Competitive Vices*

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Abstract

In markets firms have to compete following a set of rules determined by laws, regulations, and social practices or pressures. This paper investigates the effect of the degree of competition on the extent to which firms may invest in behaving according to the rules of the market. The paper models investments in following the rules of the market as increasing the marginal costs of production, but leading to a smaller probability of the firm being caught for not following the market rules. The paper shows that greater competition leads to smaller investments in following the market rules. If the market rules have some social benefit, this leads to an existence of a social optimum degree of competition which is less than perfect competition, and more competition leading to greater optimal monitoring efforts. The paper also discusses the effects on optimal market rules. The paper argues that under some conditions the early market winners are more likely to have behaved outside the market rules, and that once an industry is established, the larger firms are more likely to follow the rules of the market. If monitoring can be made contingent on market success the paper also argues that more monitoring efforts should be exerted on the market winners.

"Behind any great wealth there is a crime."
Honoré de Balzac

1. Introduction

Firms operate in markets within certain rules, the rules of the game. As noted in Hutton (2002, p. VII), *"The act of incorporation in all capitalist societies was originally conceived as winning a license to trade in return for the acceptance of obligations set out by the government of the day."* The rules of the market, the rules of the game, are determined by laws, regulations, social practices, or social pressures informed by moral and ethical values. In addition, in several instances we see competitors or third parties argue that some firm has not followed the rules of the market, has behaved unlawfully, missed some regulations or contract obligations, or entered in some activity that is unethical, immoral, or not socially responsible.[1]

Moreover, the rules of the market are often complex and sometimes poorly defined. For example, firms have to respect a proliferation of laws and regulations of their actions, and there is some heterogeneity in the degree to which firms engage in socially responsible behavior (e.g., Bradshaw and Vogel 1981, pp. xii, xxiv, Slemrod 1989, Kaplow 1995). The interpretation of the rules of the market is also often not clear, as evidenced by the sometimes intense use of the judicial system by firms in a market, or the uncertain outcome of public relations endeavors.[2]

This paper considers a model of competing firms investing in (costly) efforts to satisfy the rules of the game, under an imperfect monitoring authority (e.g., Becker 1968, Stigler 1970). The more a firm invests in trying to satisfy the rules of the game, the greater its production costs and the lower the probability of getting caught. If a firm gets caught the firm may have to pay a penalty, possibly under limited liability.

In several instances in business one hears of behavior that may not be appropriate. For example, while characterizing the robber barons, Josephson (1934, p. vii) states: *"They were aggressive men, as were the first feudal barons; sometimes they were lawless; in important crises, nearly all of them tended to act without those established moral principles which fixed more or less the*

[1] Bhattacharya and Korschun (2008) discuss the the extension of the goals of the firm to include serving the interests of multiple "stakeholders" and not just the shareholders' interests.

[2] In sports, we frequently encounter situations when it is not clear where the rules of the game may lie. As an example, in a baseball game on September 15, 2010, Derek Jeter, "the Yankee shortstop and generally perceived-to-be boy scout, feigned being hit by a pitch. He pretended that the ball had ricocheted off his hand, though as stop-action replay made evident (and as he readily acknowledged after the game), it actually hit the knob of his bat. Nonetheless, his charade fooled the umpire; he was awarded first base" (Weber, 2010). As a reaction, some showed "indignation" with the lack of "rectitude" and asked whether "truth-telling and accountability have no place in sports." Others argued that this was "testimony to a first-rate athletic instinct."

conduct of the common people of the community." Of one of the robber barons, Josephson states *"... he drove himself, men, and things with reckless energy, and with an indifference to established custom and law which stood him in good stead. 'What do I care about the law? Hain't I got the power?' "* (p. 72). Writing of another robber baron: *"He had learned, moreover, that it was not enough to conquer the whole legislature; but one must buy the judges as well"* (p. 132). On some encounters one states *"I said (after settling with him) that it was an almighty robbery; that we had sold ourselves to the devil"* (p. 134), on others market results sometimes depended on *"... armed conflicts with rivals..."* (p. 135), meeting "*force with force, bribe with bribe and duplicity with duplicity* (p. 139), and accusing each other of *"fraud, violence and morally reprehensible practices"* (p. 140) or *"unscrupulous usurpers, who by a sort of legerdemain, seized control of the stockholders' property, stole ... money, and so demoralized its service as to bring calamities of unusual horror, damage and death"* (p. 140).

In recent years we similarly often hear accusations to some companies of violations of safety or anti-trust laws, violations of the trust of consumers, violations of truth in advertising, failure to truthfully report their financial accounts, use of child labor, or actions against the environment, among others. Some recent more newsworthy cases include, for example, Enron (e.g., Fox, 2003), which also brought down the accounting firm Arthur Andersen, or Archer Daniels Midland (e.g., Eichenwald, 2000). More focused on the objectives of this paper, Snyder (2010) presents evidence that liver transplant centers faced with greater competitive pressure may overstate health problems to gain priority on the liver waiting list. Bennett et al. (2012) shows evidence from vehicle emissions tests that increased competition yields increased levels of fraud (pass customers at a higher rate).

This paper investigates the effect of the degree of competition on the extent to which firms adhere to the rules of the market. We show that under certain reasonable conditions more competition leads to firms being less careful in following the rules of the market. The argument is that with competition firms have less to lose if they are caught not following the rules of the market, and therefore, are more likely to break those rules. We investigate the implications of this effect on social welfare and on the design of optimal rules. We also show that in a stochastic environment, firms that end up with a greater market share may be the ones that are more likely to have broken the rules of the game. We show this result with both a mixed-strategy equilibrium, and with an incomplete information game where firms may have different tolerances not to follow the market rules.

Another interesting issue is whether firms with different positions in the market may behave differently with respect to following the market rules. We show that firms with more to lose from being caught are more likely to invest more in following the rules.[3] In a dynamic environment this then leads firms to take greater risks of being caught in the earlier periods; and then the ones that win are more careful in future periods. The paper also investigates the implications for optimal limited monitoring of the market rules in such a setting.

One related literature on the problems considered here looks at the question of the development of moral standards and values. Some examples are Kaplow and Shavell (2007), Tabellini (2010), Baron (2010), and Dal Bó and Terviö (2008). In relation to that literature, this paper could be seen as investigating the effect of competition on the extent to which economic agents respect the current moral standards or values. Furthermore, the paper can be seen as considering all possible rules of the market more generally, and potential implications for monitoring and rule making. Another related issue is firms investing in social responsibility practices as a response to consumer preferences (e.g., Sen and Bhattacharya 2001, Arora and Henderson 2007, Banerjee and Wathieu 2010, Gneezy et al. 2010). In relation to this possibility, the punishment of being caught not satisfying the market rules that is considered here can be seen as the result of consumer retaliation against a firm not investing enough in socially responsible practices. Kopalle and Lehmann (2010) investigate the question of firms over-claiming their quality level. They argue that greater competition leads to firms overstating to a greater extent the quality offered. This can be seen as consistent with the results presented here.

The general problem considered here can also be seen as related to the question of how the intensity of innovation in an industry is affected by the market structure, and how the possibility of innovation may affect the market structure (see, e.g., Dasgupta and Stiglitz 1980, Gilbert and Newbery 1982, Reinganum 1983, Ofek and Sarvary 2003, Aghion et al. 2005). In relation to that literature, and as it is specified below, the investment in satisfying the market rules affects profits in a particular way that can be different than the one of innovation investments. The investments in satisfying the market rules may affect the marginal costs of production, not affect the competitors' profits, affect profits for only one period, and lead to a maximum possible liability if a firm is found to not satisfy the market rules. Any of these might not be the case for typical innovation investments. Furthermore, when considering the issue of satisfying the market rules one may raise the issue of monitoring policies and optimal design of market rules, which does not have an obvious parallel in a setting of investment in innovations. Finally, one main message here is that more competition may lead to lower investments in satisfying the market rules, while in the literature on the investment in innovations one obtains in several cases that more competition leads to more innovation.

[3] Luo and Bhattacharya 2006 show that contribution to corporate social responsibility by firms having lower quality products cann affect negatively their market value.

The next Section considers a quantity competition model and shows that more competition leads to firms being less careful in fulfilling the rules of the market. Section 3 discusses implications of this possibility for the design of market rules. Section 4 presents a price competition model where equilibria are in mixed strategies, and shows that the firms that end up with a greater market share are the ones that were less careful in following the market rules. Section 5 considers the case where firms have private information, and Section 6 considers the dynamic case where firms may change the care with which they follow the market rules from period to period. Section 7 discusses optimal monitoring by the enforcer of the rules, and Section 8 concludes.

2. Static Symmetric Competition

Consider an homogenous product market with N symmetric firms competing in quantity. Denote the inverse demand function as $P(Q)$ where Q is the total quantity produced in the market, with $P'(Q) < 0$ and $2P'(Q) + QP''(Q) < 0$.[4] Each firm i chooses its quantity to produce, which we denote by q_i. We have $Q = \sum_{i=1}^{N} q_i$.

In addition to choosing the quantity to produce each firm i chooses the extent to which they decide the adhere to the rules of the market, γ_i. This variable γ_i is the probability of not being found out for breaking the market rules. Choosing a higher γ_i means having a higher marginal cost of production, $c(\gamma_i)$.[5] That is, we have $c'(\gamma_i) > 0$. Furthermore, let us assume that a greater γ_i has increasing effects on the marginal costs, $c''(\gamma_i) > 0$.

If a firm is caught breaking the market rules let us assume that all its profits are taken away. We consider the case when only its profits can be confiscated by limited liability.[6] We assume that firms are risk neutral.

The profit of a firm i can then be represented as $\pi^i(q_i, Q, \gamma_i) = \gamma_i q_i[(P(Q) - c(\gamma_i)]$. We assume that firms produce for the market even if caught. That is, firms produce first for the market, and then their profits are expropriated if found at fault. An alternative model would have firms being caught before producing. That would benefit firms that were not caught. In such a model, a firm's

[4]The latter condition is the standard second order condition for firm pricing with constant marginal costs.

