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Monopoly regulation in the presence of consumer demand-reduction☆

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HIGHLIGHTS

- The model of optimal monopoly regulation when consumers can engage in demand-reducing activities is analyzed.
- The level of demand-reducing investment is excessive in terms of welfare.
- Asymmetric information raises the average regulated price and the level of demand-reducing investments.
- Asymmetric information lowers the regulated prices for efficient monopolists.

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ABSTRACT

I study a monopoly regulation in the setting where consumers can engage in demand-reducing investments. I first show that, when the regulator ignores the consumers' investments, the excess investment occurs. Next, I analyze the case where the regulator takes consumers' investments into account and compare the optimal policy under asymmetric information with the first-best policy. Optimal policy results in higher average price, higher level of consumer investment, but lower prices for efficient firms, compared to the first-best.

1. Introduction

In utility sectors, consumers often save the demand by engaging in some investments. For example, households can use rooftop solar energies or introduce electricity-efficient consumer electronics to reduce the demand for electricity or purchase bicycles or cars to reduce the dependence on public transportation. Business enterprises also engage in energy-saving investments in the face of various environmental regulations.[1] Such demand-saving activities often have important effects on the rate-setting of the regulated firms. As reviewed by Costello and Hemphill (2014), the consequence of such an interaction between rate-setting and demand-reduction is sometimes called as "death-spiral", the situation where a high rate leads to demand-reducing investments, which damages the utility's financial viability and requires even higher rates to break even. The aim of this paper is to study the design of optimal regulatory mechanisms in the face of such demand-reducing activities.

Specifically, I study the model of optimal monopoly regulation á la Laffont and Tirole (1993), in the setting where consumers can engage in demand-reducing investments.

I first consider the case where the regulatory mechanism is designed ignoring the consumers' investments. In this case, the resulting level of investments is too high in terms of aggregate welfare. Thus, the optimal mechanism should be designed so as to limit the consumers' investments. This result is consistent with the view that to deal with the problem of death-spiral, the rate should be set at a lower level. Next, I proceed to the analysis of optimal regulation policy explicitly taking the consumers' investments into account and study the effects of asymmetric information between regulator and monopolist on the optimal policy. I show that the presence of asymmetric information results in the higher average price than the first best, which leads to the higher level of buyers' investments. Thus, the presence of asymmetric information exacerbates the problem of excess investments. Finally, I show that the regulated prices for the most efficient monopolists under asymmetric information are set below the first best levels. This result contrasts with the standard "no distortion at the top" principle that the regulated price for the most efficient types corresponds with the first best. These results would provide some theoretical

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[1] See Matsumura and Yamagishi (2017) for the examples of such investments.

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guidance for policy design in utility sectors subject to a demand-reducing investments, such as gas and electricity.

2. Model

I consider the model of monopoly regulation á la Laffont and Tirole (1993), where a continuum of consumers can engage in demand-reducing investments. I set the primitives of the model below.

Consumers. Consumers derive the utility $S(q, x)-pq$, where q is the amount of purchase, p is the unit price of the good, $x \in \mathbb{R}_+$ is the level of demand-reducing investment. I assume that S is concave, $S_q > 0$, $S_{qq} < 0$, $S_{qx} < 0$, $S_{xx} < 0$. I also assume that $S_x(q, 0) > 0$ for any q and that for any q, there exists $\bar{x}_q$ such that $S_x(q, \bar{x}_q) = 0$. These assumptions guarantee that given any level of x, there is a demand function $D(p, x)$ derived from the condition

$$S_q(D(p, x), x) - p = 0 \tag{1}$$

that is decreasing in p and x. Let $V(p, x) = S(D(p, x), x) - pD(p, x)$ be the corresponding indirect utility function. Note that $V_p(p, x) = -D(p, x)$.

The first component in the consumer utility, $S(q, x)$, can be specified depending on the contexts. For example, the cost of investment can be explicitly incorporated by specifying $S(q, x) = u(q, x) - c(x)$, where $c(x)$ is the monetary or opportunity cost of investments that may reflect the prices of substitute goods or subsidies for investments. In this case, the required assumptions on u and c are that $u(q, x) - c(x)$ is concave, $u_q > 0$, $u_{qq} < 0$, $u_{qx} < 0$, $u_{xx} - c_{xx} < 0$, $u_x(q, 0) - c_x(0) > 0$, and that there exists $\bar{x}_q$ such that $u_x(q, \bar{x}_q) - c(\bar{x}_q) = 0$ for any q.

