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A Theoretical Foundation of the Porter Hypothesis

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Abstract

This note shows that, by reducing agency costs, an environmental regulation may enhance pollution-reducing innovation while at the same time increasing firms'private benefit.

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1 Introduction

The so-called Porter hypothesis (Porter 1995, Porter and van der Linde 1995) asserts that firms can benefit from environmental regulations. It argues that well-designed environmental regulations stimulate innovation which, by enhancing productivity, increases firms'private benefits. As a consequence, environmental regulations would not only be good for society, they would also be good for firms. This point of view has found a receptive audience among policy makers and the popular press (e.g. Gore 1992). Yet it has been heavily criticized by economists (Palmer, Oates and Portney, 1995, among others) for a lack of rigorous foundations. In particular, the following issue is often raised: why is regulation actually needed for firms to adopt profit-increasing innovations?

This note provides an answer to this question. It formalizes Porter and van de Linder's idea that regulation creates external pressure to overcome organizational inertia. This is done in a stylized model of renegotiation. Following Porter, it is assumed that less polluting technologies are also more productive. Productivity is a division manager's private information. The firm must therefore offer rents to reward truthful report of high productivity. The possibilities of renegotiation prevent the firm from reducing these rents by distorting production. In this context, regulation may help because, unlike the firm, the regulator can commit to distort production to the socially efficient level so that reporting unproductive and polluting technologies becomes less attractive. Note that the regulator's ability to commit is not *ad hoc* in our model, but directly results from its objective function.

2 The model

Consider three agents in this economy: a firm F (or its shareholders), a division manager M (referred to as he), and a benevolent regulator R (referred to as she). M implements and manages a new production plant under F's hierarchical authority.

The process of founding a production plant starts with an initial investment I in R&D. The outcome of the R&D program is a technology with constant production cost $\alpha \in \{l, h\}$ with $\Delta\alpha = h - l > 0$, which is M's private information. The probability of $\alpha = l$ is $p(I)$ with $p(0) = 0$, $p' > 0$, $p'' < 0$ and $p(\infty) = 1$. For simplicity, we assume that the technology l causes no environmental damage, whereas the technology h causes damage $d(q)$ with q the production level. We assume that $d(0) = 0$, $d'(q) > 0$ and $d''(q) \geq 0$, for every $q > 0$.

The good is then produced. M incurs the cost αq and is paid w yielding an utility is $w - \alpha q$. F enjoys benefit $B(q)$ from q units produced with $B(0) = 0$, $B' > 0$ and $B'' < 0$.[1] Its utility is $B(q) - w - I$. The total private surplus generated by production is $\pi(q, \alpha) - I = B(q) - \alpha q - I$. It is maximized at the (ex post) *private* efficient level q^*_α.

The third agent, R, regulates the firm's activity by fixing an upper bound on environmental damage $\bar{d}$ (such as emission permits), thereby eventually limiting output. R maximizes the social welfare defined by the total private surplus minus environmental damage,[2] that is $\pi(q, h) - d(q)$ (respectively, $\pi(q, l)$) if $\alpha = h$ ($\alpha = l$) which is maximized at the (ex post) *social* efficient level $q^o_h < q^*_h$ ($q^o_l = q^*_l$).

3 Without environmental regulation

F and M play the following **unregulated game**:

1. F invests I and offers a contract $\{w_\alpha, q_\alpha\}_{\alpha=l,h}$ to M who accepts or refuses.

2. M observes α.

3. M sends a report $\hat{\alpha} \in \{l, h\}$ to F.

4. F offers a new contract (w, q). If M accepts, this new contract becomes the outstanding contract. If not, the initial contract remains in force.

5. F makes a production decision and pays M.

Furthermore, we assume that M can quit the game at any stage, in which case he gets his reservation utility normalized to zero. This assumption is consistent with standard employment contracts. It implies that M has limited liability: he cannot suffer from a loss of utility below the level achieved without producing any output (see Sappington, 1993, for a formal definition).

Let us denote $\{I^U, \{w^U_\alpha, q^U_\alpha\}_{\alpha=l,h}\}$ the perfect Bayesian equilibrium allocation of this game. There is no loss of generality in considering initial contracts that are not renegotiated along the

[1] B(q) could be interpreted as revenues from marketing the product or as the benefit derived from producing internally an intermediate input.