[5]At the end of this section we discuss the case when a higher γ_i has an effect on fixed costs.

[6]In Section 8 we discuss briefly what may happen if the penalty paid is less than the total profits obtained and if the penalty is contingent on the extent to which the rules were broken (which can be seen as being measured by $-\gamma_i$).

profit would also depend on the γ_i chosen by the competitors. We further discuss this case at the end of this Section.

The first order conditions for a firm i would then be

$$P(Q) - c(\gamma_i) + q_i P'(Q) = 0 \quad (1)$$

$$P(Q) - c(\gamma_i) - \gamma_i c'(\gamma_i) = 0. \quad (2)$$

Under general conditions the equilibrium is symmetric with each firm choosing the same q and γ (where we drop the subscript for each firm, given the symmetric equilibrium). Totally differentiating the equilibrium q and γ with respect to N we obtain

$$\frac{d\gamma}{dN} = \frac{qP'(Q)^2}{NP'(Q)c'(\gamma) + NP'(Q)\gamma c''(\gamma) + (P'(Q) + QP''(Q))(2c'(\gamma) + \gamma c''(\gamma))} < 0.$$

We state this result in the following Proposition.

PROPOSITION 1: *When the intensity of competition increases (number of firms increases), each firm invests less in satisfying the market rules.*

The intuition is that with more competition firms have less to lose if they are caught breaking the market rules, and therefore are more likely to be less careful about respecting those rules. As competition leads to lower prices, firms have a greater pressure in decreasing their marginal costs, lowering γ. In addition, as competition leads to lower quantity produced, firms have less incentive to lower costs (greater γ), but this effect is dominated by the former effect of having less to lose.

For the linear demand example, $P(Q) = 1 - Q$, one can obtain that the equilibrium q and γ satisfy $\gamma c'(\gamma) = q$ and $c(\gamma) + \gamma(1 + N)c'(\gamma) = 1$. If, in addition, we assume the marginal cost to be linear in γ, $c(\gamma) = c_0 + \alpha\gamma$, where $\alpha > 0$ is the effect of being careful about the market rules on the marginal costs, we have $\gamma = \frac{1-c_0}{\alpha(2+N)}$ and $q = \frac{1-c_0}{2+N}$. Note that this is the equilibrium when firms simultaneously optimize on q and γ, not when they optimize on q given γ, where the equilibrium would be $q = \frac{1-c(\gamma)}{1+N}$. To see the effect of competition on how careful firms are about the market rules, note that firms are less careful about the market rules (lower γ) the greater the number of firms in the market, N. Note also that, as expected, the greater the costs of being respectful of the market rules, α, the less likely firms are to be careful about the market rules. And this effect is greater as the number of firms in the market becomes larger.

The analysis above is done under the assumption that firms are risk neutral. If firms are risk averse then the penalty of ending with a zero payoff is more costly, and then firms invest more in satisfying the market rules.

Social Welfare

If one specifies a social welfare function with some costs of breaking the market rules, there is then an optimal (non-infinite) number of firms. The social planner may prefer not to have too much competition. To formalize this further, suppose that the social costs of firms not investing enough on being careful to follow the market rules are proportional to the expected total quantity produced that could be violating the market rules, $(1-\gamma)Q$.

The social welfare function would then be:

$$S(Q,\gamma) = \int_0^Q P(x)\,dx - c(\gamma)Q - k(1-\gamma)Q \tag{3}$$

where k represents the per unit social cost of not following the market rules. A natural threshold to consider for k is that $k > c'(1)$, such that given the total quantity Q a social planner would prefer costs to be higher, and market rules to be fully satisfied, than incur the social costs of the market rules not being fully satisfied.[7]

If the social planner could choose γ and Q, and $k > c'(1)$, it would choose $\gamma = 1$ and Q such that $P(Q) = c(1)$, the usual condition of price equal to marginal cost. If the social planner can choose γ and, while not being able to regulate the total quantity produced, it can choose the number of firms in the market, the social planner could implement the optimum by choosing $N \to \infty$.

If $\gamma < 1$ is fixed, note that the optimal total quantity in the market is no longer determined by $P(Q) = c(\gamma)$, but it is now determined by $P(Q) = c(\gamma) + k(1-\gamma)$. That is the optimal total quantity produced should be reduced with respect to marginal cost pricing because there is an extra social cost of each unit produced without following all market rules. Note also that if $k > c'(1)$ the optimal total quantity produced is lower than the optimal quantity produced when $\gamma = 1$, as $c(\gamma) + k(1-\gamma) > c(1)$ for $\gamma < 1$. To implement the optimal quantity Q^* for fixed $\gamma < 1$ the social planner now has to choose a finite N, which is $N = -\frac{Q^* P'(Q^*)}{k(1-\gamma)}$.

As seen above, the number of firms in the market also determines endogenously the equilibrium intensity with which firms try to satisfy the market rules, γ. Consider the first order condition of the optimal number of firms N for the social planner:

$$[P(Q) - c(\gamma) - k(1-\gamma)]\frac{dQ}{dN} + [k - c'(\gamma)]Q\frac{d\gamma}{dN} = 0. \tag{4}$$

As the effect of the number of firms N on γ was shown above to be negative, a greater number

[7] Note that if the social planner is not fully aware of the costs incurred in satisfying market rules, it may choose to set rules where $k < c'(1)$.

of firms leads to firms being less careful about satisfying the market rules, and we have that the endogenous γ leads the social planner to choose an even lower number of firms if $k > c'(\gamma)$, which is true for the case of $k > c'(1)$.

PROPOSITION 2: *When firms can decide in how much to invest in satisfying the market rules, and if $k > c'(1)$, then social welfare is increased by decreasing the intensity of competition (limit entry into the market) in comparison to when the extent of satisfaction of the market rules is exogenous.*

The intuition is that by reducing the intensity of competition (having fewer firms in the market), firms invest more in satisfying the market rules, which is beneficial for social welfare.

For the linear example mentioned above we would have the following. For the case when $\gamma = 1$ the optimal total quantity would be $Q = 1 - c_0 - \alpha$. For the case when we have fixed $\gamma < 1$ we would have the total optimal quantity $Q = 1 - c_0 - \gamma\alpha - (1-\gamma)k$, and an optimal number of firms $N = \frac{1-c_0-\gamma\alpha-(1-\gamma)k}{k(1-\gamma)}$. Finally, for the full endogenous case, when both the total quantity produced and the investment on satisfying the market rules are endogenous, we have $Q = 2\frac{1-c_0-\gamma\alpha-(1-\gamma)k}{2+k-\alpha}$, and $N = 4\alpha\frac{1-c_0-\gamma\alpha-(1-\gamma)k}{(2+k-3\alpha)(1-c_0)+2\alpha[\gamma\alpha+(1-\gamma)k]}$.

Fixed Costs of Satisfying the Rules of the Market

Consider now a variation of the model above where investing in satisfying the market rules is a fixed cost rather than affecting the marginal costs. Suppose also that the fixed costs of satisfying the market rules are compensated if the firm is found out not to satisfy the market rules. The profit function for a firm i is then defined as $\pi^i(q_i, Q, \gamma_i) = \gamma_i\{q_i[(P(Q) - c] - F(\gamma_i)\}$ where $F(\gamma_i)$ are the fixed costs of choosing to satisfy the market rules at the level γ_i, with $F', F'' > 0$. With any given number N of firms in the market one can compute the equilibrium $q[P(Q) - c]$ which is decreasing in N and independent of γ_i, as the quantity produced by each firm is only dependent on the marginal costs, which are independent of γ_i.

Writing the equilibrium variable profits, $q[P(Q) - c]$ as $\pi^m(N)$, the first order condition for γ_i is $F(\gamma_i) + \gamma_i F'(\gamma_i) = \pi^m(N)$. As the equilibrium firm profits, $\pi^m(N)$, are decreasing in the number of firms N, one can immediately obtain that a greater number of firms in the market leads to each firm investing less in being careful about satisfying the market rules, lower γ_i. As above, a greater number of firms leads to firms being less careful about satisfying the market rules because each firm has less to lose if caught. The social welfare results stated above would also follow in this case.

Production Only if Satisfying the Rules of the Market

The analysis above considers the case that even if a firm is caught not following the rules of the market, the quantity produced by that firm continues to be supplied to the market. Consider now the case in which if a firm is caught not following the rules of the market, its intended production is not supplied to the market, to the benefit of the firms that are not caught not satisfying the rules of the market. For the inverse demand function $P(Q)$ close to linear, the profit function for a firm can be approximated as

$$\pi^i(q_1, ..., q_N; \gamma_1, ..., \gamma_N) = \gamma_i q_i[(P(q_i + \sum_{j \neq i} \gamma_j q_j) - c(\gamma_i)],$$

Note that now the intensity with which the competitors try to satisfy the market rules affects (negatively) the payoff of a firm. Furthermore, if the competitors are less careful about satisfying the market rules, a firm would like to be more careful about satisfying the market rules. That is, the γ_i are strategic substitutes. The first order conditions are the same as above, but now, in order to totally differentiate with respect to γ and q, one has to take into account that γ and q are also changing for the competitors at the first order conditions. One can then obtain that

$$\frac{d\gamma}{dN} = \frac{\gamma q P'^2}{(c' + \gamma c'')(2 + \gamma(N-1))P' + q(1 + \gamma(N-1))P'') + c'q(1 + \gamma(N-1))P'' - P'(q(N-1)P' - c'}.$$

For P'' sufficiently close to zero, this expression is negative. That is, as above, more competition leads firms to be less careful about satisfying the rules of the market. Note also that for the equilibrium γ small, the effect of the number of firms on the equilibrium γ is smaller in absolute value than in the case above when all firms produced. In general, for the same inverse demand functions one can have either greater or lower equilibrium γ than in the case in which all firms' output goes to the market independent of a firm being caught. On the one hand, if all firms produce the same amount as above, and if some output leaves the market, the firms have more to lose if they are caught, and invest more in satisfying the rules of the market. On the other hand, firms realize that the competitor's output may be reduced, and increase their quantity produced accordingly, which could lead to less profits, and to firms being less careful in satisfying the market rules. This latter effect is greater for a smaller number of firms.

