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Abstract.

In this paper, we study how a monopolistic firm with unknown costs may behave under the threat of regulation. To this aim, we integrate the self-regulation model of Glazer and McMillan (1992) with the optimal regulatory mechanism devised by Baron and Myerson (1982) for the case of asymmetric information. Simulating the equilibrium outcome of our integrated model for a wide range of parameter values, we show that the firm threatened with regulation always constrains its price; moreover, it does so more stringently if it is less efficient. If the marginal cost of the firm is sufficiently close to the highest possible value according to the beliefs of the legislators and the regulator, the price the firm charges under the threat of regulation can be even lower than the price it has to charge when it is regulated. Our simulations also reveal how the welfares of consumers and the threatened firm may be affected in the short-run and long-run by possible variations in several attributes of our model, involving the marginal cost of production, the number of legislators, each legislator's cost of proposing a regulatory bill, the size of the market, and the weight of the firm's welfare in the social welfare function.

Keywords: Monopoly; regulation; self-regulation; asymmetric information.

JEL Codes: D42; D82; L51.

1 Introduction

Self-regulation of firms has been extensively studied since the works of Erfle and McMillan (1990) and Glazer and McMillan (1992), who formalized the hypothesis that firms facing the threat of government regulation may constrain their product prices. In this paper, we ask how this behavior of firms could be affected by the presence of asymmetric information. To answer this question, we extend Glazer and McMillan's (1992) self-regulation model with (implicitly) symmetric information to a case where a monopolistic firm threatened with regulation has private information about its cost function. Like in their model, we assume that the firm is regulated if a bill recommending regulatory action is proposed (introduced) by at least one of the legislators in the environment. The legislators can calculate the expected welfare gain from regulation by using their observations about the price chosen by the firm in periods prior to regulation. Comparing the size of this welfare gain with the cost of drafting and promoting a bill, each legislator determines his/her probability of proposing a bill. On the other hand, taking such probabilities into consideration the firm calculates the risk of regulation and its optimal product price under this risk. Glazer and McMillan (1992) theoretically show that this price is always lower than the price the firm charges when it faces no regulatory threat. They also show that the firm exhibits this pricing behavior to optimally reduce the risk of regulation. Our main purpose is to explore whether these results of Glazer and McMillan (1992) may arise under asymmetric information, as well.

To the best of our knowledge, our research question has not been studied before. The most related works are the papers of Heyes (2005) and Denicoló (2008), who study how self-regulation can be used by firms as a signaling device in the presence of asymmetric information. More specifically, Heyes (2005) shows that firms with high compliance costs may use self-regulation to signal their costs in order to obtain less stringent regulation in the future. However, they assume that self-regulation does not affect the probability of regulation. On the other hand, Denicoló (2008) studies a two-period duopoly to show that when the regulator has incomplete information about the production costs of the firms, the firm that has a comparative advantage in the cost of complying to the environmental standards enforced by the regulator may find it optimal to overcomply in the first period in order to signal that costs of complying are low, thereby inducing the regulator to enforce stricter standards in the second period. Denicoló (2008) assumes that the regulator cannot observe the first-period prices and output of the duopolistic firms. (A self-regulated firm in his model can only signal by acquiring a superior production technology.) Thus, the probability of regulation is not affected by the pricing behavior of the firms, which is at the core of our analysis.

At this point, one can argue that in our model the pricing behavior of the firm threatened with regulation can unintentionally reveal its private cost information to the legislators in the regulatory environment, simply reducing our model to the symmetric information model of Glazer and McMillan (1992). This argument is based on the fact that the legislators can calculate –for each possible value of the firm's cost information– the price that maximizes the firm's profits when it is under the threat of regulation. Using the calculated firm-optimal price schedule along with their observations on the prices actually charged by the threatened firm in periods prior to regulation, the legislators could estimate the private cost information of the firm. Clearly, an optimal regulatory policy based on these cost estimates would leave to the firm in our model no informational rents, as was implicitly assumed in the complete information model of Glazer and McMillan (1992).

While the above argument may seem reasonable, there are also other considerations. First, the inferences of the legislators about the production cost of the firm may not be verifiable to a third party such as a court or a regulatory authority. Second, even the legislators themselves may not be certain that their inferences are correct. If the firm anticipates that the legislators' inferences about its cost function may be used by a regulatory authority to implement marginal cost pricing in order to entitle consumers to the whole economic surplus, the firm may increase its price prior to regulation by an unpredictable markup over its marginal cost, so as to lead the legislators to make uncertain inferences about its costs and thereby to secure some part of its potential informational rents in periods of regulation. On the other hand, once the legislators become aware of this strategic behavior, they may also realize that a regulatory program –implementing marginal-cost pricing– based on their possibly incorrect inferences may no longer be optimal from the viewpoint of consumers or the whole society.

Characterization of a socially-optimal regulatory program under the verifiability of cost inferences –taking into account the optimal reaction of the threatened firm to this program prior to regulation– is absolutely an interesting problem, which we leave for future research. In this paper, we consider a simpler problem, by assuming that the legislators and the regulator cannot make verifiable and trustable cost inferences using their observations about the prices set by the firm prior to regulation. This will imply that the cost information of the firm will be 'officially' unknown to the legislators and the regulator before the implementation of a regulatory program. This setting will allow us to replace the arbitrary regulatory policy in Glazer and McMillan (1992) with the optimal regulatory policy of Baron and Myerson (1982) devised for the case of asymmetric information. Comparing the expected social welfare induced by this mechanism in regulatory periods with the expected social welfare induced by the actions of the firm in self-regulatory periods, we will be able to calculate the social benefit of optimal regulation. We will assume that this social benefit is internalized by each legislator as the individual benefit of proposing a regulatory bill. Weighing this benefit to an individual cost of drafting and promoting a proposal, each legislator can decide whether to propose a bill or not. Like in Glazer and McMillan (1992), we assume that these decisions are non-cooperatively made by the legislators in a strategic-form game which has a symmetric mixed strategy equilibrium. Using that equilibrium, we will calculate the endogenous probability of regulation, i.e. the probability that at least one of the legislators will propose a bill recommending the optimal regulatory policy of Baron and Myerson (1982) after all legislators have observed, prior to regulation, the output choice of the threatened firm.

We simulate the outcome of our model using a linear demand curve and a uniformly distributed belief function (representing the information the legislators and the regulator have about the marginal cost of the regulated firm), and find that the main results of Glazer and McMillan (1992) can arise under asymmetric information, as well. That is, the endogenous probability of regulation faced by the firm is always lower than the exogenous probability of regulation it would face should it charge the simple monopoly price. The firm is found to substantially mitigate the risk of regulation because it sets its price considerably lower than the simple monopoly price, especially when it is not technologically very efficient. As a matter of fact, when the marginal cost of the firm is very close to the highest possible value according to the beliefs of the legislators and the regulator, the price the firm charges under the threat of regulation can be even lower than the price it has to charge when it is regulated. Our simulations also allow us to explore how the welfares of consumers and the threatened firm are affected in the short-run and long-run by possible variations in several attributes of our model, including the marginal cost of production, the number of legislators, each legislator's cost of introducing a regulatory bill, the size of the market, and the weight of the firm's welfare in the social welfare function.

