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Remarks on Environmental Regulation, Firm Behavior and Innovation*

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Résumé / Abstract

L'hypothèse de Porter veut qu'une réglementation environnementale bien conçue encourage l'innovation et renforce la compétitivité des entreprises. Ce cahier, qui fait suite à l'invitation à participer à un récent atelier financé par la Environmental Protection Agency des États-Unis, résume la recherche théorique récente se rapportant à la validité de cette hypothèse et formule des recommandations visant à améliorer les réglements existants.

The Porter Hypothesis says that well-designed environmental regulation should trigger innovations and enhance the competitiveness of firms. This paper, which follows the invitation to participate at a recent workshop financed by the Environmental Protection Agency in Washington, summarizes theoretical findings concerning this Hypothesis and makes recommendations to improve existing regulation.

Mots Clés : Réglementation environnementale, innovation, failles organisationnelles

Keywords: Environmental regulation, innovation, organizational failure

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"The future is not what it used to be."
[Paul Valéry]

1. Introduction

Environmental regulation has a relatively long history. In his provocative book on technological innovation in the Middle Ages, for instance, Gimpel (1975) tells of a Royal decree of 1307 forbidding the use of sea coal in the London area. This type of coal was extracted just below the surface of some seashore areas in Durham and Northumberland counties and was abundant in those days. Its energetic performance was rather poor by modern standards; its smoke smelled badly and entailed significant health hazards. However, substitutes to sea coal, namely charcoal or higher-quality coal coming from Scotland, were rather expensive. A special enforcement agency had therefore to be created, in order "to find out all individuals burning sea coal in the city or its surroundings, to impose large fines on them right away, and to destroy their ovens in case of repeated offense." In another story, on September 7th, 1366, the French Parliament ruled that slaughter houses and tanneries be located on the Seine river downstream of Paris. Brewers were amongst the most vocal supporters of this decree, for slaughter houses and tanneries strongly degraded water, their main input. Each year then, about 250,000 animals were killed in Paris; tanning and butchering accounted for hundreds of tons of hazardous organic waste being thrown in the river. The new rule was thus well received by the population in general, although it affected negatively the production of slaughter houses and tanneries (that were crucial to virtually all urban economies in those days) by sensibly raising their transportation costs.

These examples illustrate two major points that remain largely uncontroversial amongst economists and environmental policy makers. First, the purpose of environmental regulation is to correct for negative externalities that decrease social welfare. Secondly, environmental regulation would usually impose costs on someone (usually the polluter).

The last decade, however, has seen these assertions face a mounting challenge. The initial proponents of an alternative view of environmental regulation came from the applied field of business policy. Their perspective has been most clearly and forcefully summarized in the work of Professor Michael Porter and is now known as the Porter hypothesis [Porter (1996), Porter and van der Lind (1995)]. According to it, environmental regulation can (and should) also

be seen as an industrial policy instrument aimed at increasing the competitiveness of firms, the underlying justification for this statement being that well-designed environmental regulation could force firms to seek innovations that would turn out to be both privately and socially profitable. Such an assertion is of course quite appealing to policy makers, for it suggests that environmental regulation could be win-win, i.e. that *all* parties could possibly benefit from it, *including* those responsible for creating negative externalities.

There are many examples that currently support the Porter hypothesis. The success of 3M's Pollution Prevention Pays program, for instance, has been widely publicized: between 1975 and 1992 this program triggered 3,000 pollution-preventing projects that lead to savings of the order of $530 million.[1] Less well-known but equally suggestive are the cases of Eka-chimie and Ciment St-Laurent, two Québec-based firms [Lanoie and Tanguay (1998)]. The former, a 75-employee firm, produces sodium chlorate. In recent years it amended significantly its production process in order to reduce water and energy consumption and decrease expenses on the mandatory treatment of effluents. Those changes costed $900 thousand but lead to immediate savings of $600 thousand in the treatment of effluents, of $2 million a year in energy consumption and of $500 thousand per year in production itself. The latter is a concrete factory that employs 200 people. It recently substituted used tires for coal in its ovens. Total cost of this action is evaluated at $600 thousand a year, but savings from the purchase of tires instead of coal amount to $1.1 million per year.[2]