For the linear example above, one obtains in equilibrium $\gamma = \frac{\sqrt{9\alpha^2 + \alpha(N-1)(1-c_0)} - 3\alpha}{2\alpha(N-1)}$ and $q = \alpha\gamma$. One can get parameters under which this equilibrium γ is lower or greater than the equilibrium γ for the case above, where all firms' output remains in the market.

3. Optimal Market Rules

The analysis above suggests that a social planner may also potentially be interested in changing the market rules such that firms may find it easier or more difficult to invest in satisfying those rules. That is, the social planner could potentially decide how strict to make the rules of the market. Let λ be an index of how strict the rules are. Stricter rules increase the marginal cost of production. That is, now the marginal cost of production can be written as $c(\gamma, \lambda)$, with $\frac{\partial c}{\partial \lambda} > 0$, and $\frac{\partial^2 c}{\partial \gamma \partial \lambda} \geq 0$.

The possibility of less strict rules may also mean that a firm may not be caught satisfying the market rules, but still hurt social welfare because it did not satisfy a potential rule which, although not part of the market rules, if satisfied, social welfare would be higher. In order to consider that, the total social welfare cost of all potential rules not being satisfied is k, as noted above. Suppose that the legislator decides how many rules to set, λ, with $\lambda \in [0, 1]$, where the first rules being set are the ones that, if not satisfied, lead to a higher social cost. If there are λ rules, the social cost per unit supplied by a firm being found as not having satisfied the rules of the market can be seen as continuing to be k per unit supplied. But now, there are are also social costs from firms that are not found to be violating the market rules, as those firms may be violating some potential market rules that are not chosen by the legislator as part of the set of actual market rules. The social cost per unit supplied from the firms that are not found not satisfying the market rules can be represented by $G(\lambda)$ where $G'(\lambda) < 0$, and $G''(\lambda) > 0$, as less strict rules leads to more social costs of potential rules not satisfied. This effect is assumed as greater when the rules are less strict, as the legislator chooses first to incorporate in the rules of the market the rules that are more important. Furthermore, we assume that $G(0) = k$ and $G(1) = 0$: If there are "no" rules the social costs are k per unit for all output and, if all the potential rules are incorporated in the set of rules of the market, then the social costs of firms not caught are zero.

So, while in the previous section the social costs of not satisfying potential rules were $k(1-\gamma)Q$, they are now $k(1-\gamma)Q + G(\lambda)\gamma Q$.

Totally differentiating the equilibrium γ and q defined by (1) and (2) with respect to λ, one obtains

$$\frac{d\gamma}{d\lambda} = -\frac{(P'(Q) + QP''(Q))\frac{\partial c}{\partial \lambda} + ((N+1)P'(Q) + QP''(Q))\gamma\frac{\partial^2 c}{\partial \gamma \partial \lambda}}{NP'(Q)\frac{\partial c}{\partial \gamma} + NP'(Q)\gamma\frac{\partial^2 c}{\partial \gamma^2} + (P'(Q) + QP''(Q))(2\frac{\partial c}{\partial \gamma} + \gamma\frac{\partial^2 c}{\partial \gamma^2})} \tag{5}$$

and

$$\frac{dq}{d\lambda} = \frac{\frac{\partial c}{\partial \lambda}(\frac{\partial c}{\partial \gamma} + \gamma\frac{\partial^2 c}{\partial \gamma^2}) - \gamma\frac{\partial c}{\partial \gamma}\frac{\partial^2 c}{\partial \gamma \partial \lambda}}{NP'(Q)\frac{\partial c}{\partial \gamma} + NP'(Q)\gamma\frac{\partial^2 c}{\partial \gamma^2} + (P'(Q) + QP''(Q))(2\frac{\partial c}{\partial \gamma} + \gamma\frac{\partial^2 c}{\partial \gamma^2})}. \tag{6}$$

From this one can obtain that if $P'(Q) + QP''(Q) < 0$ (the second derivative of the inverse demand function is not too large), then $\frac{d\gamma}{d\lambda} < 0$, stricter rules make the firms invest less in satisfying the market rules. That is, if the rules of the market are stricter, firms find it too costly to satisfy all the rules of the market, and are more likely to be found out as not satisfying the market rules. However, one can obtain that with stricter market rules, firms invest more in satisfying the market rules if the second derivatives of the marginal cost function are dominated by the first derivatives, that is, in equilibrium $c(\gamma, \lambda)$ is increasing in λ, $\frac{\partial c}{\partial \lambda} + \frac{\partial c}{\partial \gamma}\frac{d\gamma}{d\lambda} > 0$.

If the second derivatives of the cost function are dominated by the first derivatives, one can also obtain that $\frac{dq}{d\lambda} < 0$, stricter market rules lead each firm to produce less. The intuition is that stricter market rules means that the marginal costs of production are higher, and the firms respond by producing less. We state these results in the following proposition.

PROPOSITION 3: *If the second derivatives of the cost function are dominated by the first derivatives, stricter market rules lead to more firms being caught not satisfying the market rules, to greater investment in satisfying the market rules, and to lower production.*

Consider now the effects on social welfare of the market rules that are set. Given the formulation above we have that the social welfare function is

$$S(Q, \gamma, \lambda) = \int_0^Q P(x)\, dx - c(\gamma, \lambda)Q - k(1 - \gamma)Q - G(\lambda)\gamma Q. \tag{7}$$

Totally differentiating $S(Q, \gamma, \lambda)$ with respect to λ, taking into account that the equilibrium Q and γ depend on λ, one obtains

$$\frac{dS}{d\lambda} = N\frac{dq}{d\lambda}[P(q) - c(\gamma, \lambda) - k(1 - \gamma) - G(\lambda)\gamma] + Q\frac{d\gamma}{d\lambda}[k - G(\lambda)] - Q[\frac{\partial c}{\partial \lambda} + \frac{\partial c}{\partial \gamma}\frac{d\gamma}{d\lambda}] - G'(\lambda)\gamma Q. \tag{8}$$

The first term in (8) represents the social cost of less quantity in the market being offered if the market rules are stricter. This term is negative in general. The second term represents the social costs of firms being more likely to be found not satisfying the market rules when the market rules are stricter. This term is also negative. The third term represents the increase in production costs when the market rules are stricter, which also affects negatively social welfare. Finally, the fourth term represents the social benefits of having more potential rules being satisfied, which is a positive effect of having stricter market rules. The optimal market rules result from the trade-off between these four forces. Note that if the last potential rules that can be enforced have insignificant value, that is, if $\lim_{\lambda \to 1} G'(\lambda) = 0$, then at the social welfare optimum the legislator chooses not to include all the potential rules in the rules of the market.

For the linear example, $P(Q) = 1 - Q, c(\gamma, \lambda) = c_0 + \alpha\gamma + \beta\lambda$ (where α and β are parameters) we can obtain, as above, the equilibrium $\gamma = \frac{1-c_0-\beta\lambda}{\alpha(1+N)}$ and $Q = N\frac{1-c_0-\beta\lambda}{1+N}$. It is easy to see that this illustrates that the equilibrium γ and Q decrease in λ. One can also obtain the equilibrium investments in satisfying the market rules, $c(\gamma, \lambda) = \frac{1+N(c_0+\beta\lambda)}{1+N}$, increasing in λ. Finally, for this example, one can obtain that the optimal rules have to satisfy

$$G(\lambda)(1 + \frac{1}{\alpha}) - G'(\lambda)\frac{1 - c_0 - \beta\lambda}{\alpha\beta} = 2k + N. \tag{9}$$

Given that the left hand side of (9) is decreasing in λ, one can obtain for this example that more competition (greater N) and greater costs of satisfying the market rules (greater α) lead the legislator to choose less strict market rules. Greater competition leads firms to invest less in satisfying the market rules, and the legislator alleviates this effect by having less strict market rules. We state this result in the following proposition.

Proposition 4: *For linear demand and cost function, the legislator (i.e., the social planner) chooses less strict market rules when there is greater competition and greater costs of satisfying the market rules.*

4. Ex-Post Market Asymmetry

Consider now a symmetric competition model where ex-post firms end up with different market shares. This will be a model of price competition in mixed strategies based on Varian (1980) and Narasimhan (1988). Suppose that N symmetric firms compete in price, with the same assumptions on the marginal cost and effect on profits if found out not to satisfy the rules of the game as above.

A set of consumers of dimension one buys the product which has the lowest price, if it is below a reservation value r. Per firm, there is a set of consumers of dimension M that buys the product of that firm if the price is below the reservation value r.

The equilibrium is in mixed strategies, with each firm charging a price drawn from a cumulative distribution function $F(P)$. The equilibrium condition for $F(P)$ is that a firm is indifferent for all prices that it charges, and γ that it chooses:

$$\gamma(P - c(\gamma))\{[1 - F(P)]^{N-1} + M\} = K,$$

for all price P being charged with positive density, where K is the equilibrium expected profit.

For a certain price P_i charged by firm i one can obtain that the optimal γ_i is obtained as

$$P_i - c(\gamma_i) - \gamma_i c'(\gamma_i) = 0, \tag{10}$$

the same condition as above, which means that the firm will make a greater effort to adhere to the rules of the market when charging a higher price.