The rest of the paper is organized as follows: Section 2 presents our model that basically integrates the self-regulation model of Glazer and McMillan (1992) with the optimal regulation model of Baron and Myerson (1982). Section 3 contains our results and Section 4 concludes.

2 Model

Below, we extend the self-regulation model of Glazer and McMillan (1992) to the case of asymmetric cost information. Specifically, we consider an infinitely-lived environment, involving a monopolistic firm that produces a single good, an unspecified number of consumers, a finite number of legislators each of which can introduce a regulatory policy, and a potential regulator whose only task is to implement the regulatory policy designed and proposed by the legislators. We denote the number of legislators by the integer $N \geq 2$ and the common discount rate by the real number $\delta > 0$. (Thus, for any individual in our environment 1 unit of gain obtained in any period is equivalent to $1 + \delta$ units of gain obtained in the next period.) In every period, the firm's cost of production is given by

$$C(q, \theta) = \theta q \quad \text{if } q > 0, \quad \text{and} \quad C(0, \theta) = 0, \tag{1}$$

where $q \geq 0$ is the quantity of output and $\theta > 0$ is the constant marginal cost. We assume that the parameter θ is privately known to the firm before any regulatory action. The firm also faces in every period an inverse demand function $P(q)$ with $P(0) > 0$ and $P'(q) < 0$ for all $q \geq 0$. So, in any period where the quantity of output is q, the total value to consumers is given by

$$V(q) = \int_0^q P(x)dx, \tag{2}$$

while the consumer surplus is equal to

$$CS(q) = V(q) - P(q)q. \tag{3}$$

Like in Glazer and McMillan (1992), we assume that the firm is not regulated in the first period, where it only faces the threat of regulation. After the first period, this threat can be realized whenever at least one of the legislators in the environment decides to propose a bill recommending a regulatory policy, to be implemented by the regulator forever. Each legislator makes his/her decision weighing the costs and benefits of proposing a bill. The costs may include the time and effort required to prepare and promote a bill. We denote the discounted value of all such costs by the constant K. On the other hand, the benefits of each legislator from proposing a bill may involve his/her expected political and electoral gains resulting from the positive impact of regulation on the social welfare. Like in Glazer and McMillan (1992), we assume that these benefits are considered by each legislator to be equal to the discounted lifetime social welfare generated by the proposed regulatory policy net of the discounted lifetime social welfare induced by the output decision, q, of the threatened firm in the first period. We denote the value of these benefits by $B(q)$.

Unlike in Glazer and McMillan (1992), we will restrict the legislators to a specific regulatory policy, namely the optimal regulatory policy devised by Baron and Myerson (1982) for the case of asymmetric cost information. This restriction will allow us to characterize the legislators' common benefit function $B(q)$ explicitly and thereby to make various equilibrium predictions without any ambiguity. Below, we will first introduce the regulatory policy of Baron and Myerson (1982), slightly tailoring it for our model. Recall that the parameter θ is known only to the firm before any regulatory action. The legislators and the regulator in our environment are assumed to have common prior beliefs about this parameter, represented by a density function f that is positive and continuous over an interval $[\theta_0, \theta_1]$ with $\theta_1 > \theta_0 \geq 0$. We denote by F the corresponding cumulative distribution function. At this point, we assume that everything described so far, except for θ, is common knowledge. We also assume that the regulatory policies that can be proposed by the legislators must optimally regulate in every period the price and quantity of the firm under their beliefs about the private cost information of this firm. By the Revelation Principle (Dasgupta, Hammond and Maskin, 1979; Myerson, 1979; and Harris and Townsend, 1981) the legislators can without loss of generality restrict themselves to direct mechanisms that ask the firm to report its cost information and that give no incentive to lie. Baron and Myerson (1982) proposed that such a mechanism must involve the rules $\langle r(\tilde{\theta}), p(\tilde{\theta}), q(\tilde{\theta}), s(\tilde{\theta})\rangle$, defined at each possible cost report $\tilde{\theta}$. Extending their approach to the infinite-horizon case, we say that in every period of regulation $r(\tilde{\theta})$ is the probability that the firm is permitted to operate, $p(\tilde{\theta})$ and $q(\tilde{\theta})$ are the regulated price and quantity, and $s(\tilde{\theta})$ is the expected value of the subsidy given by consumers to the firm, conditional on the probability that it is permitted to operate. Given these four rules, the regulated firm, whenever it reports its marginal cost θ to be $\tilde{\theta}$, obtains the discounted lifetime profits (producer welfare) $PW(\tilde{\theta}, \theta)$ where

$$PW(\tilde{\theta}, \theta) = \frac{1}{\delta}\Big([P(q(\tilde{\theta}))q(\tilde{\theta}) - \theta q(\tilde{\theta})]r(\tilde{\theta}) + s(\tilde{\theta})\Big). \tag{4}$$

Like in Baron and Myerson (1982), we call a regulatory mechanism (policy) $\langle r, p, q, s\rangle$ *feasible* if it satisfies the following conditions for all $\theta \in [\theta_0, \theta_1]$:

(i) $r(\theta)$ is a probability function, i.e.,

$$0 \leq r(\theta) \leq 1, \tag{5}$$

(ii) $p(\theta)$ and $q(\theta)$ agree with each other on the inverse demand curve, i.e.,

$$p(\theta) = P(q(\theta)), \tag{6}$$

(iii) the regulatory mechanism is incentive-compatible, i.e.,

$$PW(\theta, \theta) \geq PW(\tilde{\theta}, \theta), \quad \text{for all } \tilde{\theta} \in [\theta_0, \theta_1], \tag{7}$$

(iv) the regulatory mechanism is individually rational, i.e.,

$$PW(\theta, \theta) \geq 0. \tag{8}$$

When the regulatory mechanism satisfies the incentive-compatibility condition in (7), the firm with the marginal cost information θ obtains the discounted lifetime welfare $PW(\theta) \equiv PW(\theta, \theta)$, whereas consumers obtain the discounted lifetime welfare $CW(\theta) = [CS(q(\theta))r(\theta) - s(\theta)]/\delta$. Using these two welfares, one can define the social welfare as

$$SW(\theta) = CW(\theta) + \alpha PW(\theta), \tag{9}$$

where $\alpha \in [0, 1]$ is the (relative) weight of the producer welfare. Given the feasibility conditions in (5)-(8), the problem of each legislator is to find, among all feasible regulatory mechanisms of the form

$\langle r, p, q, s \rangle$, the mechanism that will maximize the expected social welfare $E_\theta[SW(\theta)]$. Baron and Myerson (1982) characterizes this mechanism in a single-period setting irrespective of the form of the belief function f. When this function satisfies a condition called *monotone inverse hazard rate*, the characterization result of Baron and Myerson (1982) can be restated as follows.

