APPENDIX A: THE CHANGE IN THE ELECTRICITY PRICE FROM A CHANGE IN THE NATURAL GAS PRICE

INTRODUCTION

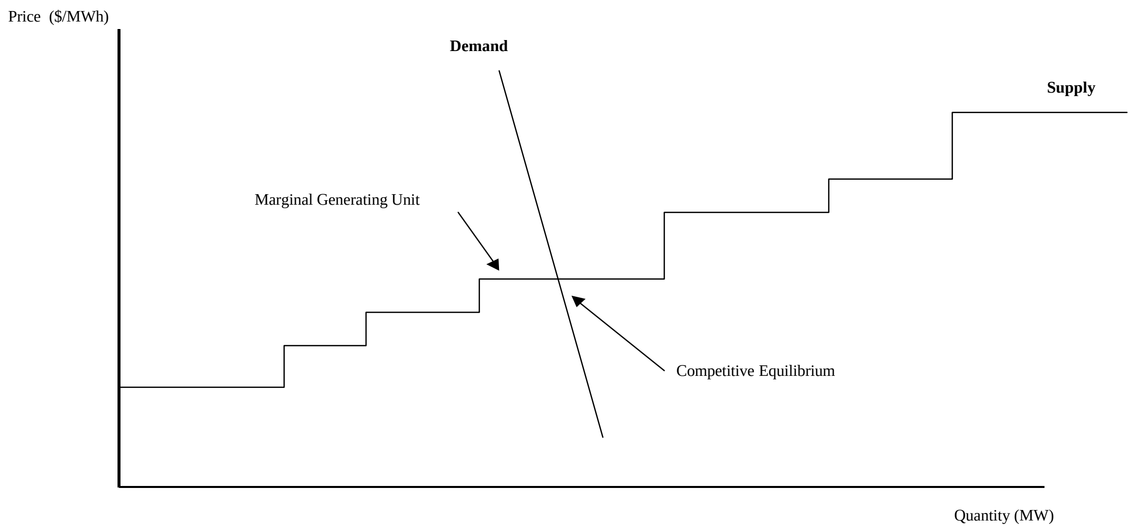
The purpose of this appendix is to demonstrate, using principles of economics, that a change in the delivered natural gas price would result in a proportionate change in the electricity price in the California PX when natural gas-fired generation is on the margin. It also demonstrates that a change in natural gas prices would result in a change in the California PX price when natural gas units are inframarginal.

In a market characterized by perfectly competitive conditions with low demand elasticity and high supply elasticity, an increase in the delivered natural gas price would manifest itself in a proportionate increase in the California PX price when natural gas units are on the margin. This result is due both to the need of the generators to recover their marginal costs in order to remain economically viable as well as to the relatively inelastic short-run demand for electricity (meaning that the short-run demand for electricity is relatively unresponsive to changes in prices). In a PX market characterized by less-than-perfectly-competitive conditions where the exercise of market power is possible, an increase in the delivered natural gas price also would manifest itself in at least a one-for-one increase, likely greater, in the California PX price when natural gas units are on the margin. A simple Cournot model of generator behavior demonstrates this result.

PERFECTLY COMPETITIVE CONDITIONS

Under perfectly competitive conditions, generators act as price-takers and bid their marginal cost of generation into the market. No single supplier is able to influence the price of electricity through his sole actions. This is in part due to the presence of many buyers and sellers in the market. The perfectly competitive equilibrium is given by the intersection of the market supply curve and demand curve as illustrated in Figure A-1. We have drawn the demand curve fairly steep in slope because the short-run demand for electricity is usually taken to be very inelastic.[1] We have drawn the supply curve as having steps corresponding to the bids that would be made by competitors within the PX. Each step represents a generator's offer to supply electricity to the PX across a certain range of output at a particular price. This flatness is a result of the PX operating as a kind of auction process that simulates the operation of a competitive market and the generators' production processes for electricity.

FIGURE A-1
Power Market Equilibrium in an Idealized World of Perfect Competition



This latter cause for the high elasticity of supply can also be seen in the aggregate supply curves for electricity in the Western States Coordinating Council (WSCC), Figure A-2 and in California, Figure A-3. The bid of the marginal generating unit (indicated in Figure A-1) determines the market-clearing price of electricity. We also assume that in the short-run, generators that use gas have essentially no capability to substitute in the short-run either other fuels or other inputs to their production process as a result of changes in the price of gas. Even where some generators could substitute some form of fuel oil, environmental restrictions will prevent this from occurring for any extended period of time.