At the highest price charged, r, one can obtain the equilibrium γ_i, γ^r, as $r - c(\gamma^r) - \gamma^r c'(\gamma^r) = 0$. The equilibrium expected profit K can be obtained as $K = \gamma^{r2} c'(\gamma^r) M$. The equilibrium mixed strategy can then be obtained as

$$F(P) = 1 - \{\frac{\gamma^{r2} c'(\gamma^r) - \gamma^2 c'(\gamma)}{\gamma^2 c'(\gamma)} M\}^{\frac{1}{N-1}} \tag{11}$$

where γ is the monotonic function of P presented in (10).

From this one can obtain that when competition increases (decrease in M) firms charge lower prices and are less careful in satisfying the rules of the market. The parameter M can be seen as a measure of product differentiation. In this model, the only thing that matters for the intensity of competition is the ratio of locked-in consumers to the consumers that choose the lowest price product (not M per se).[8]

This model can then illustrate that the firms that win (greater market share and profits) are more likely to have been the ones that invested less in satisfying the rules of the market. We state the formal result in the following proposition.

PROPOSITION 5: *In the symmetric model above with a mixed strategies equilibrium, the firm that has the largest profit and market share is the one that invested less in satisfying the market rules.*

For the example where the marginal cost is linear in γ, $c(\gamma) = c_0 + \alpha\gamma$, we can obtain that (10) leads to $P = c_0 + 2\alpha\gamma$ and we can obtain $\gamma^r = \frac{r - c_0}{2\alpha}$ and an expected profit $K = \frac{(r-c_0)^2}{4\alpha} M$. The more costly it is for firms to be careful about the market rules, α, the lower the expected profits. Furthermore, for this case we can obtain the equilibrium mixed strategy (11) as

$$F(P) = 1 - \{\frac{r - P}{P - c_0}[1 + \frac{r - c_0}{P - c_0}]M\}^{\frac{1}{N-1}}$$

[8]Changing the number of firms N in this model may lead to higher prices (e.g., Rosenthal, 1980), but here a greater N may not necessarily be seen as greater competition, as an additional firm brings additional M consumers into the market.

which is independent of the cost of being careful about the market rules, α. That is, in this case the pricing equilibrium is not affected by changes in the cost of being careful about the market rules. That is, for each price draw, an increase in the cost of being careful about the market rules, α, is associated with a decrease in how careful to be about the market rules, γ.

5. Firm Private Information

Consider now a variation of the model above where firms have private information about how much each dislikes not satisfying the market rules. That is, firms are endowed with different degrees to which they do not like to not satisfy the market rules, and each firm only knows about its own preferences. One way to consider this is to have the linear marginal cost example above augmented with a cost that is increasing in how much the firm likes to satisfy the market rules, $\widehat{c}(\gamma) = c_0 + \alpha\gamma + \eta(1-\gamma)$, with each firm having private information on its own η. The variable η represents how much the firm cares about satisfying the market rules. Firms with greater η would then be firms that are more concerned about not satisfying the market rules. Suppose that η is distributed with support $[\underline{\eta}, \overline{\eta}]$ with cumulative distribution function $G(\eta)$ with no mass points.

Then, a firm with private information η will choose a price $P(\eta)$ and an amount of care of satisfying the market rules $\gamma(\eta)$, which, similarly to the analysis above, must satisfy $P(\eta) = c_0 + 2\alpha\gamma(\eta) + \eta(1 - 2\gamma(\eta))$.

Furthermore, the optimal price $P(\eta)$ for a firm with private information α is obtained by solving the following problem:

$$\max_P \gamma(\eta)[P - c_0 - \alpha\gamma(\eta) - \eta(1-\gamma(\eta))]\{[1 - F(P)]^{N-1} + M\}. \tag{12}$$

The first order condition of this problem reduces to

$$[1 - F(P)]^{N-1} + M - [P - c_0 - \alpha\gamma(\eta) - \eta(1-\gamma(\eta))](N-1)F'(P)[1 - F(P)]^{N-2} = 0$$

Substituting for $\gamma(\eta) = \frac{P(\eta)-c_0-\eta}{2(\alpha-\eta)}$ this reduces to

$$[1 - F(P)]^{N-1} + M - \frac{P - c_0 - \eta}{2}(N-1)F'(P)[1 - F(P)]^{N-2} = 0. \tag{13}$$

Assuming that $P(\eta)$ is strictly increasing in η (which is shown below), we have that $F(P(\eta)) = G(\eta)$ and, then, $F'(P(\eta))P'(\eta) = G'(\eta)$. Using this on (13) one obtains the following differential equation on $P(\eta)$,

$$P'(\eta)\{[1-G(\eta)]^{N-1}+M\}-(N-1)\frac{P(\eta)-c_0-\eta}{2}G'(\eta)[1-G(\eta)]^{N-2}, \tag{14}$$

which confirms that $P'(\eta)>0$, and which has as solution the equilibrium pricing policy as a function of the private information η,

$$P(\eta)=\frac{rM+\frac{c_0+\eta}{2}[1-G(\eta)]^{N-1}}{M+[1-G(\eta)]^{N-1}}, \tag{15}$$

using the condition that $P(\overline{\eta})=r$. The equilibrium γ as a function of η can then be obtained as

$$\gamma(\eta)=\frac{P(\eta)-c_0-\eta}{2(\alpha-\eta)}. \tag{16}$$

Note that the equilibrium prices are not a function of α and that for the firms that care most about satisfying the rules of the market, the equilibrium prices are similar to each other, $\lim_{\eta\to\overline{\eta}} P'(\eta)=0$. From the equilibrium conditions one can also obtain that the firm that has the greatest market share is the one that cares less about satisfying the market rules, i.e., the firm with the lowest η charges the lowest price. Note, however, that it is not necessarily the firm that cares most about satisfying the market rules that ends up investing most in satisfying the market rules, i.e., choosing higher γ. That is, $\gamma(\eta)$ is not necessarily increasing over the whole range of η. The intuition is that an increase in η also means an increase in the marginal costs, which the firm can reduce by decreasing γ. In particular, one can obtain $\lim_{\eta\to\overline{\eta}}\gamma'(\eta)=\frac{r-c_0-\alpha}{2(\alpha-\overline{\eta})^2}$ which is negative if $\alpha>r-c_0$. This means that it is possible that the firm that has the lowest price in a certain market realization is the one which invested more in satisfying the rules of the market (even though it is the one that cares less about the market rules). Note, however, that if the support of η is small enough we are guaranteed that γ is increasing in η in a significant range, as when the support of η converges to zero, the equilibrium converges to the equilibrium in the previous section (with the appropriate re-definition of c_0 and α), which means that $P(\eta)$ increases from the minimum price of the previous section to the reservation price r. We state these results in the following proposition.

Proposition 6: *If firms have price information about how much they care about satisfying the market rules, then a firm's price is increasing in how much it cares about satisfying the market rules. A firm's investment in satisfying the market rules is increasing in some range on how much it cares about satisfying the market rules, but can be decreasing for a different range. The firm that has the largest market share may not necessarily be the one that invested less in satisfying the market rules.*

Figure 1 illustrates the equilibrium functions $P(\eta)$ and $\gamma(\eta)$ for the example $c_0=.3,\alpha=2,N=$

$8, M = .5, r = 3$, and η distributed uniformly on $[1.1, 1.2]$, a case where $\gamma(\eta)$ is strictly increasing for the range of η. Figure 2 illustrates the equilibrium functions for the same example, except that $\alpha = 4$, a case where $\gamma(\eta)$ is non-monotonic.

In addition to the existence of private information on how much firms dislike not satisfying the market rules, it could also be that firms have private information about their base marginal costs of production, c_0. In that case, the equilibrium price and investment in satisfying the market rules for each firm would be a function of that firm's base marginal costs, c_0, and dis-utility of not satisfying the market rules, η, that is, $P(\eta, c_0)$ and $\gamma(\eta, c_0)$. In that case, the equilibrium price for a firm would be increasing in its base marginal cost, and the investment in satisfying the market rules for a firm would be decreasing in its base marginal cost. That is, firms with lower marginal costs invest more in satisfying the market rules. The intuition is that if a firm has a lower marginal cost it has more to lose if caught without satisfying the market rules. This result would then have that firms that are more likely to have greater market share are those with lower marginal costs (lower c_0), and less dis-utility for not satisfying the market rules (lower η). The first effect is positive from a social welfare point of view, while the second effect is negative. Which effect is more important depends on whether there is greater variation in c_0 or in η.

6. Dynamics

6.1. Introduction

In order to investigate the dynamics of firms investing to satisfy the rules of the market, consider a two-period variation of the model in Section 4 where L consumers who buy at the lowest price become loyal in the second period to the firm from which they bought in the first period. In the second period, the firm that had the lowest price in the first period has now $M + L$ loyal consumers, and firms compete on price over $1 - L$ consumers.

The punishment if a firm is caught not satisfying the market rules in one period is only any potential profit in that period. That is, if a firm is caught not satisfying the market rules only in the first period, it loses its first period profits (and only that amount). If a firm is caught not satisfying the market rules only in the second period it loses its second period profits (and only that amount).

We consider the case where if a firm is caught not satisfying the market rules in the first period, it can still operate in the market in the second period. We then discuss what happens if a firm that is caught not satisfying the market rules in the first period is not allowed to operate in the market in the second period. Firms discount the second period profits with the discount factor $\delta \in [0, 1)$.

6.2. Second Period

Consider the second period of this industry with N firms. Suppose that $N > 2$, such that if the firm that won the largest market share in the first period were taken out of the market there would still be competition in the market.[9] In this case, suppose that the firm that won the largest market share in the previous period charges a price equal to the reservation price r. Then, the competitors would behave as described in Section 4, but now with $N-1$ firms. The equilibrium strategies for each of those firms would then be characterized by

$$\gamma_2[P_2 - c(\gamma_2)]\{[1 - F_{2L}(P_2)]^{N-2}(1-L) + M\} = \pi_{2L} \tag{17}$$

where P_t and γ_t represent the price and investment in satisfying the market rules in period t, F_{2L} is the cumulative distribution function of the prices in the second period by a firm that has not won the largest market share in the first period, and π_{2L} is the second-period expected profit for a firm that has not won the largest market share in the first period.