Proposition 1. Assume that $F(\theta)/f(\theta)$ is non-decreasing for all $\theta \in [\theta_0, \theta_1]$. Then, the optimal regulatory (OR) mechanism under feasibility conditions (5)-(8) is given by $\langle r^{OR}, p^{OR}, q^{OR}, s^{OR} \rangle$ satisfying equations (10)-(13) for all $\theta \in [\theta_0, \theta_1]$:

$$p^{OR}(\theta) = \theta + (1-\alpha)\frac{F(\theta)}{f(\theta)} \tag{10}$$

$$q^{OR}(\theta) = P^{-1}(p^{OR}(\theta)) \tag{11}$$

$$r^{OR}(\theta) = \begin{cases} 1 & \text{if } V(q^{OR}(\theta)) - p^{OR}(\theta)q^{OR}(\theta) \geq C(q^{OR}(\theta), \theta) - \int_0^{q^{OR}(\theta)} C_x(x, \theta)dx \\ 0 & \text{otherwise} \end{cases} \tag{12}$$

$$s^{OR}(\theta) = \left[\theta q^{OR}(\theta) - p^{OR}(\theta)q^{OR}(\theta)\right] r^{OR}(\theta) + \int_\theta^{\theta_1} r^{OR}(x)q^{OR}(x)dx \tag{13}$$

Proof. The above proposition is a simple extension of Proposition 1 in Baron and Myerson (1982). The reason is that the expected social welfare maximized by the legislators or the regulator in our model is a constant multiple of the expected social welfare maximized by the regulator in Baron and Myerson (1982). Thus, our single-period regulatory mechanism must be essentially the same as theirs, with a unique difference caused by the assumption we make on f, requiring that $F(\theta)/f(\theta)$ is always non-decreasing in θ. Thanks to this assumption, we do not need the convexification in the optimal regulated price as was done by Baron and Myerson (1982). Our monotonicity assumption on $F(\theta)/f(\theta)$ simply implies that the optimal price rule $p^{OR}(.)$ is always increasing, and therefore the optimal output rule $q^{OR}(.)$ is always decreasing. Moreover, we have $r^{OR}(\theta) = 1$ for all $\theta \in [\theta_0, \theta_1]$. Thus, the incentive-compatibility condition in (7) always holds. □

In the optimal regulatory mechanism above, the optimal probability of operation $r^{OR}(\theta)$ gets equal to one (zero) when the consumer surplus at the regulated price and quantity, $V(q^{OR}(\theta)) - p^{OR}(\theta)q^{OR}(\theta)$, is not below (is below) the fixed cost of production, $C(q^{OR}(\theta), \theta) - \int_0^{q^{OR}(\theta)} C_x(x, \theta)dx$. Since there is no fixed cost of production in our model, the probability $r^{OR}(\theta)$ is always equal to one, implying that the firm, when regulated, is allowed to operate at all possible cost reports. Note also that if the firm is regulated according to the mechanism in Proposition 1 at some period $T \geq 2$, the regulatory mechanism $\langle r^{OR}, p^{OR}, q^{OR}, s^{OR} \rangle$ will be implemented in periods after T, as well. That is to say, even though the firm will reveal its cost information in period T, the incentive-compatibility condition requires that the firm must be offered the informational rents $\int_{\theta}^{\theta_1} r^{OR}(x)q^{OR}(x)dx = \int_{\theta}^{\theta_1} q^{OR}(x)dx$ in every period $t \geq T$.

Given the optimal regulatory mechanism in (10)-(13), the lifetime producer welfare and the consumer welfare when discounted to the beginning of period one, respectively become

$$PW^{OR}(\theta) = \frac{1}{\delta} \int_{\theta}^{\theta_1} q^{OR}(x)dx \tag{14}$$

and

$$CW^{OR}(\theta) = \frac{1}{\delta} \left(V(q^{OR}(\theta)) - \theta q^{OR}(\theta) - \int_{\theta}^{\theta_1} q^{OR}(x)dx \right). \tag{15}$$

On the other hand, the single-period producer and consumer welfares in period 1, when discounted to the beginning of that period, respectively become

$$PW^{1,OR}(\theta) = \frac{\delta}{1+\delta} PW^{OR}(\theta) \tag{16}$$

and

$$CW^{1,OR}(\theta) = \frac{\delta}{1+\delta} CW^{OR}(\theta). \tag{17}$$

Now, we will consider the problem faced by the legislators when they have to decide at the end of period 1 (and similarly at the end of each period where any regulatory action has not taken yet) whether to propose a bill that will recommend the regulation of the firm in the subsequent periods according to the Baron and Myerson's (1982) optimal mechanism. First note that if the firm produces the output q starting from period 1 onwards, the discounted lifetime welfare of the society becomes

$$SW(q,\theta) \quad = \quad \frac{1}{\delta} \left[CS(q) + \alpha(P(q)q - \theta q) \right]. \tag{18}$$

We assume that the legislators cannot make verifiable and trustable inferences on the cost parameter θ in periods where the firm is not regulated. This implies that the legislators cannot calculate the actual value of the lifetime social welfare $SW(q,\theta)$ in (18). However, given their beliefs about θ, the legislators can calculate the expected value of this welfare, i.e.

$$E_{\theta}[SW(q,\theta)] = \frac{1}{\delta} \int_{\theta_0}^{\theta_1} \left[CS(q) + \alpha(P(q)q - \theta q) \right] f(\theta)d\theta. \tag{19}$$

Also, the legislators can calculate the expected value of the lifetime social welfare obtained under the optimal regulatory mechanism in Proposition 1 as follows:

$$\begin{aligned} E_\theta[SW^{OR}(\theta)] &= \int_{\theta_0}^{\theta_1} CW^{OR}(\theta)f(\theta)d\theta + \alpha\int_{\theta_0}^{\theta_1} PW^{OR}(\theta)f(\theta)d\theta \\ &= \frac{1}{\delta}\int_{\theta_0}^{\theta_1}\left[V(q^{OR}(\theta)) - \left(\theta + (1-\alpha)\frac{F(\theta)}{f(\theta)}\right)q^{OR}(\theta)\right] r^{OR}(\theta)f(\theta)d\theta \end{aligned} \quad (20)$$

Given (19) and (20), the legislators can calculate in every period the benefit $B(q)$ from optimally regulating the firm with output q starting from the next period onwards:

$$B(q) = E_\theta[SW^{OR}(\theta)] - E_\theta[SW(q,\theta)] \quad (21)$$

Now, we are ready to consider the strategic game played by the legislators in the first period (and also in every period where the regulatory action has not been taken yet). In this game, each legislator has to non-cooperatively decide whether or not to propose a bill. As shown by Glazer and McMillan (1992), this game has a symmetric mixed strategy equilibrium, implying the following.