Despite the abundance of such cases that confer it some plausibility, however, the Porter hypothesis still lacks theoretical foundations that would clarify its scope and convince the critics. The main objection that needs to be met is summarized in the economist's well-known maxim: "There is no free lunches." Accordingly, innovation itself is not free, and if one prices managerial time and all other inputs correctly at their opportunity cost, it should become clear that putting stronger environmental requirements on polluting firms generally increases their production cost more than their revenue [see, for example, Palmer, Oates and Portney (1995)]. There can be notable exceptions, of course: stricter environmental regulation obviously benefits environmental consultants and lawyers, as well as developers of green technologies; it might also

[1] ELI (1999) presents other examples and a summary of some empirical studies relating to the Porter hypothesis.

[2] To conclude rigorously that these innovations truly brought positive net social benefits, however, some general equilibrium analysis would be necessary.

make a few polluting firms better off *ex post*, either by luck or by making them be the first ones to move ahead on adopting some new process, technology or product. But success stories and win-win situations are certainly not the rule.

At this point, it seems that no compelling theory in favor of the Porter hypothesis will come from avoiding altogether the paradigm and discourse of neoclassical economics. A more fruitful program rather consists in opening up some of the field's well-known "black boxes", following and refining the advances of mainstream economics on relevant topics such as innovation [Rosenberg (1982)] or the management of the firm [Milgrom and Roberts (1992); Gibbons (1998); Tirole (1999)]. In our initial joint work on environmental economics, Landis Gabel and I have repeatedly emphasized this approach [Gabel and Sinclair-Desgagné (1993; 1994; 1995)]. This paper presents and extends the results obtained so far that seem most useful for a better understanding of the Porter hypothesis and the consequent improvement of environmental regulation.

This presentation unfolds as follows. The next section focuses on current justifications for the existence and pervasiveness of low-hanging fruits, i.e. of cheap incremental innovations that firms just see after facing some pressure. Section 3 deals with innovations that specifically reduce the risk of a major environmental accident; those innovations deserve special attention because they relate to *nondeterministic* environmental externalities whose elimination might therefore be hard to value. Section 4 is devoted to radical innovations, which I believe to be the ones the Porter hypothesis mainly refers to. Section 5 contains concluding remarks concerning environmental regulation.

2. Low-hanging fruits

There seems to be anecdotal evidence that low-hanging fruits are abundant. In addition to the 3M case of the introduction, another illustration of this is provided, for instance, by the eighteen-month project run by the Centre for the Exploitation of Science and Technology in the United Kingdom, in order to enhance waste reduction and the use of cleaner technologies: in total the 11 participating companies saved more than £11 million a year, mostly from simple changes in processes which reduced inputs of water, energy and raw materials.

Standard neoclassical-economics models, however, do not support the systematic presence of low-hanging fruits. The reason is that, in these models, firms are perfect and never

fail to implement a profit maximizing strategy. Few environmental economists have so far attempted to relax this assumption. *Yet it seems inconsistent to keep assuming that markets are imperfect while firms are not.* Furthermore, the modern economic theory of the firm now offers helpful ideas for capturing organizational failures in a rigorous, non-adhoc way.

Once it is accepted that firms do not act as single-minded omniscient entities, it is not hard to cope with low-hanging fruits. Multi-person units may fail for a variety of reasons which relate to either *incentive* or *coordination problems*. Failures of the former type have so far received the most attention and are now well understood. In their seminal paper on the multitask principal-agent problem, for instance, Holmström and Milgrom (1991) show that ill-designed compensation packages and difficulties in performance assessment can draw a manager's attention away from certain tasks. This provides a rationale for one natural explanation of low-hanging fruits, which invokes sudden shifts in employees' attention towards environmentally-friendly activities. Models like the one studied in Sinclair-Desgagné (1994) also capture some features of centralization that can lead a firm to momentarily overlook some good business opportunities.