Note first that, as obtained above, there is an optimal relationship between the price charged and the investment by a firm in satisfying the rules of the market, $P - c(\gamma) - \gamma c'(\gamma) = 0$, which leads to $\gamma[P - c(\gamma)] = \gamma^2 c'(\gamma)$. Note also that if a firm that has not won the largest market share in the first period charges a price of r, it will get a demand of only M. We can then obtain from (17) the second period expected profit for the firm that has not won the largest market share in the first period as $\pi_{2L} = \gamma^{r^2} c'(\gamma^r)M$.

If the firms that did not win the largest market share in the first period followed the strategies described in (17), the best response for the firm that won the largest market share would be to charge the reservation price r, as assumed, and invest γ^r in satisfying the rules of the market. This is because a lower price would lead to lower profits than what this firm can get by charging r, $\gamma^{r^2} c'(\gamma^r)(M + L)$, as $[1 - F(P)]^{N-1} < [1 - F(P)]^{N-2}$, and with the proposed equilibrium strategies the firms that have not won the largest market share in the first period are only able to get an expected profit of $\gamma^{r^2} c'(\gamma^r)M$.

Therefore, the strategies in (17) for the firms that have not won the largest market share in the first period, and the price equal to the reservation price r for the firm that has won the largest market share in the first period, constitute a second period market equilibrium. In fact, one can show that this is the only equilibrium with the same strategies for all the firms in the same situation

[9] The analysis of the case $N = 2$ is slightly different than the one presented below (Narasimhan 1988), but leads to the same messages as the ones presented here. With $N = 2$, the firm that did not win the largest market share in the first period can benefit from the higher prices charged by its competitor.

(all the firms without extra loyal consumers) as a lower price for the firm that has won the largest market would lead its competitors to even lower prices, which would then lead the firm with the largest market in the first period to charge the reservation price r.

From this one can then obtain that the equilibrium strategies of the firms that have not won the largest market in the first period satisfy

$$[1 - F_{2L}(P)]^{N-2} = \frac{\gamma^{r^2} c'(\gamma^r) - \gamma^2 c'(\gamma)}{\gamma^2 c'(\gamma)} \frac{M}{1-L}. \tag{18}$$

The equilibrium expected profits in the second period are $\pi_{2L} = \gamma^{r^2} c'(\gamma^r) M$ for the firms that have not won the largest market share in the first period, and $\pi_{2W} = \gamma^{r^2} c'(\gamma^r)(M + L)$, for the firm that has won the largest market share in the first period. Note that the firms that have not won the largest market share in the first period compete more aggressively (and invest less in satisfying the market rules) the greater is L. Furthermore, for L close to zero, those firms compete more aggressively (and invest less in satisfying the market rules) than in Section 4 above (given the same N).

From this we can see that a firm that won the largest market share in the first period has, as expected, a higher expected profit, and has an equilibrium strategy on the investment in satisfying the market rules that stochastically dominates (first order) the equilibrium strategy of the other firms.

The intuition is that the firm that won the largest market share in the first period has more to lose if caught not satisfying the market rules. This could be seen as an illustration of large companies being more careful in satisfying the market rules, as they may have more to lose if caught not satisfying those rules.[10] In fact, there is anecdotal evidence of larger firms investing more in legal departments, public relation offices, or activities that would make them less of a target of monitoring activities such as environmentally friendly activities or charitable and political contributions.[11]

[10] In the example above, in the second period the "large" firm ends up with a demand of $M + L$ while the firm with the lowest price ends with a demand of $M + 1 - L$. The "large" firm continues to be the firm with the largest market share if $L > 1/2$. Alternatively, one could construct models where the effects above go through, and the "large" firm continues to be the one with the largest market share in the second period for all parameter values.

[11] See, for example, the charitable contributions in the Bernard Madoff case, "Another View: The Madoff Scheme," *New York Times*, Dec. 15, 2008, P. J. Henning.

6.3. First Period

Consider now the first period decisions. The equilibrium strategies in the first period will involve again mixed strategies. The expected present value of profits for a firm can be written as:

$$\gamma(P - c(\gamma))M + \delta\pi_{2L} + [1 - F_1(P)]^{N-1}[\gamma(P - c(\gamma)) + \delta(\pi_{2W} - \pi_{2L})] = \pi_1 + \delta\pi_2 \qquad (19)$$

where $F_1(P)$ is the cumulative probability distribution of the equilibrium pricing strategy for each firm, and where π_t is the expected profit in period $t = 1, 2$.

From this one can obtain again that for a certain price P each firm chooses an investment in satisfying the rules of the market determined by $P - c(\gamma) - \gamma c'(\gamma) = 0$. One can then obtain that the equilibrium expected value of profits in the first period is $\pi_1 + \delta\pi_2 = \gamma^{r^2} c'(\gamma^r)M + \delta\pi_{2L}$, and that the equilibrium pricing strategy in the first period is determined by

$$F_1(P) = 1 - [\frac{\gamma^{r^2} c'(\gamma^r) - \gamma^2 c'\gamma}{\gamma^2 c'\gamma + \delta\gamma^{r^2} c'(\gamma^r)L} M]^{\frac{1}{N-1}}. \qquad (20)$$

This then yields that in the first period firms price more aggressively, and invest less in satisfying the market rules, than in the case in Section 4 above. This is because firms try to gain the second period prize of having been the firm with the largest market share in the first period. That is, in markets where there are complementary dynamic effects (a greater market share today leads to competitive advantages in the future) firms will be less careful in satisfying the rules of the market in the early periods. We summarize these results in the following proposition.

PROPOSITION 7: *In a dynamic two-period environment where early advantages carry on into the future, firms are more aggressive in not satisfying the market rules in the first period. In the second period the largest firm from the first period is more careful in satisfying the market rules.*

In this model we considered that even if a firm is caught not satisfying the market rules in the first period it can still operate in the second period. Now suppose that if a firm is found to have not satisfied the market rules in the first period, then it cannot operate in the second period. To simplify the analysis, suppose that in the second period there are always more than two firms in the market (potentially through more entry). In this case the expected present value of profits for a firm is now represented by

$$\gamma[M(P-c(\gamma))+\delta\pi_{2L}]+\gamma[1-F(P)]^{N-1}[P-c(\gamma)]+\gamma\delta(\pi_{2W}-\pi_{2L})[1-\int_{\underline{P}}^{P}\gamma(P)F'(P)\,dp]^{N-1}=\pi_1+\delta\pi_2 \tag{21}$$

for a range of prices and investments in satisfying the market rules, where $\pi_1+\delta\pi_2$ is the expected discounted value of profits, and $\gamma(P)$ is the equilibrium γ for each price P. This yields that for a certain price P each firm chooses an investment in satisfying the rules of the market determined by $[P-c(\gamma)-\gamma c'(\gamma)]\{M+[1-F(P)]^{N-1}\}+\delta\pi_{2L}+\delta(\pi_{2W}-\pi_{2L})[1-\int_{\underline{P}}^{P}\gamma(P)F'(P)\,dp]^{N-1}=0$. This means that in this case $P-c(\gamma)-\gamma c'(\gamma)<0$, which means that for each price P firms are now investing more in satisfying the market rules. This is expected, as now firms want to be more careful with respect to satisfying the market rules, as getting caught represents also losing the second period profits.[12] For this case one can also show that the expected present value of profits is now lower as firms caught do not earn the second-period profits, and firms price higher, as they may be able to win the largest market share in the first period without charging the lowest price.

7. Optimal Monitoring

This section considers the possible decision by a social planner on the monitoring levels on whether firms are complying with the rules of the market. We consider the model in Section 4, and restrict attention to the case in which monitoring can only be made contingent on the market share obtained by the firm, and not on the price charged by the firm. The idea is that prices may not be necessarily observed by the monitoring authority (potential for secret price cuts) while market shares (or overall profitability) may be observable. In the context of the model of Section 4 this means that the monitoring authority can monitor with different intensities the firm that won the largest market share (the firm with the lowest price) and the other firms. We denote the intensity of monitoring of the firm with the largest market share as m^H and the intensity of monitoring the other firms as m^L. One particular case is when $m^H=m^L$.

We consider the following timing. First, the monitoring authority commits to m^H and m^L, then the firms choose their prices and the intensity with which they comply with the market rules, and finally, monitoring takes place at the committed levels. At the end of this section we briefly discuss the case in which the monitoring authority cannot commit ex-ante to the monitoring levels.