Proposition 2. *At least one legislator proposes a bill, recommending the optimal regulation of the firm, with probability*

$$L(q) = 1 - (K/B(q))^{N/(N-1)}. \quad (22)$$

Proof. Let s be the probability that a legislator proposes a bill. The probability that at least one legislator proposes a bill is $1-(1-s)^N$. Pick any legislator x. Then the probability that some legislator other than x proposes a bill is $1-(1-s)^{N-1}$. Legislator x becomes indifferent between proposing a bill and not proposing if

$$B(q)[1-(1-s)^{N-1}] = B(q) - K, \quad (23)$$

implying

$$s = 1 - (K/B(q))^{1/(N-1)}. \quad (24)$$

Therefore, at least one legislator proposes a bill with probability $1-(K/B(q))^{N/(N-1)}$. □

The probability $L(q)$ is called the endogenous probability of regulation, as it depends on the output q of the threatened firm. This probability is always between zero and one, and it is decreasing in q, implying that the firm can reduce the threat of regulation by constraining its price. We should also note that an increase in K or N lead to a decrease in $L(q)$, if we keep the firm's output choice q constant.

Knowing the probability of regulation $L(q)$ for each possible value of q, the firm (and each legislator in the environment) can calculate its optimal output choice under regulatory threat, as we will see below. Let $PW^{SR}(q,\theta)$ denote the (expected) discounted lifetime profits of the self-regulated (SR) firm. To calculate these profits, note that if the firm produces in the first period the quantity q, its single-period profits (discounted to the beginning of period one) become $[P(q)q-\theta q]/(1+\delta)$. In the next period, the firm may be optimally regulated with probability $L(q)$. If regulated, the firm obtains the discounted lifetime profits $PW^{OR}(\theta)/(1+\delta)$. On the other hand, if the firm is not regulated in the next period, it obtains the discounted lifetime profits $PW^{SR}(\theta)/(1+\delta)$. So, the firm's expected discounted lifetime profits must satisfy

$$\begin{aligned} PW^{SR}(q,\theta) &= \frac{P(q)q-\theta q}{1+\delta}+\frac{1}{1+\delta}\left[L(q)PW^{OR}(\theta)+(1-L(q))PW^{SR}(q,\theta)\right] \\ &= PW^{OR}(\theta)+\frac{1}{L(q)+\delta}\left[P(q)q-\theta q-\delta PW^{OR}(\theta)\right]. \end{aligned} \tag{25}$$

Given (25), the problem of the firm is to solve

$$max_q \, PW^{SR}(q,\theta). \tag{26}$$

Let $q^{SR}(\theta)$ be the solution to this problem, yielding the welfare $PW^{SR}(q^{SR}(\theta),\theta)$. On the other hand, the discounted producer welfare obtained in period 1 is given by

$$PW^{1,SR}(q^{SR}(\theta),\theta)=\frac{1}{1+\delta}\left[P(q^{SR}(\theta))q^{SR}(\theta)-\theta q^{SR}(\theta)\right]. \tag{27}$$

For further reference, we can also calculate the discounted lifetime consumer welfare

$$CW(q^{SR}(\theta),\theta)=CW^{OR}(\theta)+\frac{1}{L(q^{SR}(\theta))+\delta}\left[CS(q^{SR}(\theta))-\delta CW^{OR}(\theta)\right] \tag{28}$$

and the discounted consumer welfare in period 1

$$CW^{1,SR}(q^{SR}(\theta),\theta)=\frac{CS(q^{SR}(\theta))}{1+\delta}. \tag{29}$$

Finally note that the firm when it faces no regulatory threat chooses in every period the price $p^M(\theta)$ and the output $q^M(\theta)$ satisfying $p^M(\theta)+P'(q^M(\theta))q^M(\theta)=\theta$, to maximize its profits at the level $\pi^M(\theta)=(p^M(\theta)-\theta)q^M(\theta)$. So, for this firm the discounted lifetime producer welfare $PW^M(\theta)$ becomes equal to $\pi^M(\theta)/\delta$ while the discounted single-period producer welfare $PW^{1,M}(\theta)$ in period 1 becomes equal to $\pi^M(\theta)/(1+\delta)$. Correspondingly, the discounted lifetime consumer welfare $CW^M(\theta)$ becomes equal to $CS(q^M(\theta))/\delta$ while the discounted single-period consumer welfare $CW^{1,M}(\theta)$ in period 1 becomes equal to $CS(q^M(\theta))/(1+\delta)$. Using the definitions above, we will calculate and compare, in the following section, the producer and consumer welfares obtained under the cases where the monopoly is optimally regulated, not regulated, and self-regulated.

3 Results

Due to the complexity of the optimization problem in (26), we are unable to analytically calculate the optimal behavior of the self-regulated firm. However, we can simulate this behavior numerically with the help of a computer, using Gauss Version 3.2.34 (Aptech Systems, 1998). (The source code and the simulated data can be requested from the author.)

For our simulations, we consider a linear inverse demand function $P(q) = a - q$. Also, we assume that the common beliefs about the marginal cost parameter θ are uniformly distributed, i.e., $f(\theta) = 1/(\theta_1 - \theta_0)$ for all $\theta \in [\theta_0, \theta_1]$. Regarding the model parameters, we make the settings $K = 2$, $\delta = 0.025$, $\theta_0 = 1.5$, and $\theta_1 = 2.00$, and vary the remaining parameters. Specifically, we change:

– the marginal cost parameter θ from 1.50 to 1.95 with increments of 0.05;

– the cost of legislation K from 2.1 to 3.9 with increments of 0.2;

– the weight parameter α in the social welfare function from 0.1 to 1.0 to with increments of 0.1;

– the number of legislators N from 2 to 47 with increments of 5; and

– the inverse demand intercept a from 3.1 to 4.0 with increments of 0.1.

Thus, considering 10 distinct values for each of the parameters θ, K, α, N, and a, we obtain a total of 10^5 simulations of our model outcomes, including the probability of regulation L, the product price, the welfares of the firm and consumers in their first-period and in their whole life span, which are all calculated when the firm is unregulated, optimally regulated, and self-regulated. We illustrate the results of our simulations in Figures 1-5. Each figure plots comparative statics results with respect to one of the parameters in $\{\theta, K, \alpha, N, a\}$ by averaging out 10^4 simulation outcomes obtained from the variations in the remaining four parameters.

In Figure 1 we consider the effects of variations in θ. We observe in panel (i) that the price determined by the firm facing no regulatory threat (blue curve) is always above the price dictated to the optimally regulated firm (red curve), while the corresponding price gap is decreasing in θ. Also, we note that the firm constrains its price under regulatory threat (orange curve), in comparison to the case of no threat (blue curve). In fact, the price of the self-regulated firm can become very close to the price set by the unregulated firm if θ is sufficiently low and it can become, in the other extreme, very close to, and even lower than, the price dictated to the optimally regulated firm if θ is sufficiently high. By constraining its price very tightly, especially at medium and high values of θ, the self-regulated firm reduces the endogenous probability of regulation (green curve) to very low levels near zero, as illustrated in panel (ii). In the same panel we can also see that the exogenous probability of regulation, which the firm would face if it did not constrain its price, is always extremely high and slightly increasing in θ. On the other hand, the endogenous probability of regulation is decreasing when the price of the self-regulated firm is above the price of the optimally-regulated firm and slightly increasing elsewhere. Panels (iii) and (iv) show that the single-period pre-regulation welfares of the firm and consumers are extremely affected by the pricing behavior of the firm under regulatory threat. When the production cost of the firm is sufficiently high, the self-regulated firm (consumers) can obtain in the first period (and in each period with regulatory threat) an amount of welfare almost as low (high) as it (they) would obtain under the optimal regulatory action. However, the welfare effects of self-regulation are less pronounced when the production cost is lower. In fact, when the production cost is sufficiently low, the short-run welfare distribution in the industry is nearly the same when the firm is self-regulated and unregulated. Finally, panels (v) and (vi) show that self-regulation and external regulation yield almost the same welfare distribution in the long-run.