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1 *See*, for example, Carol Dahl, "Findings from a Survey of Energy Demand Electricities" Table 4 on p. 5 in *Energy and the Environment, Papers and Proceedings of the 15th International Association for Energy Economics*, Seattle, Washington, October 10-13, 1993, pp. 1-13.

FIGURE A-2
1996 WSCC Electric Supply Curve

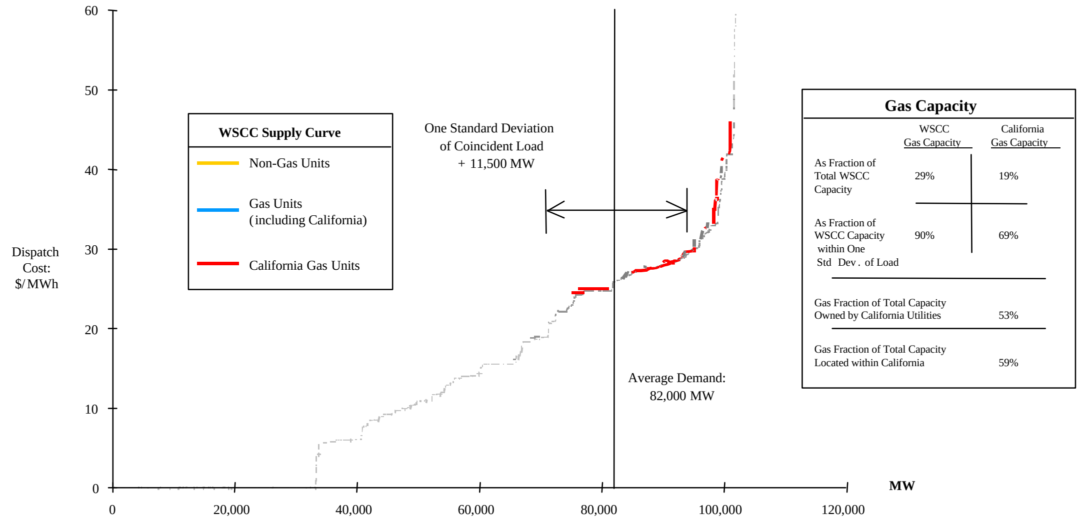
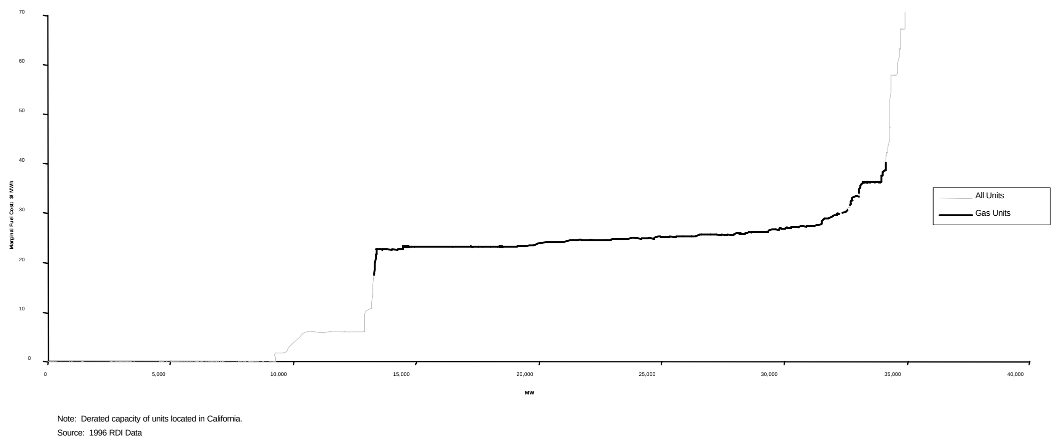


FIGURE A-3
California Supply Curve



A change in marginal costs for some generating units, for instance an increase in delivered natural gas prices[2] to units in Southern California, can result in two possible situations in equilibrium in the PX under perfect competition. The most straightforward case is when a unit that experiences an increase in marginal costs is the marginal supply unit both before and after the natural gas price increase. This is depicted in Figure A-4. As can be seen in the diagram, an