In order to consider the different monitoring rules, we change slightly the notation of Section 4. We consider now that firms choose their marginal costs c (with higher marginal costs meaning

[12]This can be seen as related to managers making more long-term investments the further away they are from retirement (e.g., Dechow and Sloan 1991, Mizik 2010).

greater care in satisfying the market rules), which, together with the monitoring level m, determines the probability with which the firm is not found not complying with the rules of the market, $g(c,m)$. The probability $g(c,m)$ is increasing in the marginal costs c and decreasing in the monitoring level m.[13] Denoting the cumulative probability distribution of prices (the equilibrium is in mixed strategies with no mass points) as $F(P)$, the expected value of profits can be written as

$$[1-F(P)]^{N-1}g(c,m^H)(P-c)(1+M)+\{1-[1-F(P)]^{N-1}\}g(c,m^L)(P-c)M \tag{22}$$

which can be re-stated as

$$\pi = g(c,m^L)(P-c)M+(P-c)[1-F(P)]^{N-1}[g(c,m^H)(1+M)-g(c,m^L)M]. \tag{23}$$

In order to obtain sharper results we concentrate on the case in which $g(c,m)$ is linear in c and m, $g(c,m)=g_0+\beta c-m$.[14]

Consider first the optimal combination of prices and marginal costs for a firm. That is, what is the optimal marginal cost (how much to invest in satisfying the rules of the market) for each price P that is charged. Differentiating (23) with respect to c and making it equal to zero one obtains

$$[\beta(P-c)-g(c,m^L)][M+(1-F(P))^{N-1}]+(1+M)(1-F(P))^{N-1}[m^H-m^L]=0. \tag{24}$$

This equation allows us to make the following observations. First, if the monitoring level is the same for all firms, $m^L=m^H$, then this condition reduces to the same as that obtained in the previous sections, equation (10). Second, for the price equal to the reservation price, $P=r$, this condition is also the same as obtained in the previous sections, equation (10), as $F(r)=1$. Note then that at the price equal to the reservation price the degree to which a firm invests in satisfying the market rules is obtained by $\beta(r-c)-g(c,m^L)=0$, which leads to $c^r=\frac{\beta r-g_0+m^L}{2\beta}$. Third, if the monitoring intensity is higher for the firm that has the greatest market share than for the other firms, $m^H>m^L$, then a firm with a price P chooses to invest more in satisfying the market rules

[13]In what follows we assume that at the level of monitoring that is possible, $g(c,m)$ is bounded such that the probability of being caught not satisfying the market rules does not change too much with the monitoring level m. That is, it is not possible to apply infinite monitoring such that a firm that violates the market rules is always caught not satisfying those rules.

[14]There could also potentially be an effect of the interaction between a firm's investment in complying with the market rules and the monitoring level on the probability of a firm being caught. For example, if firms are very unlikely to be caught not satisfying the market rules, it could be that a greater monitoring level is more able to discern between the firms that are investing more and less in satisfying the market rules. However, the interaction may be the other way if most firms end up getting caught not satisfying the market rules.

(greater c) than what is obtained in Section 4. This effect is greater for lower prices, as for lower prices the firm is more likely to be the one with the greatest market share.

Substituting (24) into (23) one obtains $\pi = \beta(P-c)^2\{M + [1-F(P)]^{N-1}\}$ for all prices charged in equilibrium and $\pi = \beta(r-c^r)M$. This last equation yields that in this model the firms' equilibrium profits are independent of any difference between monitoring levels across firms with different market shares. The pricing strategy of each firm then has to satisfy

$$F(P) = 1 - [\frac{(r-c^r)^2 - (P-c)^2}{(P-c)^2} M]^{\frac{1}{N-1}} \tag{25}$$

which is independent of any difference between monitoring levels across firms with different market shares. That is, the cumulative distribution of the margins $P-c$ is independent of the difference among monitoring levels, but for each price P each firm is now "choosing" (investing in satisfying the market rules) a higher marginal cost c. Using (25) in (24) one can then obtain the relationship between the optimal price P and marginal costs c as

$$P = c + \frac{\beta(r-c^r)^2 - \sqrt{\beta^2(r-c^r)^4 - 4(1+M)\Delta(r-c^r)^2[g_0 + \beta c - m^L - (1+M)\Delta]}}{2(1+M)\Delta} \tag{26}$$

where $\Delta \equiv m^H - m^L$. Figure 3 illustrates the comparison of the relationship of price and marginal costs for the pairs with positive density for the cases where $\Delta = 0$ and $\Delta > 0$, showing that for the same price when $\Delta > 0$ firms invest more in satisfying the market rules, and have greater marginal costs. Figure 4 illustrates a comparison of the cumulative distribution function of the marginal costs for the cases of $\Delta = 0$ and $\Delta > 0$, showing that when $\Delta > 0$, firms invest more in satisfying the rules of the market. Figure 5 presents the cumulative distribution function of prices illustrating that when there is a difference in the monitoring levels, the equilibrium prices are higher.

Consider now the issue for the monitoring authority of whether to set a difference in the monitoring levels across firms with different market shares, that is, whether to set $\Delta > 0$. To see this consider that the monitoring authority is maximizing social welfare, with costs $T(m)$ of monitoring one firm at the level m, and that the social costs of firms not investing enough to satisfy the market rules are proportional to the expected quantity produced that could be violating the market rules at an exogenous level of monitoring $\overline{m}$, $k(1-g(c,\overline{m}))$. We assume $T', T'' > 0$, and focus on the case in which M is small. We also assume $\beta k > 1$, such that the monitoring authority prefers higher costs with more compliance with the rules of the market than lower costs and lower compliance with the market rules. The social welfare function can then be represented by:

$$S(m^L, \Delta) \;\; = \;\; r(1+NM) - E(c^{\min}) - E(c)NM - k[1 - g_0 - \beta E(c^{\min}) + \overline{m}]$$

$$-kNM[1 - g_0 - \beta E(c) + \overline{m}] - T(m^L + \Delta) - (N-1)T(m^L), \tag{27}$$

where $E(c^{\min})$ is the expected value of the minimum marginal cost in the market, and $E(c)$ is the expected value of the marginal cost of a given firm.

Now consider what is the effect on social welfare of increasing Δ when $\Delta = 0$, and under the condition that the firm is choosing the optimal level of m^L. This latter condition is

$$\frac{\partial S}{\partial m^L}_{|\Delta=0} = (\beta k - 1)[\frac{\partial E(c^{\min})}{\partial m^L} + NM\frac{\partial E(c)}{\partial m^L}] - NT'(m^L) = 0. \tag{28}$$

Taking then the derivative of $S(m^L, \Delta)$ with respect to Δ evaluated at $\Delta = 0$, using (28), one obtains,

$$\frac{1}{\beta k - 1}\frac{\partial S}{\partial \Delta}_{|\Delta=0} = [\frac{\partial E(c^{\min})}{\partial \Delta} - \frac{1}{N}\frac{\partial E(c^{\min})}{\partial m^L}] + NM[\frac{\partial E(c)}{\partial \Delta} - \frac{1}{N}\frac{\partial E(c)}{\partial m^L}]. \tag{29}$$

Define the margin at the reservation price $u^r \equiv r - c^r$, which as noted above is independent of Δ, and the general margin as $u \equiv P - c$. Then we can obtain the cumulative distribution of the margin as $F_u(u) = 1 - [\frac{u^{r^2} - u^2}{u^2}M]^{\frac{1}{N-1}}$, and the density by $F'_u(u)$, both independent of Δ.

Now, from (24) we can obtain c as a function of u as

$$c(u) = u - \frac{g_0}{\beta} + \frac{m^L}{\beta} + (1 - \frac{u^2}{u^{r^2}})\frac{1+M}{\beta}\Delta. \tag{30}$$

Consider the value of $E(c^{\min})$ and $E(c)$ for M being close to zero. For M close to zero, the cumulative distribution $F_u(u)$ converges to one, that is, firms are offering u close to the lowest value of u, $\underline{u} = \sqrt{\frac{M}{1+M}}u^r$, which converges to zero when M converges to zero. We have then that $\lim_{M\to 0} E(c^{\min}) = \lim_{M\to 0} E(c) = c(0)$. Therefore, we have $\lim_{M\to 0} = \frac{\partial E(c^{\min})}{\partial \Delta} = \lim_{M\to 0} \frac{\partial E(c)}{\partial \Delta} = \frac{\partial E(c^{\min})}{\partial m^L} = \lim_{M\to 0} \frac{\partial E(c)}{\partial m^L} = \frac{1}{\beta}$. Then, using this in equation (29), we obtain that $\lim_{M\to 0} \frac{\partial S}{\partial \Delta}_{|\Delta=0} > 0$, that is, the optimal Δ is strictly greater than zero.

This yields the expected result that firms that do well may be monitored more aggressively by the monitoring authority. This is reasonable as this has greater effect in providing incentives on firms to invest in complying with the rules of the market.

If the monitoring authority cannot commit to the monitoring levels prior to market competition, then the benefits on the incentives for firm behavior of monitoring more aggressively the firms with the greater market share would disappear. However, if the monitoring authority itself has the incentive of appropriating the greatest fines, the monitoring authority would then choose ex-post to monitor more aggressively the firm with the greatest market share.

8. Concluding Remarks

This paper investigates the question of how much firms decide to invest in satisfying the rules of the market, depending on its effects on costs and the monitoring technology. The paper shows how greater competition intensity may lead firms to invest less in complying with the market rules. This could be seen as a force for a social planner not to allow too much competition in a market. The paper also shows that in a dynamic environment, firms may invest less in satisfying the market rules in the early periods, but that, in the later periods, firms that did well in the past may now become more careful in satisfying the rules of the market. The paper also illustrates how a monitoring authority may benefit from choosing different monitoring levels for different firms depending on their market shares.

The analysis above focused on the case in which a firm, when found to be not satisfying the market rules, loses all its profit. The main messages of this model can also be obtained if the penalty of not satisfying the market rules is proportional to the profit obtained. In that case a firm also chooses to invest less in satisfying the market rules with more competition, as in that case there is also less to lose if caught not satisfying the market rules. If the penalty depends in the extent to which a firm violates the market rules, however it is defined, then one may obtain in some cases that competition does not affect the degree of investment in satisfying the market rules. However, if there is some uncertainty as to how the monitoring authority evaluates the extent to which a firm violates the market rules then, again, if there is limited liability and sufficient uncertainty, the main messages presented above would still be present.

The point illustrated by this paper could also be seen as relevant in settings where a principal offers an incentive scheme to agents. Steeper incentive schemes could then potentially lead agents to invest less in satisfying the rules of the market, which could be seen as a cost to the principal. Investigating these effects in greater detail could be interesting for future research.