In Figure 2 we consider the effects of variations in K, the cost incurred by each legislator when he/she drafts and promotes a bill for the implementation of the optimal regulatory policy. Note that an increase in K reduces both the exogenous and endogenous probabilities of regulation. As a matter of fact, we know from (22) that an increase in K reduces the endogenous probability of regulation even when the threatened firm does not change its price (and output). Interestingly, when the cost of legislation becomes higher, the threatened firm finds it optimal to reduce its price, as shown in panel (i), in response to an expected reduction in the risk of regulation. Because of that, the reduction in the endogenous probability of regulation is much steeper than in the exogenous probability of regulation, as illustrated in panel (ii). Panels (iii) and (iv) show that an increase in K followed by a decrease in the price of the threatened firm leads in the first period to a decrease in the welfare of the threatened firm and an increase in the welfare of consumers, if K is sufficiently small. On the other hand, in panels (v) and (vi) we observe that the short-run welfare effects of K working through the price reduction of the threatened firm dissipate in the long-run, where the welfares of the firm and consumers are mainly affected by the reduction in the endogenous probability of regulation. Due to this, the lifetime welfare of the firm (consumers) always increases (decreases), when K becomes higher and the risk of regulation becomes smaller.

Figure 3 plots our comparative statics results with respect to the social welfare weight parameter α. By definition, α has no effects on any model variables when the firm faces no regulatory threat (blue curves). Panel (i) shows that the price set by the self-regulated firm is always increasing in α, while the price dictated to the optimally-regulated firm is always decreasing. Accordingly, we see in panel (ii) that the endogenous probability of regulation is increasing in α, while the exogenous probability of regulation is slightly decreasing. Because of the pricing behavior of the self-regulated firm in panel (i), we observe in panels (iii) and (iv) that in the first period, where the optimal regulation is not implemented yet, the firm (consumers) can obtain a higher welfare when α is higher. Moreover, the last two panels of Figure 3 show that the positive short-run effect of an increase in α on the welfare of the firm, arising due to the relaxed price restraint of the firm, always dominates the negative long-run effect channeling through the increased risk of regulation. Consequently, an increase in α leads to an increase (decrease) in the welfare the firm (consumers) in the long-run, as well.

In Figure 4, we consider the impacts of variations in N, the number of legislators. As should be obvious, the parameter N can affect the model variables only when the firm faces regulatory threat. The six panels of Figure 4 show that an increase in N may have an impact only when N is sufficiently small. In such a case, an increase in N reduces both the exogenous and the endogenous probability of regulation, as should be expected from (22). Despite this, the self-regulating firm finds it optimal to constrain its price slightly more, reinforcing the reduction in the risk of regulation. In result, when N is sufficiently small, the pre-regulation welfare of the firm(consumers) slightly decreases (increases) with respect to N. On the other hand, panels (v)-(vi) imply that the long-run welfare effect of the reduction in the endogenous probability of regulation dominates the short-run welfare effect arising from the tightened price restraint; thus we observe that the lifetime welfare of the firm (consumers) slightly increases (decreases) when N becomes higher over its effective range.

Finally, in Figure 5 we illustrate the impacts of variations in the demand parameter a, i.e., the potential size of the market. Panels (i) and (ii) show that the effects of a change in a on the pricing behavior of the firm and the endogenous probability of regulation are almost negligible. Thus, when the parameter a rises, say due to a positive demand shock, almost all welfare effects occur only because of the expansion in the potential social surplus. In panels (iii)-(vi) we observe that this expansion benefits consumers and the firm both in the short-run and long-run, as expected.