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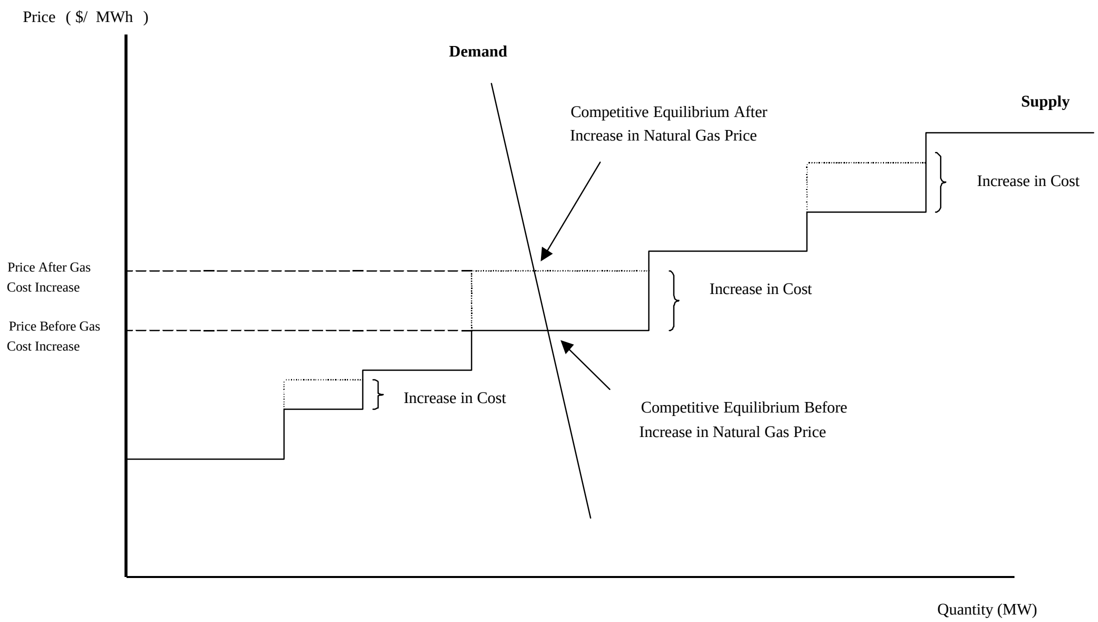
[2] The terms price and cost are used somewhat interchangeably here. Clearly SoCalGas and gas suppliers charge a "price" to deliver gas to generators, hence the phrase "delivered natural gas price." From the generator's perspective, this is obviously a cost.

increase in the cost for the marginal unit results in a one-for-one increase in the bid price of electricity. To the extent that the remainder of the supply curve consists of units that use gas subject to the cost increase, the remainder of available supply would be similarly shifted upward. The equilibrium shifts up the demand curve by the same amount as the amount of the increase in the marginal cost.

FIGURE A-4
The Effect of a Natural Gas Increase on the Marginal Supplier in the Perfectly Competitive World



The second situation arises when the marginal unit before the price increase (*i.e.*, an affected natural gas unit) is displaced by another type of unit subsequent to the price increase. As a result, under the new equilibrium, the unit that was originally above the affected gas unit becomes the new marginal unit. This situation is illustrated in Figures A-5a and A-5b. Thus, in Figure A-5a, which depicts the equilibrium before the increase in gas prices, gas-fired unit A is marginal and the market closes at P_A, the bid price of unit A. In Figure A-5b, depicting the post-gas price increase equilibrium, units A and B have switched position in the supply ladder. Unit A must bid P'_A, while unit B can continue to bid P_B. The gas unit affected by the gas price increase switches position on the supply curve with the unit previously above it. Thus, while unit B (the unaffected unit) comes after unit A (the affected unit) before the cost increase, it comes before unit A after the cost increase. So, there is an increase in the price of electricity given by the step in cost from the original cost for unit A to the cost of unit B, or P_B-P_A on the diagram.

FIGURE A-5a
The Effect of a Natural Gas Price Increase When the New Marginal Supplier of Electricity Does Not Use Natural Gas in the Perfectly Competitive World