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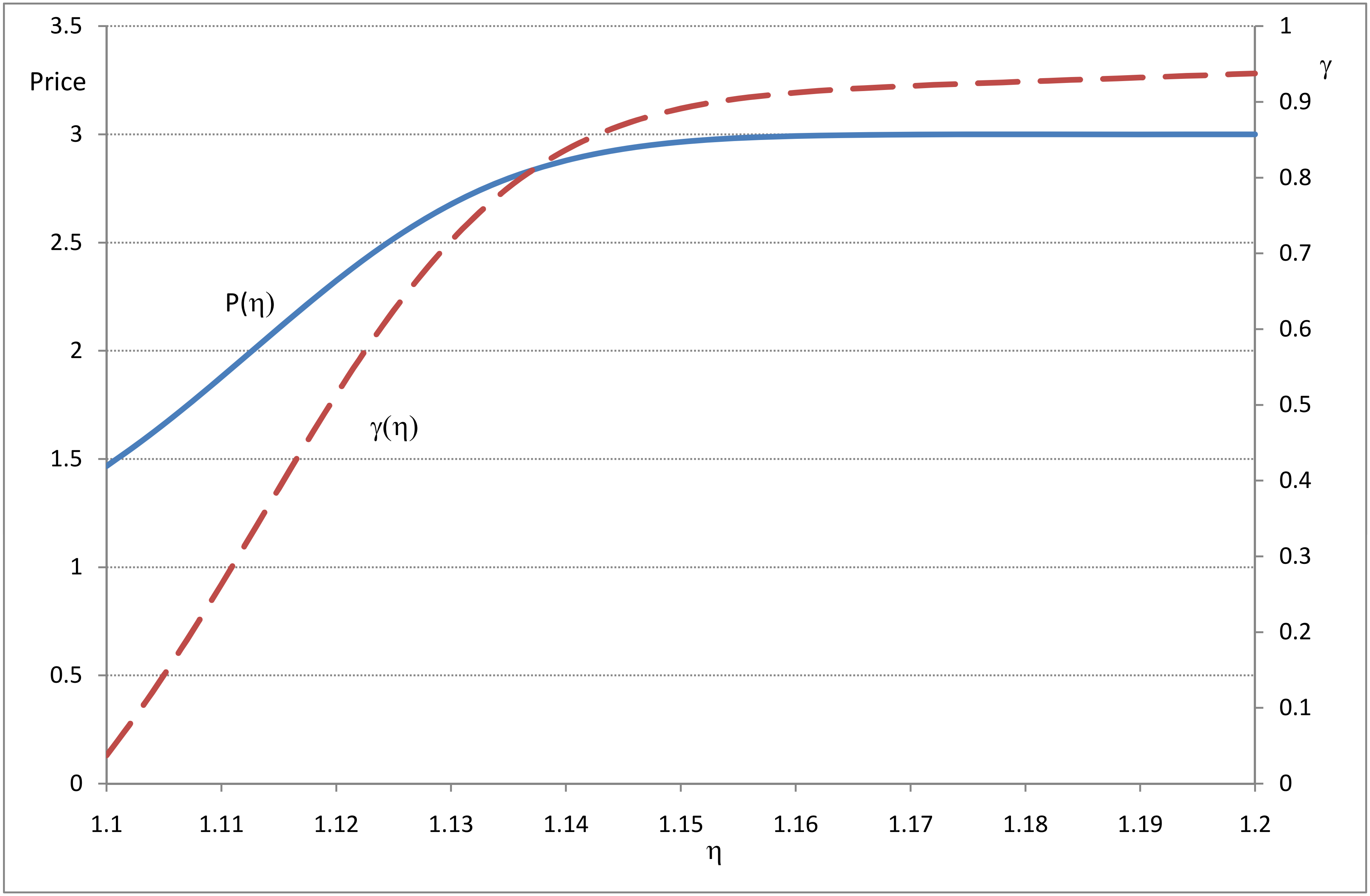

Figure 1: Equilibrium price and investment in satisfying market rules under private information for example in text with α=2.

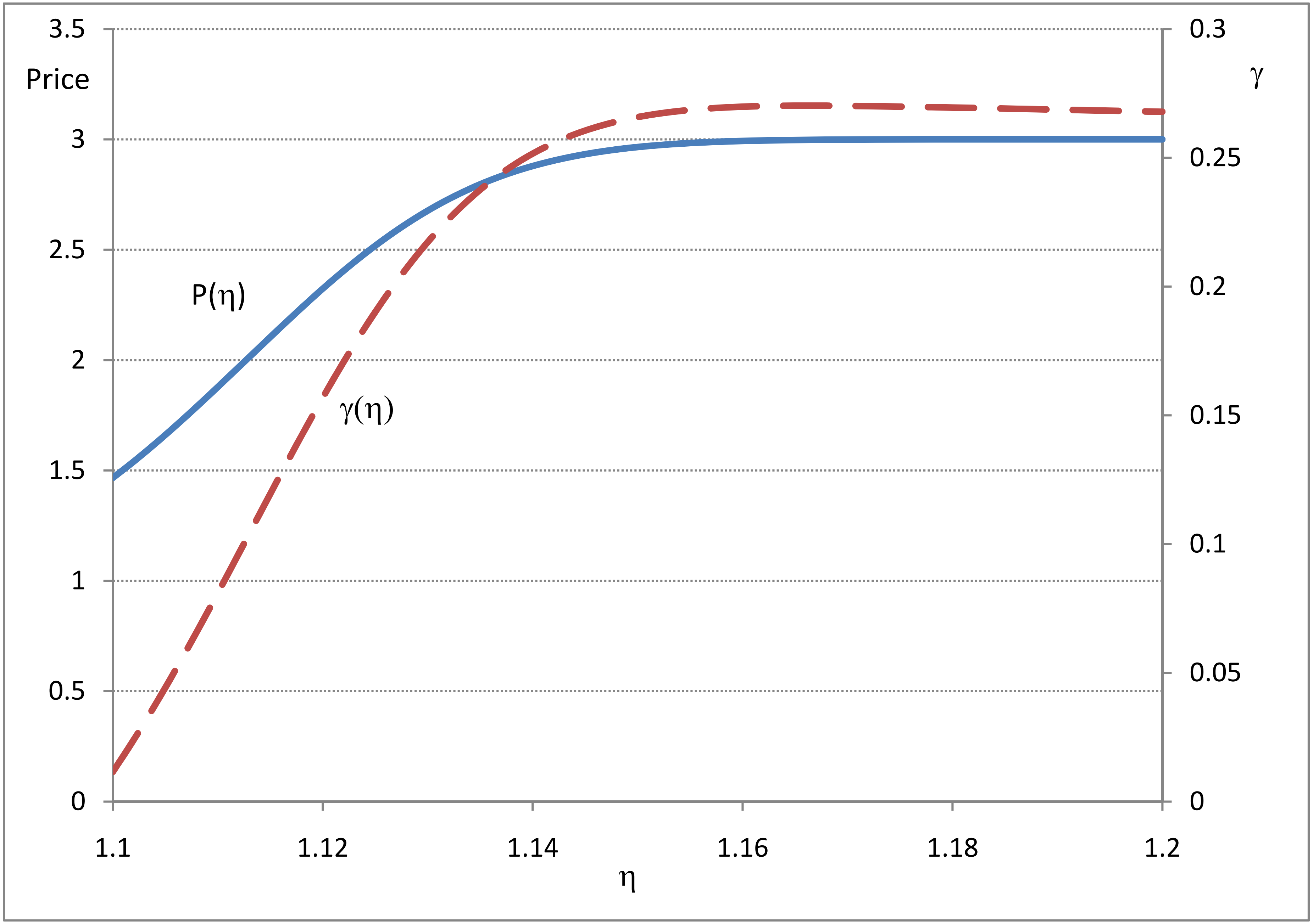

Figure 2: Equilibrium price and investment in satisfying the market rules under private information for example in text with α=4.