Figure 1. The Effects of θ on Various Outcomes

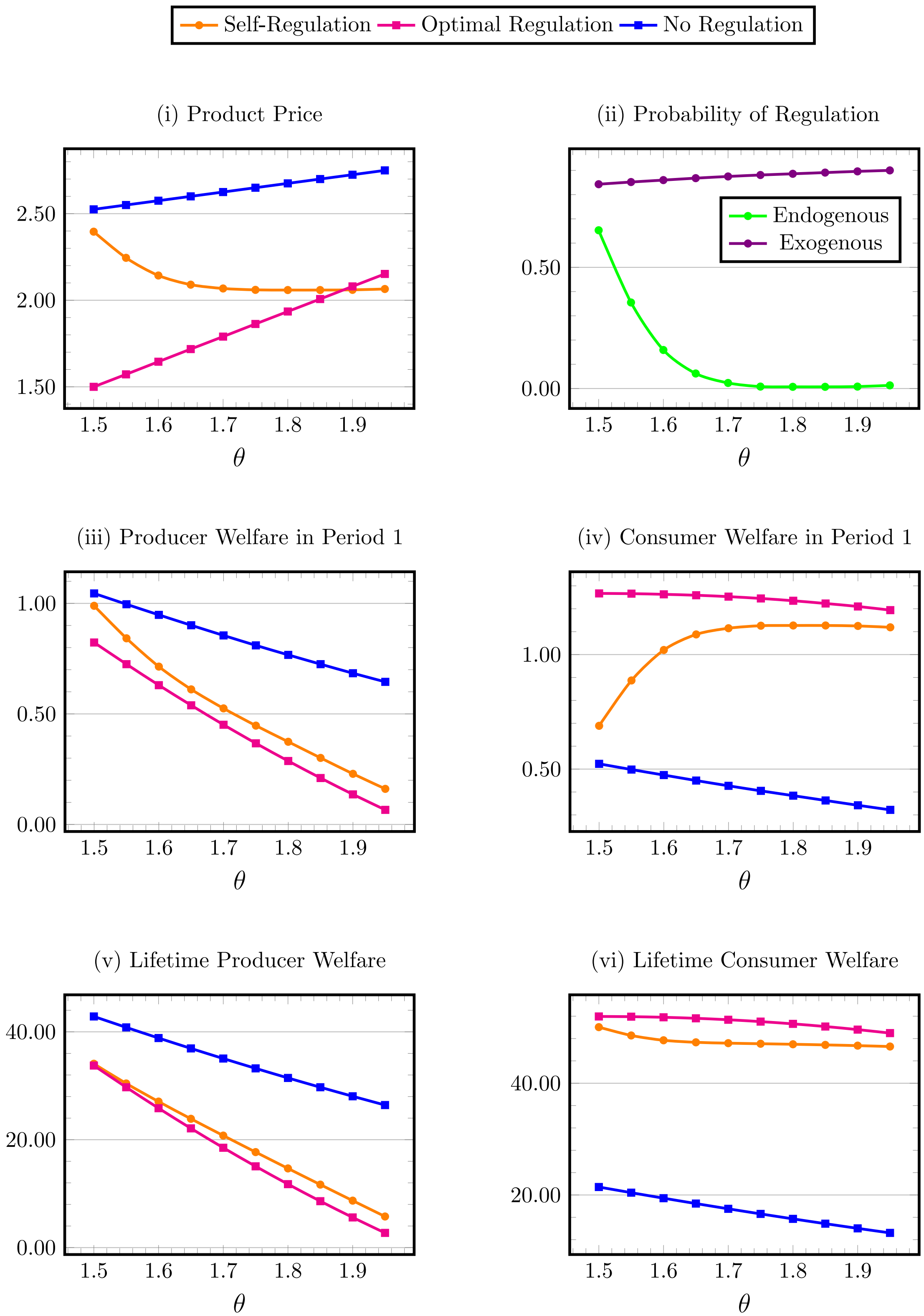


Figure 2. The Effects of K on Various Outcomes

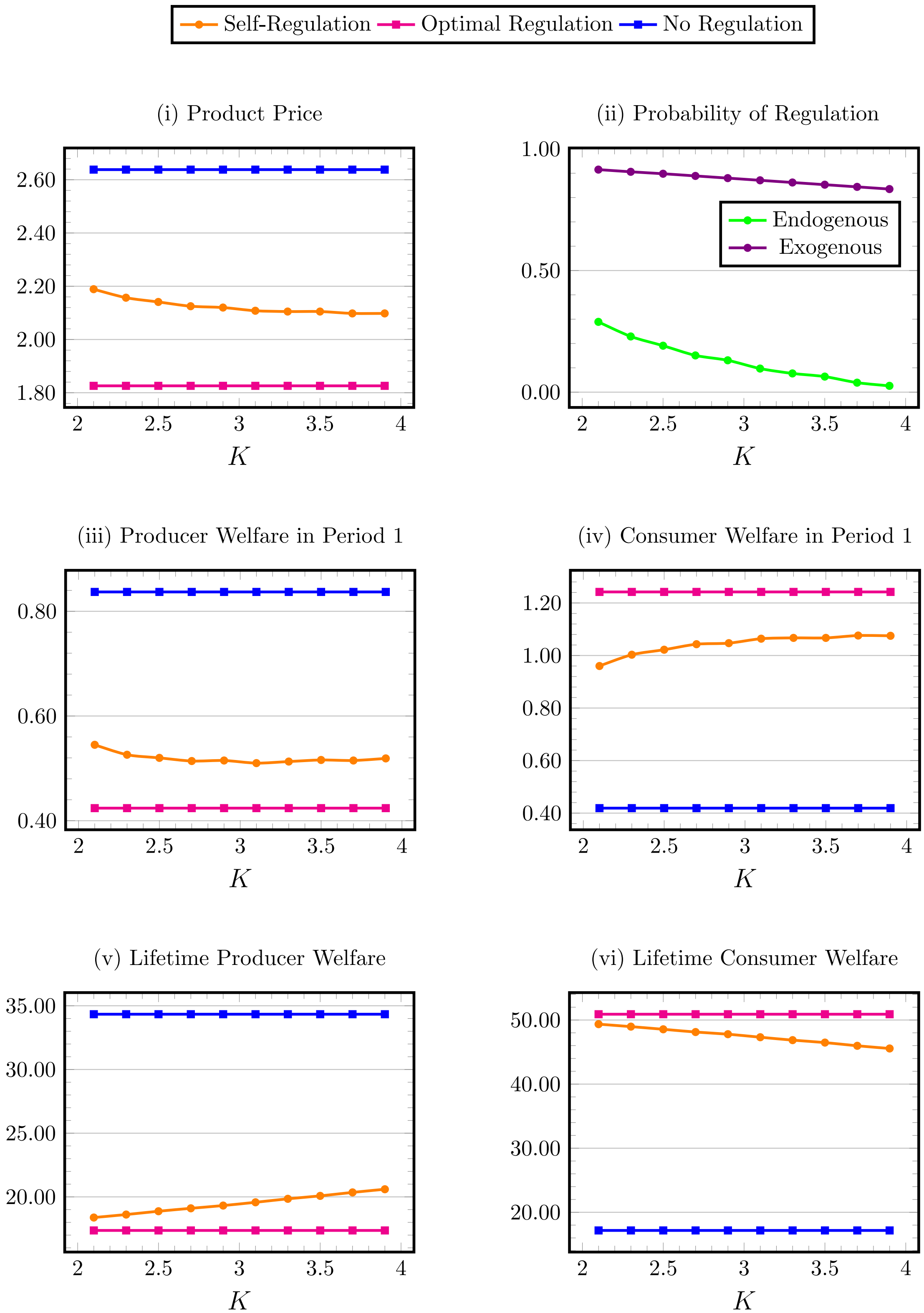