Several interesting principles for the design of environmental regulation emerge from these analyses. Most importantly, environmental regulators should add to their traditional set of instruments - pigouvian taxes, quotas, tradeable pollution permits, command-and-control systems - tools that pierce the corporate veil, such as corporate liability or mandatory standards for environmental management systems. This might not only decrease the cost of enforcement of and compliance with environmental regulation, it is also possible that the instruments deployed by the regulator enhance the firm's own internal incentive system.[3] In the latter case, we would have a win-win situation.

Low-hanging fruits can also arise from ex ante coordination failures within the firm. Coordination is generally achieved through communication and habits. Several models now capture communication problems that result in systematic errors and losses [see Sah and Stiglitz (1986); Radner (1992); Bolton and Dewatripont (1994)]. These models suggest that regulatory requirements on information production can have a significant impact on a firm's operations,

[3] The latter is an original idea that could be inferred from Segerson and Tietenberg's (1992) work, for instance. It needs to be examined further.

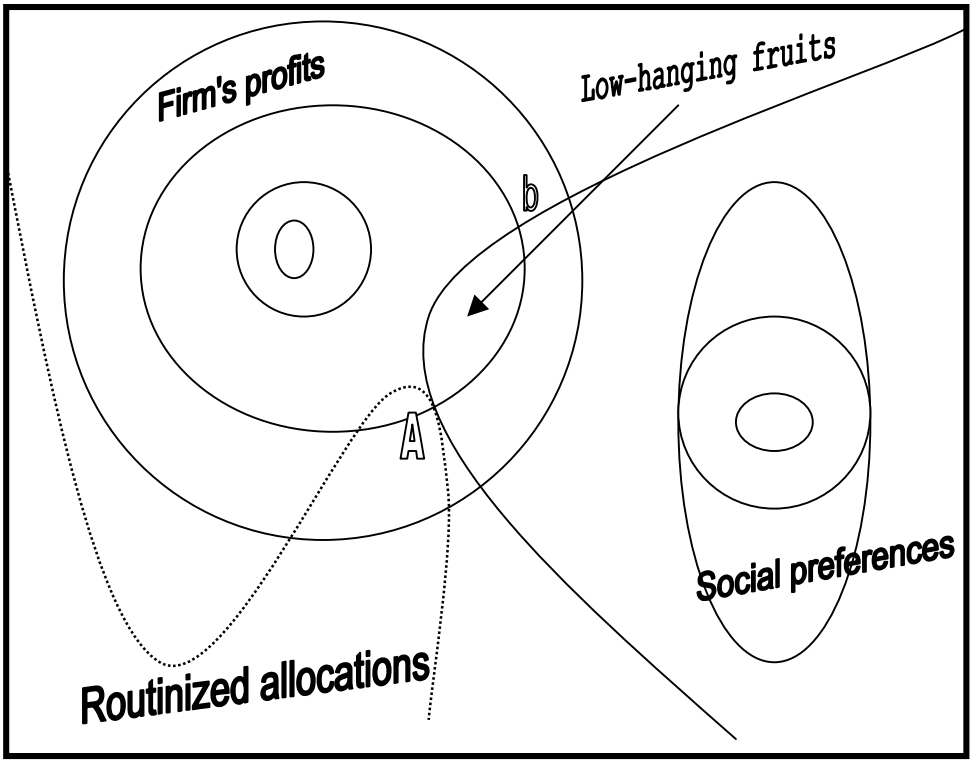
leading to a profitable harvest of low-hanging fruits.[4] The other type of coordination failure, that due to habits which keep a firm away from the global optimum, has recently been explored by Gabel and Sinclair-Desgagné (1998; 1999).

