the previous decade, capacity was added more or less at the same rate as the rate of demand growth. Policy changes at the national level that marked the beginning of the power sector reforms in India in 1991, envisioned that the private sector (in the form of IPPs) would play a significant role in adding new generation capacity. Since 1990, the World Bank, one of the main lenders for the public sector power projects in developing countries, adopted a policy of not lending to the public sector projects. This policy was formally announced in 1993 (Woodhouse, 2005). These policy changes at the national and international level significantly slowed the capacity addition by the state sector in India. In terms of the capacity additions by the private sector, there was exuberance in the IPP market in the first half of the 1990s. Many IPP projects

[38] The growth rates were estimated using data on yearly peak demand and capacity additions for the last four decades. Data on the capacity additions by MSEB were obtained from MSEB generation report 2004 (MSEB 2004c) and the data on the capacity addition by NTPC and private utilities were based on the installation dates of power plants owned by these entities as displayed on their web-sites.

were planned with IPPs and state utilities signing long-term power purchase agreements. In this exuberance, rational power planning and economic consideration gave way to a frenzy of signing long-term contracts. About 90,000 MW of contracts were signed in a few years out of which only about 6,000 MW of private projects have been constructed (Prayas, 2004). In MH state, only one IPP project (Enron's Dabhol Power Project) has been constructed. This project is currently not operating as a result of the dispute between MSEB and Enron. Capacity additions by the private sector have been significantly below the expectations and can be considered as one of the main reasons for the supply shortages in India. The main reasons stated for the limited success of the policy of capacity additions through private sector include: uneconomical projects, non-transparent decision marking process, problems with fuel linkages, and the tenuous financial position of the state utilities (Prayas, 2004).

The Demand-Supply Position in the Coming Years

There is an increasing realization that private sector alone can not fulfill the investment needs of the power sector in developing countries (World Bank, 2004). In India, significant capacity additions are planned by the state and the central sector utilities. As discussed earlier in this paper, even if I make a conservative estimate of the new generation capacity coming online in the next few years, supply shortages are likely to be reduced significantly. Historically, at least in MH state, severe power shortage is a recent phenomenon experienced in the last five years. As indicated by the table AI 2, capacity additions have significantly lagged behind the demand growth only in the last decade. It is reasonable to expect that the demand supply situation will resume to a state where supply just meets demand or supply is a little short of demand, which generally has been the case with the exception of the last five years.

Appendix II

Forecasting Fuel Prices for the Year 2007-08

Coal Prices

Coal India Ltd., a government-owned enterprise, is the major producer of coal in Indiaand sets coal prices for most of the coal produced in India. A small fraction of the coal is sold on the open market. Coal India Ltd. revises coal prices based on the trends in domestic and international coal prices and also based on a formula linked to the average industrial inflation. Setting coal prices is also a political process and there is no exact formula in which all these factors are taken into account to determine coal prices. I use past trends in coal prices to project future prices. Although this method is somewhat crude, I believe that is the best I can do given the nature of the process of setting coal prices. Based on coal prices for the last 10 years, the average annual growth rate of coal prices (in nominal terms) for the coal used in power plants is 9.5%.[39] I use this escalation rate to estimate the fuel cost of coal-based power plants in 2007– 08. Note that the coal prices for different power plants vary substantially due to the differences in transportation costs. Railways that run on electricity or coal transport most of the coal in India. Since more than 70% of electricity produced in India is based on coal power plants, I assume that transportation costs are likely to escalate at approximately the same rate as coal prices.

Domestic Natural Gas Prices

[39] Coal prices for coal power grade coal are based on the data from Coal India Ltd.

Gas Authority of India Ltd. (GAIL), a government owned enterprise, determines prices of domestically produced natural gas in India. The government of India has a policy of gradually increasing the price parity between the domestic natural gas and international oil prices. Currently the parity with the international oil price is 75%. GAIL also sets a cap and a floor for domestic natural gas prices. In the recent years, gas prices have always been at the price cap due to high oil prices. GAIL has recently revised (in June 2005) the cap for gas price by 15% to Rs.3200/1000 standard cubic meter (SCM) which is equivalent to a price of $2.1/ MMBtu (GAIL 2005). The gas price cap is not expected to be revised again in the near future. Hence I assume the current gas price will remain the same for the year 2007-08. There is a scarcity of domestic natural gas in India. Therefore GAIL and GOI decide the allocation of domestic natural gas to power stations. Domestic gas is provided to public sector companies on a priority basis.