Figure 3. The Effects of α on Various Outcomes

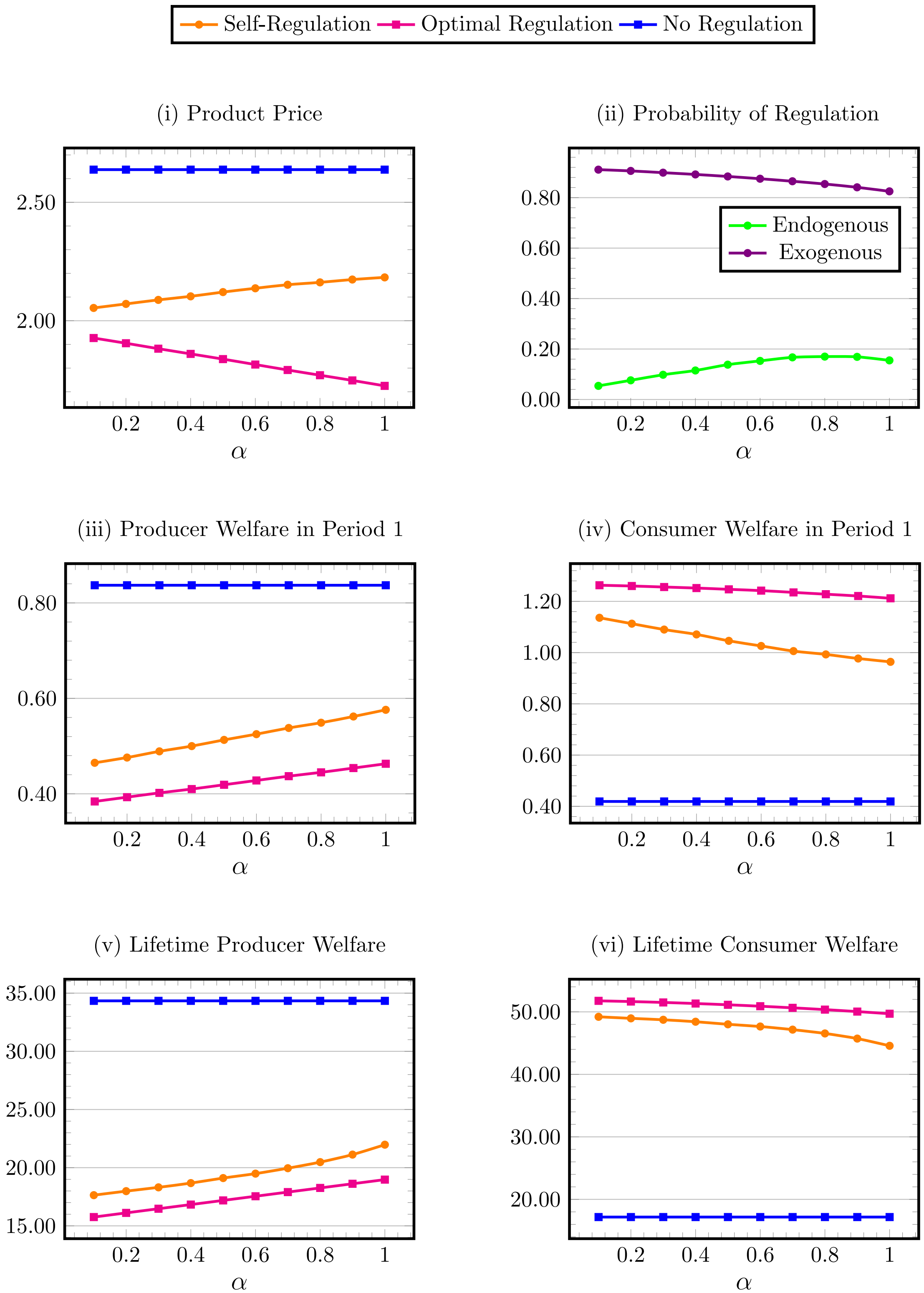


Figure 4. The Effects of N on Various Outcomes

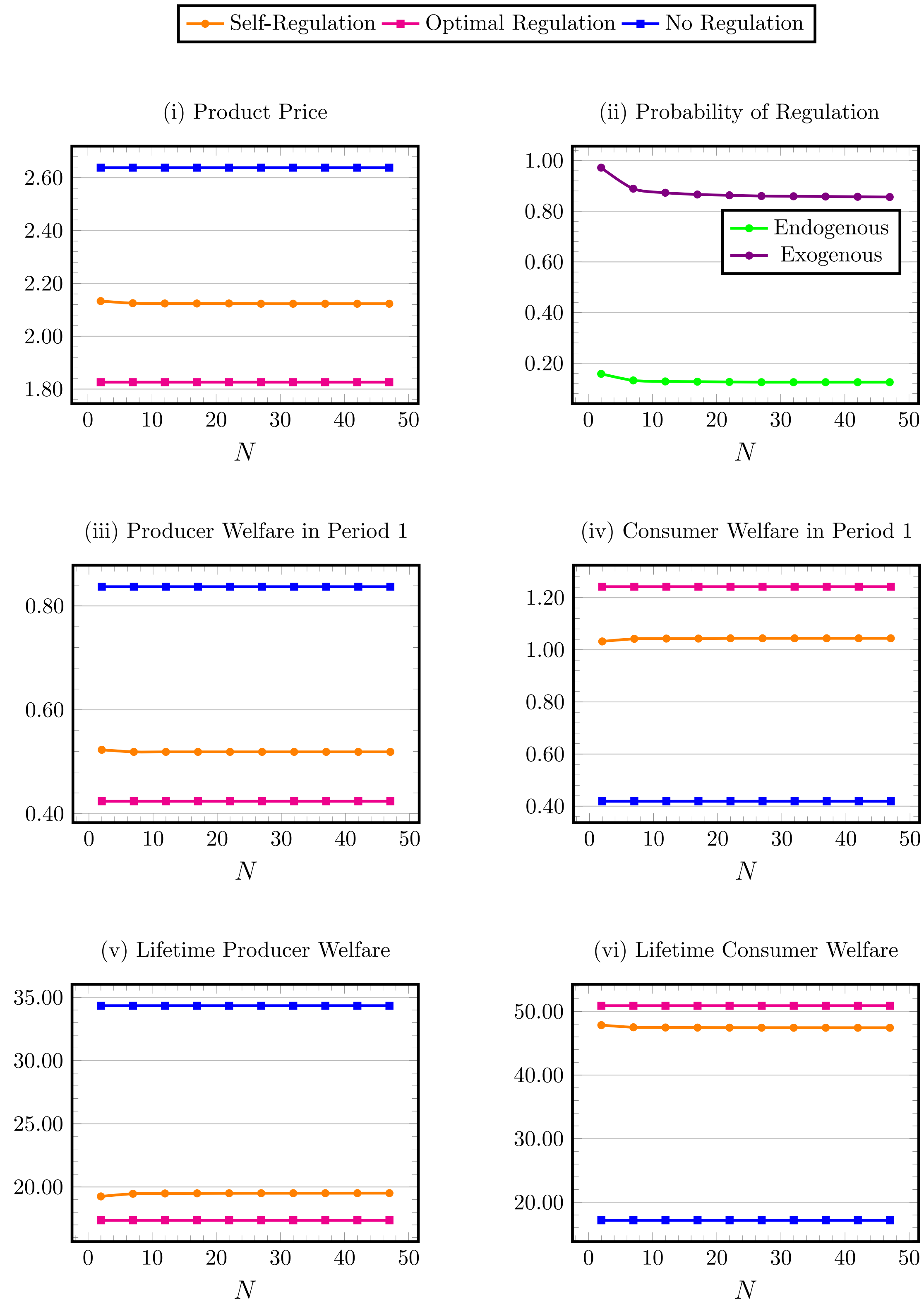
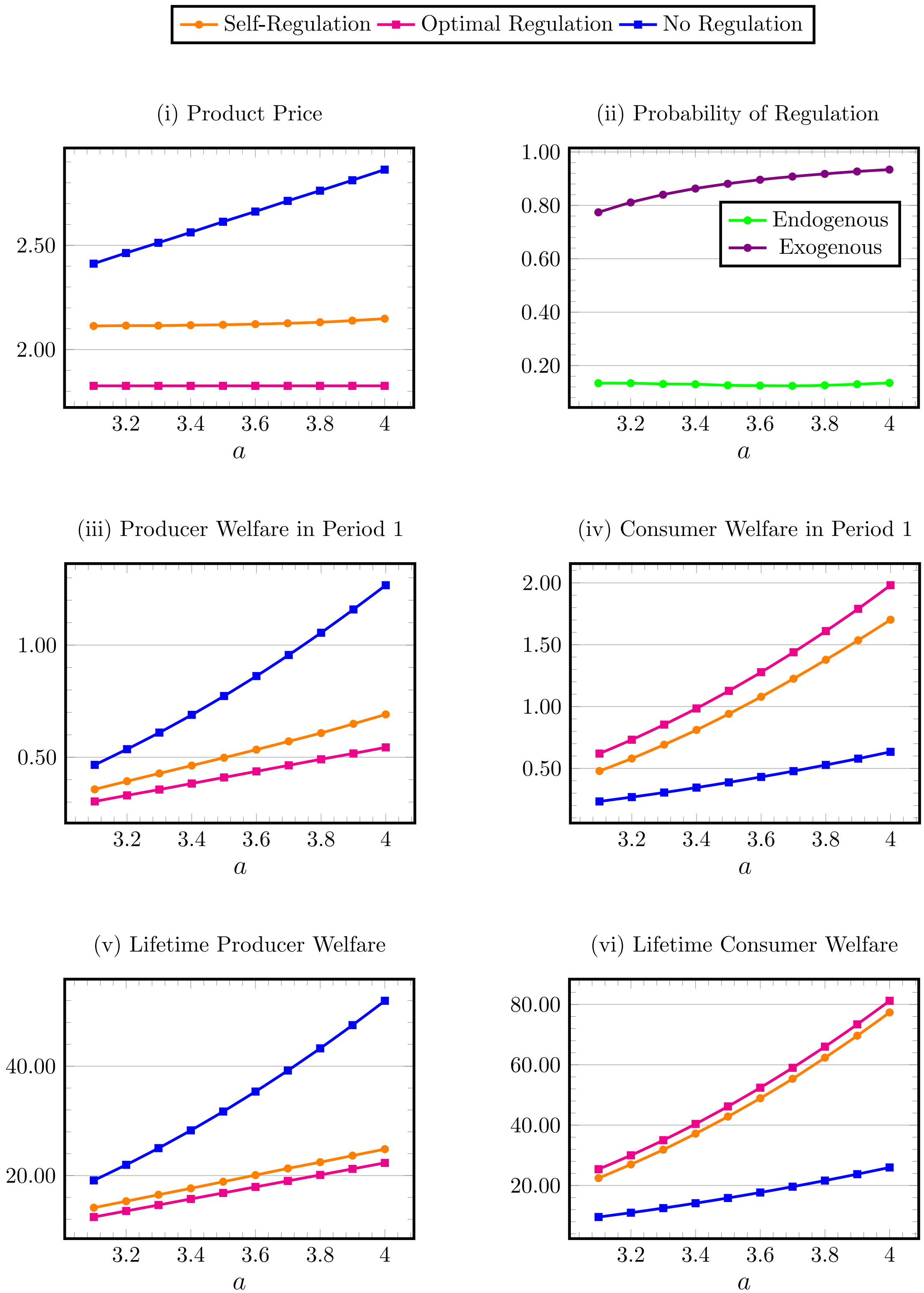