The fact that firms' decisions are constrained by production habits is well-documented. According to Cyert and March (1992), for instance, "The way in which the organization searches for alternatives is substantially a function of the operating rule it has. (…) The organization uses standard business procedures and rules of thumb to make and implement choices. In the short run these procedures dominate the decisions made." By forcing a firm to reconsider its actual processes and reengineer its existing routines, stricter environmental regulation might actually bring the firm closer to its own private optimum. This situation is illustrated in figure 1.

This figure depicts the level curves of two hills corresponding respectively to the firm's profits and to social preferences over the firm's production. The fact that the summits do not coincide means that there is some externality generated by the firm. Assume that the firm initially optimizes but over the one-dimensional locus indicated by the dotted curve. This locus represents a routine, in the sense that picking a point on it determines *without further deliberation* how much of the elementary inputs shall be used. The regulator, who does not presumably have better knowledge nor optimization capabilities than the firm, would seek to implement point A. One can see that, if the firm thereby revises its current routine, then there is a win-win region inside the two arcs starting at point A and meeting at *b* where both the firm and society could be made strictly better off. This captures the argument that low-hanging fruits are often found when environmental regulation pushes the firm to revise carefully its current processes and methods.

[4] This again needs to be checked more carefully.

Figure 1. Routine-induced low-hanging fruits



Most economists will probably remain unsympathetic to this type of illustration, because it seems to rely on firms being systematically ignorant of production opportunities and improvements. The illustration, however, does not depart from the standard framework of optimization; it simply takes seriously the fact that the elements of a firm's choice set, or its inputs, *always* sit on more basic, elementary, often unconscious ones. One rationale for this was formulated some time ago by Alfred North Whitehead and runs as follows:

> "it is a profoundly erroneous truism, repeated by all copy-books and by eminent people making speeches, that we should cultivate the habit of thinking of what we are doing. The precise opposite is the case. Civilization advances by extending the number of operations which we can perform without thinking about them."

This rationale was recently formalized within a standard optimization framework [see Sinclair-Desgagné and Soubeyran (1999)].

An important implication of the latter line of arguments is finally that reengineering, defined as tracing down elementary inputs and bunching them back into better routines, always delivers low-hanging fruits. However, reengineering can also be quite costly, so that the firm might not (ex ante or ex post) find it worth undertaking. Part of this cost can be attributed to basic resistance to change within the firm [Rumelt (1995)]. Some of the cost might also come from the fact that there are plenty of routines in the organization and that these can be complementary, which implies that amending just one of them would be unwise and leaves the firm with no choice but to undergo large-scale reforms [Milgrom and Roberts (1994)]. One goal of environmental public policy could be to alleviate those cost factors, through such means as subsidized training and the diffusion of best business practices.

3. Risk reduction

Environmental regulation seeks not only to correct for ongoing negative externalities but also to prevent and deter accidental damages to Nature and human beings. The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), for instance, deals with cleanup costs following some environmental accident and specifies the responsibilities of involved parties. Such regulation surely affects the firms' efforts to reduce the risk of an environmental accident. Risk reduction activities, however, seem less likely to fit the Porter hypothesis, unless their bottom line is clear in the short run.

One channel that may yield tangible rewards for inventive actions that reduce the risk of environmental accidents is liability insurance. Insurance contracts usually ask lower premium and deductibles from diligent firms. The financial payoff for those firms can be significant and gives them strong incentives to keep their risks under control. Lender's liability would also have the same effect. The regulator's intervention on those two markets – insurance and banking – might therefore yield an appropriate framework that would trigger socially beneficial innovations.

Another possibility for the regulator is to facilitate convergence on appropriate standards for environmental risk management systems. In some recent papers, I have proposed a stylized version of such a system that, once implemented, might enhance *both* risk reduction and regular business activities [Sinclair-Desgagné and Gabel (1997); Sinclair-Desgagné (1999); Boyer and Sinclair-Desgagné (1999)]. This scheme works as follows:

> Consider, for instance, a plant manager whose limited time and attention must be split between short-term returns and the reduction of long-term environmental risks. Denote the former and the latter task by A and B respectively.
>
> Assume that the manager's performance on task A is regularly monitored through the firm's accounting system. Performance on task B, on the other hand, will be audited only if performance on task A is high.
>
> Now, let incentive pay be set such that the manager's expected utility (or satisfaction) is higher when an audit takes place than when no audit occurs. However, if an audit yields a bad assessment of performance on task B, then the manager's ex post compensation will be inferior to what it would have been if no audit had taken place.