Liquefied Natural Gas (LNG) Prices

India is currently importing five million tons per annum (mtpa) of LNG from Qatar at the Dahej terminal in Gujarat at a fixed price of $2.53/MMBtu which translates into a delivered price of $3.85/MMBtu. This price includes a shipping cost of $0.25/MMBtu, regasification cost of $0.4/MMBtu, and $.69/MMBtu of taxes and duties. The LNG prices have gone up recently due to an increase in demand and the current base price is about $3.5/MMBtu which translates into a total price of around $5/MMBtu (Economic Times, 2005). I assume that the LNG price will be $5/MMBtu for the year 2007-08.

Naphtha Prices

Naphtha prices are almost perfectly correlated (correlation above .97) with crude oil prices. I estimate an average naphtha price of $12.5/MMBtu for the year 2007-08 based on an oil price of $60/bbl. This oil price is an average of the oil futures price in November 2005 for the year 2007-08.[40]

Appendix III: Estimation of the Demand Response Potential in Industrial Consumers

Availability of Back-Up Generation

A survey of industrial generators above 1 MW shows that their total installed capacity in MH state in the year 2002-03 was 1,250 MW (Infraline, 2004). Not all of these generators are back-up generators as some of them act as a substitute for the power from the grid. A survey by MSEB of large industrial generators (also knows as captive power plants) in MH state shows that about 40% of the captive power plants are below 25 MW of capacity and use liquid fuels (mostly diesel) (MERC, 2004 c). It is believed that diesel-based captive plants are used as back-up generation and not as a substitute for power from the grid as the marginal cost of power from diesel based generation is almost double the average industrial tariff. Hence approximately 500 MW (40% of 1,250 MW) of back-up industrial generation capacity was available in MH state in the financial year 2002-03. MH state suffered heavy load shedding in the financial years 2003-04, 2004-05, and 2005-06. Anecdotal evidence suggests that back-up generator sales were at their peak during these years and a large percentage of industries now have back-up generation facilities. A large number of small and medium scale industries are likely to have back-up generators of capacity less than 1 MW and their capacity

[40] Crude oil futures prices are based on NYMEX crude oil futures prices (www.nymex.com).

is not counted in these surveys.[41] There are no estimates available for the total industrial back-up generation capacity in MH state. A recent survey of industries in Pune urban zone shows that back-up generation capacity of generators of size 0.5 MW and above is about 350 MW. The average connected industrial load in Pune urban zone is about $1/8^{th}$ of the total average connected industrial load for MSEB (MSEB, 2005d). If I extrapolate from the Pune urban zone to the whole of Maharashtra, the total industrial back-up generation capacity would be around 4,000 MW. Actual back-up generation capacity in MH state could be even more than my estimate as I am not counting the capacity of back-up generators below 0.5 MW of capacity. Since there is uncertainty about the validity of this extrapolation, I make a conservative assumption that only 1,500 MW of industrial back-up generation capacity is available in MH state.

Variable Cost of Back-Up Generation

Most back-up generators use diesel as a fuel while some of them use fuel oil. The current (November 2005) diesel price in MH state is Rs.26/Liter ($2.6/gallon). GOI estimates that the diesel price needs to be increased by Rs.5/Liter to bring it in line with the international crude oil prices (GOI, 2005). GOI has been taking steps to increase the parity between the domestic fuel prices and international crude oil prices. I assume that diesel price to be Rs. 31/Liter in the year 2007-08. Based on an estimate of typical fuel consumption of diesel-based power plants (CII, 2005), the marginal cost of power generation is estimated to be 18 cents/kWh.

Demand Response from Industrial Consumers

To assess the demand response possibilities from industrial consumers, I first analyze some characteristics of the industrial consumers. Industrial consumers are categorized as high-tension (HT) consumers if their maximum demand is above 50 kW and as low-tension consumers (LT) if their demand is below 50 kW. Table 8 gives some characteristics of MSEB's industrial consumers.