[2] We are only concerned by environmental regulation. We exclude regulations based on other market failures such as, for instance, natural monopoly positions. Therefore, we do not include the consumer's surplus into the regulator's objective function.

equilibrium path, that is, renegotiation-proof contracts. Therefore, we look for contracts that are not renegotiated in stage 4 along the equilibrium path.

In this framework, it is easy to show that the equilibrium renegotiation-proof contract must be separating and lead to production levels that maximize, *ex post*, the total private surplus i.e. $q_\alpha^U = q_\alpha^*$ for $\alpha = l, h$. Indeed, any other production schedule would imply that it is possible for F to propose a new contract at stage 4 that increases his surplus without reducing M 's utility for any realisation of α. This proposal will be accepted by M.[3]

The equilibrium investment I^U and transfers $\{w_\alpha^U\}_{\alpha=l,h}$ are the solution to:

$$\begin{array}{lll} \max_{I,\{w_\alpha\}_{\alpha=l,h}} & E[B(q_\alpha^*) - w_\alpha | I] - I & \text{subject to} \\ & w_l - l q_l^* \geq 0 & LL_l \\ & w_h - h q_h^* \geq 0 & LL_h \\ & w_l - l q_l^* \geq w_h - l q_h^* & IC_l \\ & w_h - h q_h^* \geq w_l - h q_l^* & IC_h \end{array}$$

The first two constraints, LL_l and LL_h, represent limited liability constraints that forbid F to pay M less than its cost. Note that these constraints guarantee that M's *ex ante* participation constraint is satisfied. The two additional constraints, IC_l and IC_h, represent incentive compatible constraints, stipulating that M prefers to report truthfully its private information.

It is easy to show that the binding constraints are LL_h and IC_l. To extract more surplus, F would like to set M on his limited liability constraint. However in such a case, M would have an incentive to report a high-cost when the cost is actually low. In order to induce M to reveal truthfully his cost, F has to increase the wage paid for a low-cost technology up to the point where the incentive constraint IC_l is binding. Transfers are, therefore:

$$w_h^U = h q_h^*,$$

$$w_l^U = \Delta\alpha q_h^* + l q_l^*.$$

F concedes informational rent $\Delta\alpha q_h^*$ when the technology is l to induce truth-telling. Investment I^U is defined by the marginal benefits to investment for F:

$$p'(I^U)(\pi(q_l^*, l) - \Delta\alpha q_h^* - \pi(q_h^*, h)) = 1.$$

We now introduce the regulated game.

[3] This result is formally shown in Beaudry and Poitevin (1995). Notice that renegociation-proofness implies ex post private efficiency as well when M makes the renegociation offer.

4 With environmental regulation

F, M and R play the following **regulated game**:

1. F invests I and offers a contract $\{w_\alpha, q_\alpha\}_{\alpha=l,h}$ to M who accepts or refuses.
2. M observes α.
3. M sends a report $\hat{\alpha}$ to F and R.
4. R sets an upper bound on damage $\bar{d}$.
5. F offers a new contract (w, q). If M accepts, this new contract becomes the outstanding contract. If not, the initial contract remains in force.
6. F makes a production decision and pays M.

This game differs from the unregulated game in two aspects. First, the report sent by M is made public.[4] In other words, at stage 3 M sends the same report $\hat{\alpha}$ to F and R. Second, at stage 4, after M has sent his report, R offers a take-it-or-leave-it upper bound on environmental damage $\bar{d}$ which, in turn, defines an upper bound on production depending on the technology α. If F refuses to conform to the regulation, no production is performed. M gets his reservation utility, whereas F ends up loosing its initial investment. As in the unregulated game, we assume that M can quit the game at any stage.

Let us denote $\{I^R, \{w^R_\alpha, q^R_\alpha\}_{\alpha=l,h}\}$ the perfect Bayesian equilibrium allocation of the regulated game. A dominant strategy for R is to set $\bar{d} = d(q^o_h)$. It ensures that the production level will be q^o_h (respectively, q^*_l) when the technology is h (l). Indeed, in the renegotiation subgame, F can benefit from renegotiating any other production level. He would, therefore, do it by proposing q^o_h (q^*_l) when the technology is h (l). Hence, R is sure to obtain her preferred production level for each $\alpha = l, h$ and therefore maximizes her expected utility.