The intuitive reason why this scheme could help overcome what is usually seen as a strict tradeoff between financial returns and long-term risk reduction is straightforward. Under the above scheme the manager would like to be audited. She would then be lead to spend more effort on task A, in order to increase the likelihood of showing high performance on this task and triggering an audit. But since there is no benefit to be audited if performance on task B is ultimately assessed to be low, she would be lead to work harder as well on task B. This means that the respective efforts expended on tasks A and B have now become *complementary* from the viewpoint of earning higher payoffs. If this complementarity is strong enough, it will alleviate

current demands on managerial time and favor the creation of synergies between financial and environmental duties.

This scheme relies on internal audits. The regulator's can be quite helpful in harmonizing practices of environmental auditing and therefore lower its cost, as shown by the success of the the ISO 14000 and the EMAS standards. The benefits of harmonization can be non-negligible: for example, Ciba Clayton took three man-years to establish the eco-management system at its first registered site in the United Kingdom, including time talking with other companies regarding the requirements of the then-nascent standards; the company estimates that the time would be cut by two-thirds under the final version of EMAS. Furthermore, standardized auditing practices, because they make audit results comparable and credible, are essential for the above win-win management system to be implemented.

4. Radical innovations

The fact that well-crafted environmental regulation might trigger not only incremental (low-hanging fruits) but also radical innovations is probably the most appealing and controversial version of the Porter hypothesis.

Such a proposition was analyzed formally in Cadot and Sinclair-Desgagné (1995a and b). We consider the problem of a small-country government balancing a desire for stricter environmental standards against a concern for the competitive position of home firms. The government ends up using the *threat* of imposing the best available cleaner technology as the basic incentive device. Regulation at one time period is always uncertain, but the probabilities of regulation tend to decrease over time, as the firm successfully completes intermediate stages of the technology-development process. As the private return to technology development increases, the probability of regulation goes down, i.e. incentives become softer and the probability of completion increases. Therefore, the inefficiency associated with a positive probability of regulation is minimal for the best projects. As the government's preference for immediate regulation – a proxy for environmentalist pressure – increases, the firm's probability of successful development, which of course depends on the firm's efforts, goes up. As the government's preference for successful development of a domestic cleaner technology – a proxy for industrial policy concerns – increases, the firm's probability of development goes down.

This model was inspired by the case of Peugeot SA, the French car maker, and the lean-burn engine [Gabel (1991)]. While automobiles sold in the United States have had to be equipped with anti-pollution devices for many years as a result of gradual tightening of the 1970 Clean Air Act, progress towards a reduction in automobile emissions has been slower in Europe. All automobiles sold on the American market have to be fitted with three-way catalytic converters that convert hydrocarbons into CO_2 and water and reduce nitrogen oxide emissions at the engine's exhaust. Catalytic converters are efficient ways of reducing pollution provided that the engine is hot enough; the downside being the amount of pollution released before the engine heats up, increased fuel consumption, and the necessary maintenance cost of the equipment. By contrast, Peugeot SA (as well as Ford of Europe) have pursued during the 80s the development of an alternative technology called the "lean-burn" engine. A different design allows lean-burn engines to run on higher air/fuel ratios than conventional ones, thus saving on fuel consumption and reducing at the same time carbon and nitrogen oxyde emissions at the source. In the late 1980s, the French government was facing a tradeoff similar to the one we modelled: on the one hand, there was growing pressure from environmentalists lobbies and important trade partners like Germany to adopt stricter standards on car emissions (German car manufacturers had already adopted the catalytic converter), on the other hand, Peugeot SA, one of the country's major employer, was just completing a painful turnaround and had a head start on a the development of a better technology.