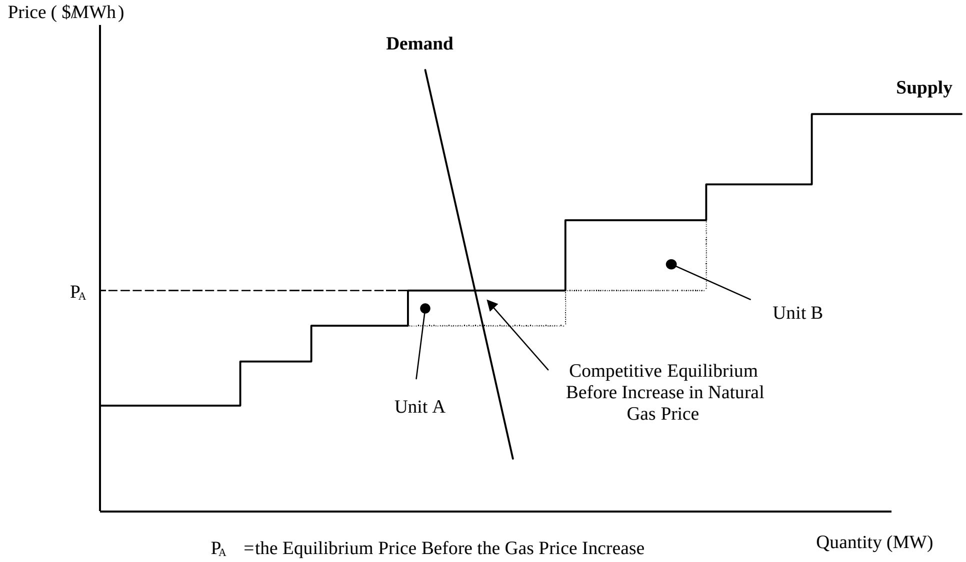
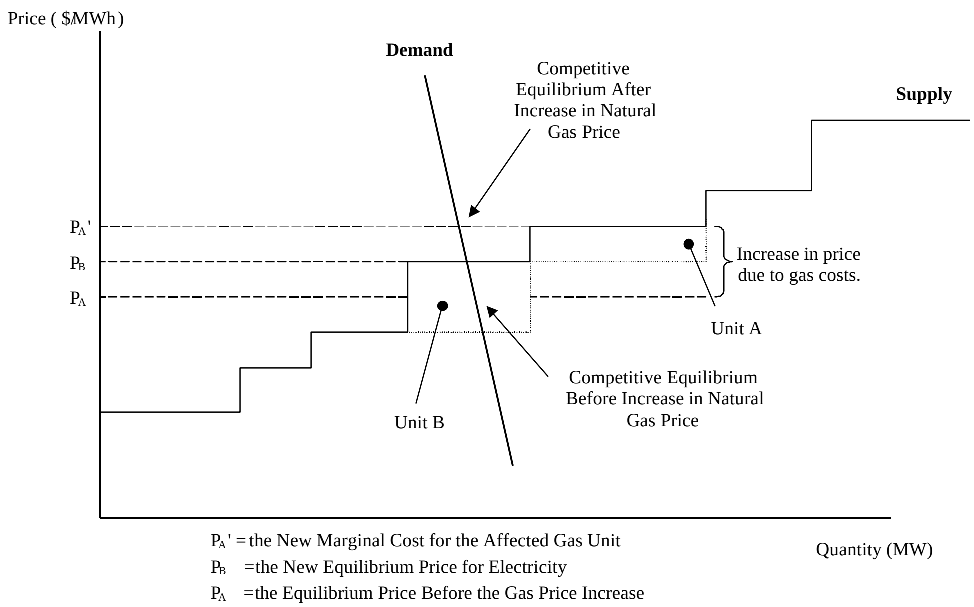


FIGURE A-5b
The Effect of a Natural Gas Price Increase When the New Marginal Supplier of Electricity Does Not Use Natural Gas in the Perfectly Competitive World



LESS-THAN-PERFECTLY COMPETITIVE CONDITIONS

In the perfectly competitive world, price equals marginal cost. When market power is present, however, prices may exceed marginal costs.[3] In this case, the issue is whether increases in a generator's marginal cost leads to increases in price even when the price begins at a point above the original marginal cost. It is shown below that prices do increase with increased marginal costs, even when there is market power.[4] In fact, prices can increase even if they are originally far above marginal costs.

Some contend that market power is present in the California PX market. Whether there is or not is not the issue at hand. The following shows that even if there is market power in the California PX (*i.e.*, if conditions are not perfectly competitive), an increase in the price of natural gas would result in an increase in the market price of electricity.

An economic model frequently used to examine issues of market power in the electric power industry is a Cournot model.[5] In a Cournot model, firms are assumed to make profit-maximizing output decisions based on the output choices of their rivals, with implied knowledge of how all output decisions are likely to affect market prices. An equilibrium is attained in a Cournot model when each firm's output choice maximizes its profits given its rivals' output decisions. Consequently, no firm has an incentive to alter its output level. This equilibrium is commonly referred to in the economics literature as a Cournot-Nash equilibrium.