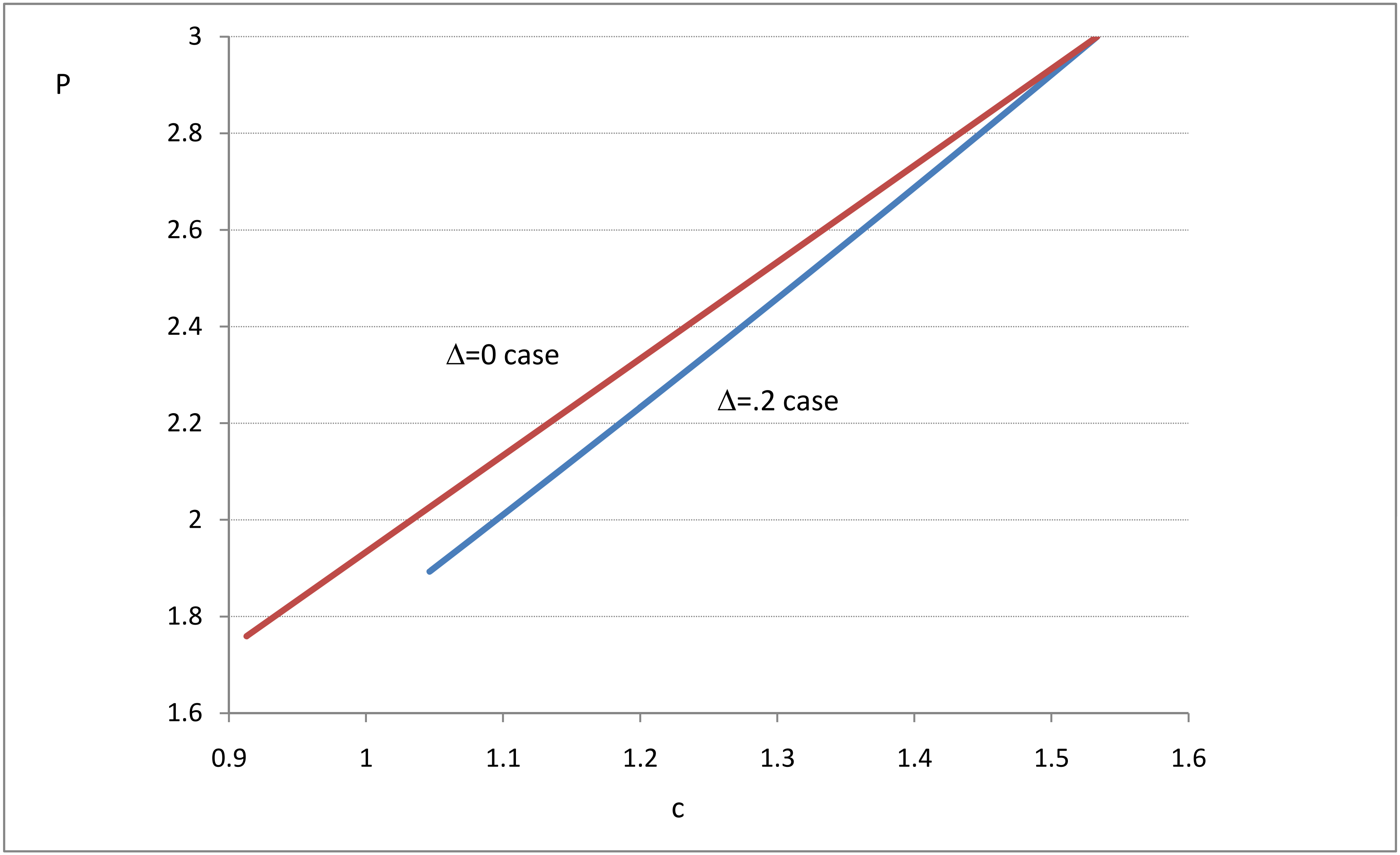

Figure 3: Relation of optimal price and marginal cost for cases with $\Delta=0$ and $\Delta=.2$, for M=.5, r=3, $g_0=.3$, $\beta=1.5$, $m^L=.4$, and N=4.

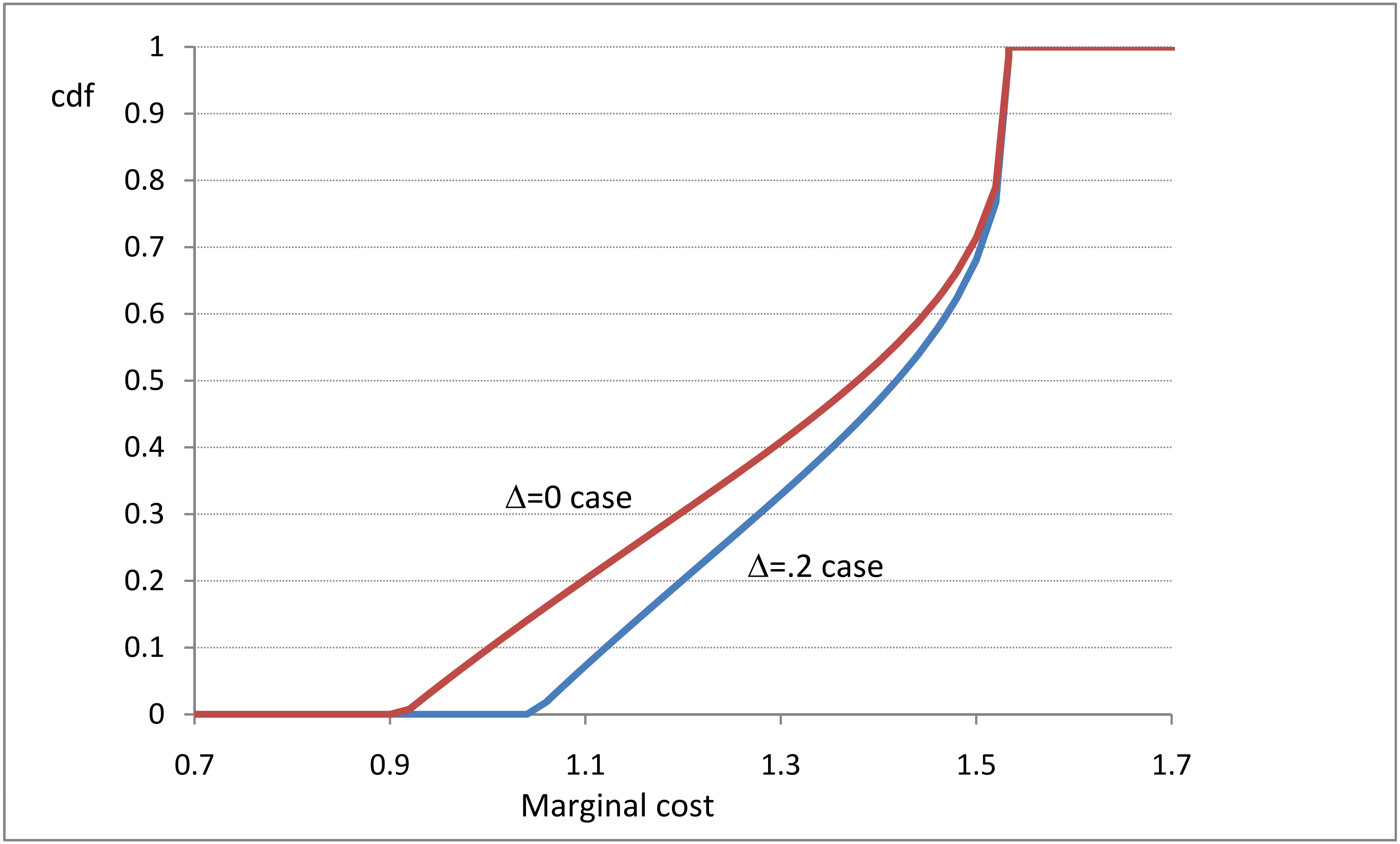

Figure 4: Cumulative distribution function of marginal cost for cases with Δ=0 and Δ=.2, for M=.5, r=3, g_0=.3, β=1.5, m^L=.4, and N=4.

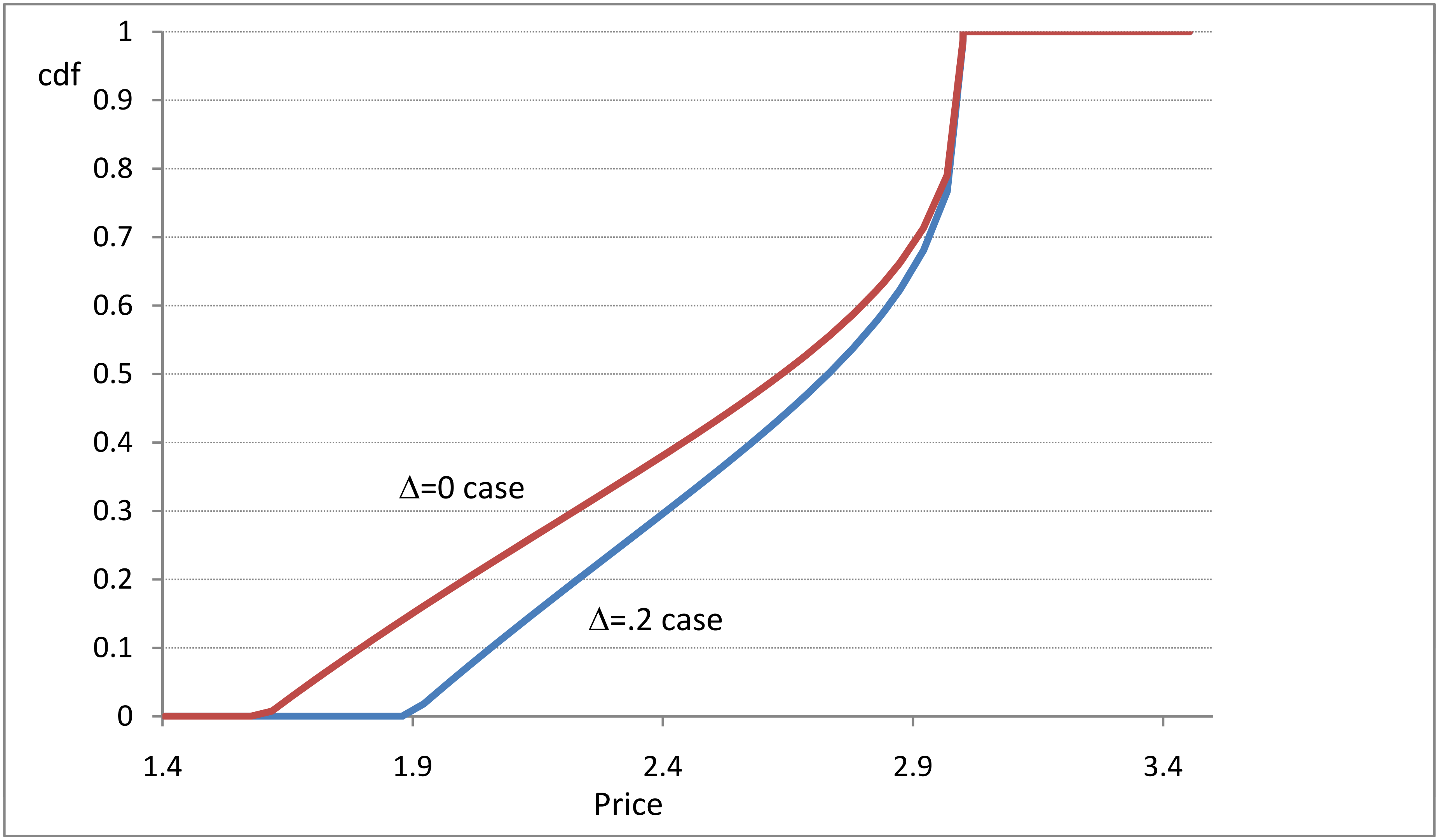

Figure 5: Cumulative distribution function of price for cases with Δ=0 and Δ=.2, for M=.5, r=3, g_0=.3, β=1.5, m^L=.4, and N=4.