As one knows ex post, the development of the lean-burn engine was not successful: after delaying compliance with European norms for many years, France finally had to impose them on its car makers, which killed Peugeot's development efforts. This case and the model yield nevertheless some interesting conclusions concerning the role environmental regulation can play in triggering radical innovation. First, contrary to common wisdom, regulation based on the best available technology might not deter innovation ex ante, provided it is first raised as *a credible threat*. The use of such threats by the regulator, however, requires foresight and commitment beyond current government mandates.[5] Secondly, regulators that care too much too openly about domestic competitiveness rather than about environmental depletion are taken hostage by the firms, and this slows down radical innovation.

[5] For the problems linked to these requirements, see respectively Mello-e-Souza (1993) and Boyer and Laffont (1999).

5. Concluding remarks

This paper discussed the plausibility of the so-called Porter hypothesis - that strict environmental regulation can contribute to increase both social welfare and firm's profitability by giving the latter incentives to innovate. The hypothesis *cannot* be rejected on theoretical ground, unless one sticks to a very narrow view of neoclassical economics. The regulations most likely to fit the hypothesis and yield win-win situations depend on the type of innovation that is pursued - incremental (low-hanging fruits), risk reducing or radical. To enhance the discovery of low-hanging fruits, the regulator should not only enforce environmental standards that are strict in their objectives but flexible respective to the means, it should also contribute to lifting current obstacles to reengineering practices within the firm. The latter requires a systemic view of the corporate landscape in order to uncover all factors of organizational inertia *and* especially their *complementarities*. Innovations in the reduction of major environmental risks can arise most likely if one *overcomes tradeoffism*, i.e. the current view held in most firms that dealing with risks involving small probabilities (of large damages) always means sacrificing some short-run financial returns. The regulator can contribute to this by supporting new standards for environmental auditing and management systems that would render possible the implementation of win-win incentives and control schemes like the one sketched in section 3. Finally, radical innovation often presupposes a shift of paradigm on the part of firms and researchers. The regulator can promote and accelerate the right shift through persistent *selective intervention* (instead of uniform policies) that favors well-managed and environmentally-friendly firms.

References

Bolton, Patrick and Mathias Dewatripont, "The Firm as a Communication Network," *Quarterly Journal of Economics* 109 (1994), 809-839.

Boyer, Marcel and Bernard Sinclair-Desgagné, "Corporate Governance of Major Technological Risks," in Henk Folmer, Shelby Gerking and Adam Rose (eds.), *Frontiers in Environmental Economics*, Edward Elgar, 1999 (forthcoming).

Boyer, Marcel and Jean-Jacques Laffont, "Toward a Political Theory of the Emergence of Environmental Incentive Regulation," *Rand Journal of Economics* 30 (1999), 137-157.

Cadot, Olivier and Bernard Sinclair-Desgagné, "Environmental Standards and Industrial Policy," *Journal of Environmental Economics and Management* 29 (1995a), 228-237.

_____, "Innovation under the Threat of Stricter Environmental Standards," in Carlo Carraro, Yiannis Katsoulacos and Anastasios Xapapadeas (eds.), *Environmental Policy and Market Structure*, Kluwer, 1995b.

Cyert, Richard and John March, *A Behavioral Theory of the Firm*, 1992 (second edition), Blackwell.

Environmental Law Institute, 1999. Winning from Innovation: Perspectives on Business, Policy and Legal Factors that May Affect the Porter Hypothesis. Washington D.C. (February).

Gabel, H. Landis, "European Exhaust Emission Standards for Small Cars," INSEAD Case Study, 1991.

Gabel, H. Landis and Bernard Sinclair-Desgagné, "Standard Business Procedures and Environmental Public Policy," in Henk Folmer, Shelby Gerking and Adam Rose (eds.), *Frontiers in Environmental Economics*, Edward Elgar, 1999 (forthcoming).