A general property of Cournot models is that in equilibrium, firms charge a price equal to a mark-up over marginal cost, where each firm's mark-up is related to both the price elasticity of demand in the market and the firm's own market share. This and the main result of this appendix

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3 *See Modern Industrial Organization*, Dennis W. Carlton and Jeffrey M. Perloff, Harper-Collins, 1994, p. 922, who define market power as "the ability of a firm to set price profitably above competitive levels (marginal cost)."

4 For example, "Diagnosing Market Power in California's Deregulated Wholesale Electricity Market", Severin Borenstein, James Bushnell, and Frank Wolak, *1999 Power Electricity Industry Restructuring: A Research Conference*, Program on Workable Energy Regulation, University of California Energy Institute, states that "…during the summer of 1998…there was significant market power."

5 See Borenstein, Bushnell and Wolak cited above.

for Cournot equilibria, *i.e.*, that changes in marginal cost lead to changes in price, are rigorously proven in Appendix B.

To start, consider the profit maximizing strategy of a single firm. Profit maximization occurs when its marginal revenue equals its marginal costs.[6] To see this, consider the two other possibilities where either marginal revenue exceeds marginal costs, or marginal costs exceed marginal revenues. If marginal revenues exceed marginal costs, a firm could profit more by producing more and, thus, moving closer to the point where marginal revenue equals marginal cost. If marginal costs exceed marginal revenues, then a firm is losing money at the margin and could make more profit by reducing its output and, thus, move closer to the output that equals marginal revenue and marginal cost.

The Cournot equilibrium from a single firm's point of view is illustrated in Figure A-6. Note than unlike the perfectly competitive case, equilibrium in this case is given by the intersection of the marginal revenue and marginal cost curves. This is because in the Cournot case – unlike the perfectly competitive case – a firm can influence the market price and thus its marginal revenues by changing its level of output. As a result, the price resulting from the Cournot equilibrium is higher than that given by the perfectly competitive equilibrium.

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[6] Assuming differentiability and the standard convexity and continuity conditions for the existence of a market equilibrium. *See*, for example, A.Mas-Colell, M.D. Whinston and J. Green, Microeconomic Theory (N.Y.: Oxford University Press, 1995).