Table AIII 1: Characteristics of the Industrial Consumers in 2003

	Industrial Consumers			% of total for MSEB		
	HT	LT	Total	HT	LT	Total
Connected Load (MW)	7,500	3,600	11,100	28%	13%	41%
No of consumers	8,770	297,612	306,382	0.07%	2.24%	2.30%
Consumption(GWh)	12,400	3,912	16,312	32%	10%	42%
Average bill ($/year)	104,012	967	3,917			

Source: MSEB Administrative Report 2002-03 (MSEB, 2003)

It is interesting to note that only 8,770 consumers, which are .07% of the total number of MSEB's consumers, account for almost 30% of the connected load and consumption. If data from Mumbai is included, the percentage of HT industrial consumption is going to be even higher due to high concentration of large industries in Mumbai. Since I am estimating back -up generation capacity of generators with capacity greater than 0.5 MW, HT consumers own all the back-up generation capacity that I estimate. Following are some of the options for demand response from industrial consumers.

[41] This assessment in based on an interview with S. P. Ranade, Director, MH Chamber of Commerce, Energy Division (interview conducted on August 16^{th}, 2005)

Real-Time Pricing for the HT Consumers

HT consumers could be exposed to the wholesale spot price at least at the margin. Placing the 8,870 HT consumers on real time pricing will get almost 30% of the demand in MH state on real time pricing. The one time cost of installing real time meters for all HT consumers is estimated to be $15 million [42] which is approximately 1.5 days worth of revenue for MSEB. I do not know how elastic the demand of HT consumers is but I know for certain that if the wholesale spot price goes above the marginal cost of the back-up generation, industrial consumers will generate from their back-up generators. Industrial consumers may also respond to wholesale prices below the price 18 cents/kWh which will further increase the competitiveness of the wholesale market.

Utility Initiated Demand Response

A distribution utility could install meters on the back-up generation plants of its industrial consumers. It could instruct these consumers to generate from their back-up generation plants if the wholesale price goes above the marginal cost of the back-up generation. The distribution utility can pay these consumers for the electricity produced from their back-up generators at a price equal to the marginal cost of the back-up generation. This solution is inferior to real-time pricing as consumers will not be able to respond to the wholesale price if the price is below the marginal cost of back up generation. If for political or any other consideration real-time pricing can not be implemented, then metering and compensating industrial consumers for their back-up generation is another option for accessing the back-up generation capacity. Due to the rapid advances in telecommunication technologies, giving such instructions to industrial consumers is easily possible. A simple automated SMS on a cell phone at the facility would be sufficient. For my simulations, I assume that 1,500 MW of industrial back up generation capacity will be available at a price of 18 cents/kWh. I assume that the small elasticity of demand considered for the simulations mostly comes from these industrial consumers.

Appendix IV: Hydro Generation and the Seasonal Variation in Demand.

Figure IV 1 shows the peak demand, the residual peak demand (obtained after subtracting hydro generation from the peak demand), and the 'most common residual demand'.[43]

[42] The cost of installing real time meters for 21,000 consumers in California was $35 million (NRDC, 2005) which is about $1600 per consumer. For about 9000 consumers, the cost would be approximately $15 million.

[43] Refer to the section 3.7 for the definition of most common demand for each month in 2007-08.

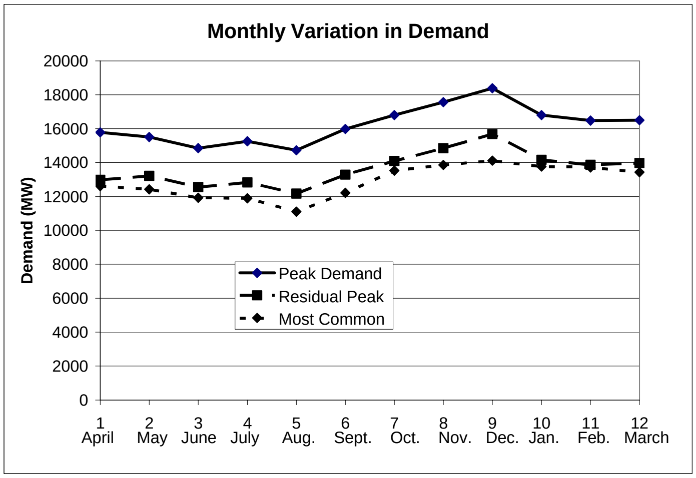

Figure IV 1: Monthly Variations in Demand

The majority of the monthly variation in demand is driven by the variation in the agricultural pumping demand. Agricultural demand is low in May because there is not much agricultural activity. It is also low from June to September as this is the rainy reason and the demand for irrigation (hence pumping) drops significantly.