Again, we restrict our attention to renegotiation-proof contracts which must be separating. To be renegotiation-proof given R's strategy, the production should always include production levels $q^R_h = q^o_h$ and $q^R_l = q^*_l$. Investment and transfers solve a maximization program similar to 3 except that q^*_h is replaced by q^o_h. Transfers are:

$$w^R_h = hq^o_h,$$

[4] This assumption is not crucial in our very simple model but it allows for generalizations to more general settings.

$$w_l^R = \Delta\alpha q_h^o + l q_l^*.$$

Investment is defined by

$$p'(I^R)(\pi(q_l^*, l) - \Delta\alpha q_h^o - \pi(q_h^o, h)) = 1.$$

5 Comparison of the two outcomes

By distorting the output when the technology is h to the social efficient level, regulation 1) reduces informational rents, and 2) decreases the private surplus when the technology is h. These two effects have an unambiguous positive impact on investment in R&D as the marginal benefit to investment increases: $I^R > I^U$. However, the two effects have opposite impacts on F's expected payoff. Since the total effect is ambiguous, we characterize tractable sufficient conditions for a net positive effect.

Since I^R maximizes F's expected payoff in the regulated game then $E[B(q_\alpha^R) - w_\alpha^R | I^R] - I^R \geq E[B(q_\alpha^R) - w_\alpha^R | I^U] - I^U$. A sufficient condition for F's expected payoff to be higher in the regulated game is $E[B(q_\alpha^R) - w_\alpha^R | I^U] \geq E[B(q_\alpha^U) - w_\alpha^U | I^U]$, which simplifies to

$$\frac{p(I^U)}{1 - p(I^U)} \Delta\alpha \geq \frac{\pi(q_h^*, h) - \pi(q_h^o, h)}{q_h^* - q_h^o}. \tag{1}$$

Equation 1 isolates the two opposite effects of regulation on F's expected payoff. The second factor in the left-hand side of 1 represents savings in rent. The right-hand side quantifies the loss of profit. Equation 1 suggests that the Porter hypothesis is likely to be satisfied when the following conditions are met. First, the likelihood of obtaining a more productive and cleaner technology is high. Second, the marginal productivity gain induced by more productive technologies is high. Third, regulation has a relatively small impact on the profit generated by the polluting technology compared to its effect on output decision.

We keep simplifying 1. Notice first that $\pi(q, h)$ concave and $q_h^* > q_h^o$ imply $\pi(q_h^*, h) - \pi(q_h^o, h) \leq \frac{\partial \pi(q_h^o, h)}{\partial q}(q_h^* - q_h^o)$. Second, recall that q_h^o satisfies $\frac{\partial \pi(q_h^o, h)}{\partial q} = d'(q_h^o)$. Taking into account these two points leads to:

$$\frac{p(I^U)}{1 - p(I^U)} \Delta\alpha \geq d'(q_h^o). \tag{2}$$

It is easy to find realistic parameters that satisfy 2. Indeed, fixing other parameters, there always exist marginal environmental damages sufficiently low such that 2 holds. We can now formulate our result.

Proposition *Environmental regulations can increase simultaneously investment in R&D and firms' expected profit.*

6 Concluding remarks

To conclude, we briefly discuss how the result could be extended to encompass other forms of regulations. First, suppose that the regulator imposes end-of-pipe treatments that translate into supplementary marginal costs $c > 0$. The unit cost of producing with the polluting technology becomes $h+c$. This moves the privately efficient output to the socially efficient level q_h^o, which lowers rents to $\Delta\alpha q_h^o$. Second, assume that production is taxed when the technology is h. This Pigouvian tax raises the marginal cost to $h+\tau$ so that, again, the privately efficient output coincides with the socially efficient one, thereby reducing rents to $\Delta\alpha q_h^o$. Notice that these two regulations increase the firm's costs in equilibrium, and, therefore, have a more severe impact on the profit generated by polluting technologies. Consequently, they are less likely to increase the firm's expected payoff.

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