Figure 5. The Effects of a on Various Outcomes



4 Conclusion

In this paper, we have studied the pricing behavior of a monopolistic firm with unknown costs under the threat of regulation. Basically, we have integrated the legislative-choice model of Glazer and McMillan (1992), dealing with the self-regulation hypothesis under (implicitly) symmetric information, with the optimal regulation model devised by Baron and Myerson (1982) for the case of asymmetric information. Simulating the outcome of our integrated model using a linear inverse demand function and uniformly distributed beliefs representing the legislators' and the regulator's knowledge about the private cost information of the firm, we have established that the main results of Glazer and McMillan (1992) can arise under asymmetric information, as well. Specifically, we have showed that the endogenous probability of regulation, i.e., the probability that at least one of the legislators in the environment proposes a bill recommending the implementation of the optimal regulatory policy of Baron and Myerson (1982), is always lower than the exogenous probability of regulation that would be faced by the firm if it charged the 'simple' monopoly price. We have also showed that the firm is able to mitigate the risk of regulation by choosing a price considerably lower than the simple monopoly price at all possible cost values. Interestingly, we have found that when the marginal cost of the firm is very close to the highest possible value according to the beliefs of the legislators and the regulator, the price the firm charges under the threat of regulation can be even lower than the price it has to charge when it is optimally regulated. While this last result is novel to our study, the result that firms under the threat of regulation may limit their output prices to absorb increases in their production costs was already highlighted by Glazer and McMillan (1992) as a theoretical possibility, which they also argued to be in line with the evidence reported in Olmstead and Rhode (1985). As a matter of fact, Glazer and McMillan (1992) also claimed that increases in production costs might increase the profits of the firm under the threat of regulation, since the firm –by holding down its product price– could reduce the endogenous probability of regulation. However, our findings show that this is not the case when the firm holds private information about its production costs. Although the threatened firm constrains its price at all possible cost levels and can reduce the risk of regulation to very low levels, even to levels as low as zero when its marginal cost is sufficiently high, its welfare –both in the short-run and in the long-run– becomes smaller when its marginal cost becomes higher. It seems that the direct negative effect of cost increases on the welfare of the firm threatened with the optimal regulatory policy of Baron and Myerson (1982) always offsets the indirect positive effect channeling through the reduction in the risk of regulation.

With the help of our simulations, we have also explored the impacts of variations in several attributes of our model. Among several results, we have showed that an increase in the legislative cost of drafting and promoting a regulatory bill decreases both the endogenous and the exogenous probability of regulation, as expected. Moreover, we have found that the decrease in the endogenous probability of regulation is not only due to the best response of the legislators to the increased cost of regulation. A part of this decrease is caused by the threatened firm's constraining its price even more stringently when the cost of legislation becomes higher, which was already conjectured by Glazer and McMillan (1992) as an interesting possibility. We have found that the observed reaction of the threatened firm to an increase in the cost of legislation may slightly reduce its short-run welfare while at the same leading to a significant increase in its long-time welfare, at the expense of an almost equal welfare loss for consumers.

We have also illustrated that the outcomes of our model are not sensitive to changes in the number of legislators, unless this number is unrealistically small. On the other hand, variations in the size of the market and in the social welfare function may both have significant impacts on the pricing behavior of the firm under regulatory threat. Specifically, we have found that an increase in the weight assigned to the firm's welfare in the social welfare function decreases the exogenous probability of regulation, while at the same time increasing the endogenous probability of regulation, unless this weight is already very large. These findings suggest that the observed increase in the endogenous probability of regulation must be due to the optimal reaction of the threatened firm. Indeed, our results have confirmed this. We have found that the firm constrains its price less tightly when the social welfare function become more equitable. Consequently, the firm's welfare becomes higher and consumers' welfare becomes lower in the short-run. In fact, this short-run welfare effect is so large that it offsets an opposite long-run effect channeling through the increased probability of regulation. Thus, the firm becomes better-off and consumers become worse-off even in the long-run if the regulator increases the weight of the firm's welfare in the social welfare function. On the other hand, when the size of market increases, say due to a positive demand shock, our findings show that the welfares of both the firm and consumers become higher in the short-run as well as in the long-run, while the endogenous probability of regulation and the price of the threatened firm remain almost constant.

Future research may extend our work to study the impact of cost-reducing research and development (R&D) activities on the self-regulation of a monopolistic firm with unknown costs. One can conjecture that the expected social welfare in pre-regulation periods may become higher when the firm threatened with regulation engages in R&D more heavily, which may in turn reduce the endogenous probability of regulation. On the other hand, once the firm realizes this mitigating effect of R&D on the risk of regulation, it may constrain the price of its product less tightly and engage in more R&D, provided that the relative cost of R&D is sufficiently small. The validity of this conjecture can be empirically investigated by simply testing whether during the past episodes of economic crises firms with higher R&D spendings have charged higher prices under political pressure than firms with lower R&D spendings.

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