FIGURE A-6
Equilibrium for a Single Cournot Firm

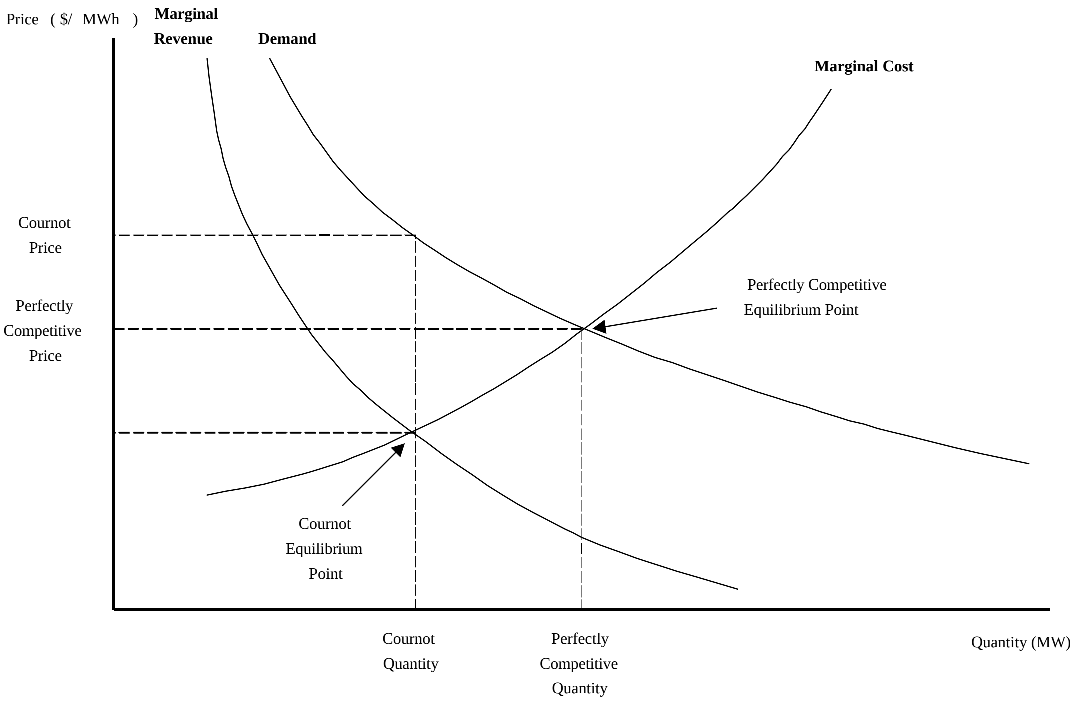
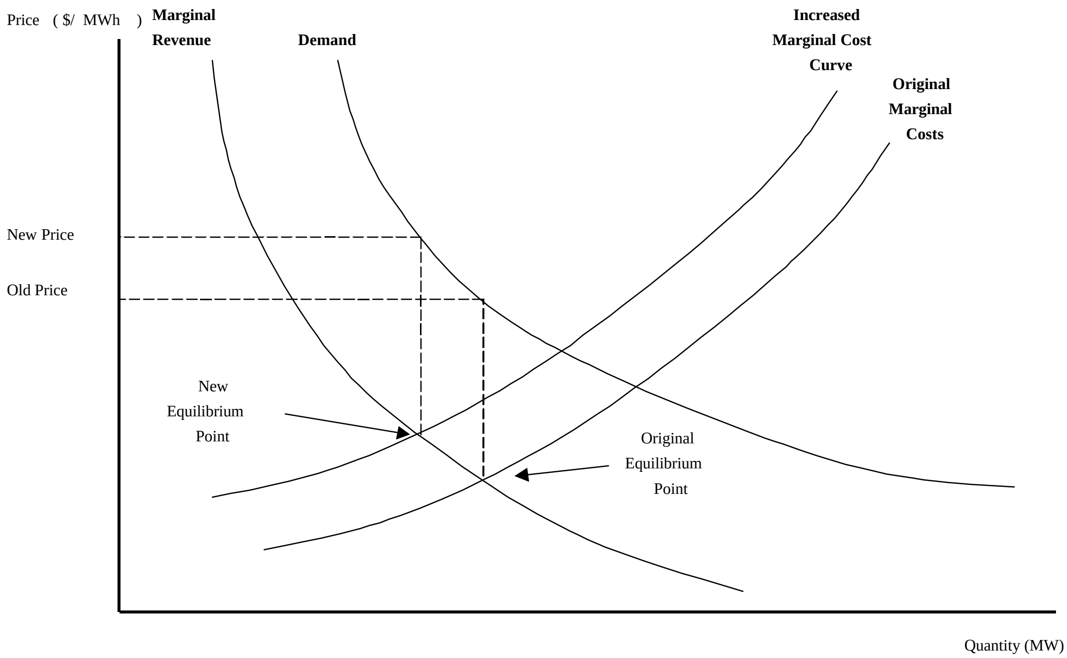


Figure A-7 illustrates the effect of an increase in marginal costs on a single firm. An increase in costs moves the equilibrium point up the marginal cost curve resulting in a new equilibrium point with a higher price. If the demand is highly inelastic, as it is in California, then this price increase can be relatively larger than the corresponding increase in costs. This diagram shows the intuition, but does not take into account the reaction of other firms. Appendix B develops these notions more rigorously.

FIGURE A-7
Change in Equilibrium for a Single Cournot Firm
Due to an Increase in Marginal Costs



To see how this can happen, we begin with the extreme case of a monopolist. For a monopolist, the margin of price over marginal costs, *i.e.*, (price-marginal cost)/price, is given by the inverse of the demand elasticity (using the convention that demand elasticities are positive), *i.e.*, 1/elasticity. Thus, a demand elasticity of 2 yields a price-cost margin of two, *i.e.*, the price is double that of marginal cost.

In the Cournot-Nash equilibrium case, the impact of having multiple firms is to dilute this effect. Thus, assuming that there are competitors of roughly the same size, the price-marginal cost margin is given by 1/(n x elasticity). For example, if the price elasticity of demand is 2.0, and there are four firms then the price-cost margin relative to price is 1/(4 x 2.0) = 1/(8). That is, price is 14.3% over marginal cost.

To sum up, an increase in the price of natural gas would yield proportionate increases in the California PX market whether that market is assumed to be competitive or not, and in the latter case has the potential for yielding greater than proportionate increases.