_____, "The Firm, its Routines, and the Environment," in Tom Tietenberg and Henk Folmer (eds.), *The International Yearbook of Environmental and Resource Economics: A Survey of Current Issues*, Kluwer, 1998.

_____, "Corporate Responses to Environmental Concerns," in Henk Folmer, H. Landis Gabel and Hans Opshoor (eds.), *Principles of Environmental and Resource Economics : A Guide for Students and Decision Makers*, Edward Elgar Publishing, 1995 (first edition) and 1999 (second edition; forthcoming).

_____, "Environmental Auditing in Management Systems and Public Policy," *Journal of Environmental Economics and Management* 33 (1997), 331-346.

_____, "From Market Failure to Organizational Failure," in Robert Welford and Nigel Roome (eds.), *Business and the Environment*, European Research Press, 1994.

_____, "Managerial Incentives and Environmental Compliance," *Journal of Environmental Economics and Management* 24 (1993), 229-240.

Gibbons, Robert, "Incentives in Organizations," *Journal of Economic Perspectives* 12 (1998), 115-132.

Gimpel, Jean, *La révolution industrielle du Moyen-Âge*, 1975, Éditions du Seuil.

Holmstrom, Bengt and Paul Milgrom, "Multi-Task Principal-Agent Analysis: Incentive Contract, Asset Ownership and Job Design," *Journal of Law, Economics and Organization* 7 (1992; special issue), 24-52.

Lanoie, Paul and Georges A. Tanguay, “Dix exemples de rentabilité financière liés à une saine gestion environnementale,” CIRANO Working Paper 98s-05, 1998.

Mello-e-Souza, Carlos Alberto, “Mortal Managers and Long-Term Goals: An Impossibility Result,” *Rand Journal of Economics* (1993), 313-327.

Milgrom, Paul and John Roberts, “Complementarities and Systems: Understanding Japanese Economic Organization,” *Estudios Económicos*, 9 (1994), 3-42.

_____, *Economics, Organization, and Management*, 1992, Prentice-Hall.

Palmer, Kurt, Wallace E. Oates and Paul Portney, "Tightening Environmental Standards : The Benefit-Cost or the No-Cost Paradigm," *Journal of Economic Perspectives* 9 (1995), 119-131.

Porter, Michael E., “America’s Green Strategy,” *Scientific American*, 1996 (April).

_____ and Claas van der Lind, “Towards a New Conception of the Environment-Competitiveness Relationship,” *Journal of Economic Perspectives* 9 (1995), 97-118.

Radner, Roy, “Hierarchy: The Economics of Managing,” *Journal of Economic Literature* 30 (1992), 265-298.

Rosenberg, Nathan, *Inside the Black Box : Technology and Economics*, 1982, Cambridge University Press.

Rumelt, Richard, “Inertia and Transformation,” in Cynthia Montgomery (ed.), *Resource-Based and Evolutionary Theories of the Firm*, Kluwer, 1995.

Sah, Rajiv K. and Joseph Stiglitz, “The Architecture of Economic Systems: Hierarchies and Polyarchies,” *American Economic Review* 76 (1986), 716-727.

Segerson, Kathleen and Tom Tietenberg, “The Structure of Penalties in Environmental Enforcement,” *Journal of Environmental Economics and Management* 23 (1992), 179-200.

Sinclair-Desgagné, Bernard, “How to Restore Higher-Powered Incentives in Multi-Task Agencies,” *Journal of Law, Economics, and Organization* (June 1999), forthcoming.

_____, "La mise en vigueur des politiques environnementales et l'organisation de la firme,” *L'Actualité Economique* 70 (1994), 211-224.

_____ and Antoine Soubeyran, "When is deliberation needed?," Unpublished manuscript, CIRANO, March 1999.

Tirole, Jean, “Corporate Governance,” 1998 Presidential Address to the Econometric Society, to appear in *Econometrica*.

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