Monopolist. The monopolist incurs a constant marginal cost $\beta \in [\beta_L, \beta_H]$ and a fixed cost K of production. Thus, the profit of the monopolist at a price level p and the sales q is given by

$$(p - \beta)q - K. \tag{2}$$

β is privately known by the monopolist and distributed according to the strictly increasing smooth distribution function F with the density function f. I assume that the function F/f is increasing.

Regulator. The regulator can offer a menu $(p(\beta), s(\beta))_{\beta\in[\beta_L,\beta_H]}$ of contracts that specifies the price p and the amount of subsidy s. I assume that the subsidy is costly due to shadow cost of public funds λ.

Then the aggregate welfare with the price p, the subsidy s, investment level x, and the marginal cost β is given by the sum of consumer surplus, producer surplus, and the welfare loss from subsidy:

$$S(D(p, x), x) - \beta D(p, x) - K - \lambda s. \tag{3}$$

Timing. The timing of this game is as follows:

1. The regulator offers a menu $(p(\beta), s(\beta))_{\beta\in[\beta_L,\beta_H]}$ of contracts.
2. Consumers choose the level of demand-reducing investments x. At the same time, the monopolist observes β and chooses the contract $(p(\beta'), s(\beta'))$ that maximizes his profit.
3. Given the price $p(\beta')$ consumers choose the amount of purchase.[2]

[2] Here I assume that the regulator chooses the policy before the consumers engage in investments. This might no be realistic in several situations where the investment decision takes a longer time than the regulatory decision. Even if a fraction of consumer investments are allowed to take place before the investment decision, the qualitative results are unchanged if at least there is some fraction of investment decisions which take place after the regulatory decision. Our analysis can also be seen as a normative one on how the regulator should design the policy when she can commit to a long-run policy.

3. Optimal regulation

In this section, I study the optimal regulation under two scenarios: (i) complete information with exogenous investments, (ii) asymmetric information with endogenous investments. In the course of analysis, I study how the presence of demand-reducing investments affects the aggregate welfare and interacts with the asymmetric information.

To this end, I first consider how the consumers make investment decisions. Suppose that the monopolist with type β is regulated to set the price $p(\beta)$. Then the expected surplus is $E_\beta[V(p(\beta), x)]$. Thus, the first-order condition for consumer investment is given by

$$\mathbb{E}_\beta[S_x(D(p(\beta), x), x)] = 0. \tag{4}$$

3.1. Benchmark: Complete information with exogenous investments

As a first benchmark, consider the setting where there is no asymmetric information between the monopolist and the regulator, and the regulator takes the consumers' investments as given. In this setting, a standard derivation yields

$$s(\beta) = K - (p(\beta) - \beta)D(p(\beta), x)$$

and

$$\frac{p(\beta) - \beta}{p(\beta)} = \frac{\lambda}{1 + \lambda}\frac{1}{\eta(p(\beta), x)}, \tag{5}$$

where

$$\eta(p, x) := -\frac{D_p(p, x)p}{D(p, x)} > 0 \tag{6}$$

is the price elasticity of demand. This is the standard Lerner formula obtained in the models of monopoly regulation with a cost of public funds.

Now consider the welfare consequence of buyer investments. Let x be determined by the condition (4) and slightly increase from the equilibrium level. After some algebra, its effect on the welfare is written as

$$(1 + \lambda)\mathbb{E}_\beta\left[D_x(p(\beta), x)(p(\beta) - \beta)\right] < 0. \tag{7}$$

This immediately implies the following proposition.

Proposition 1. *Under the complete information, if the regulator sets the policy taking the consumers' investments as given, the amount of the investments is too high in terms of social welfare.*

The intuition is as follows. While the government needs to guarantee some profit of the monopolist to reduce the subsidy, consumers choose their investment level to maximize their surplus. As a result, the welfare loss due to an increase in subsidy is ignored by consumers, resulting in the excess investments.

This proposition gives an implication that the optimal regulation should be designed so as to keep consumers from engaging in too many investments. With this proposition in mind, let me proceed to the analysis of optimal regulation in the presence of consumers' investments.

3.2. Regulation under asymmetric information

In this subsection, I solve the regulator's problem taking the information asymmetry and consumers' investments into account.[3] The regulator needs to set the menu of contracts so as to satisfy the incentive compatibility constraints:

$$\beta = \arg\max_{\beta'}(p(\beta') - \beta)D(p(\beta'), x) - K + s(\beta'). \tag{8}$$

[3] For the detail of each derivation step, see Laffont and Tirole (1993) Chapter 2.