Ph.D. Dissertation in Mineral and Energy Economics

THE OPTIMAL REGULATION OF ACCIDENTAL POLLUTION AND MARKET POWER IN THE MINERAL AND ENERGY INDUSTRIES: POLICY IMPLICATIONS FOR THE U.S.A. AND PERU

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by

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ABSTRACT

Recent research on regulation have concentrated on studying ways of controlling continuous sources of pollution such as SO_2 and CO_2 emissions by means of permit trading and carbon taxes. However, the oil spill in the Gulf of Mexico after the Deepwater Horizon blowout and the red-mud tailings spill in Hungary in 2010 have shown that accidental pollution can also generate serious social damages. Regulating accidental pollution in natural-resource industries with some degree of market power, such as in the oil and mining industries, has been an elusive topic in the literature and in policy debates. Guaranteeing the viability of mineral and energy activities when people around the world demand more regulations to protect the environment and control anticompetitive practices requires a public governance system that balances the interests of the State and the mineral and energy companies and that regulates multiple market failures. The objective of this dissertation is to study how to organize and administer this governance system by analyzing the optimal way to achieve the right balance among the interests of these different participants in the mining and energy industries and by adopting a holistic analytical approach that combines economics, law, and politics. The dissertation develops an optimal multi-tier principal-agent model where the State regulates accidental pollution and market power, taking into account the problems of corruption, moral hazard, the random nature of accidental pollution, and the organization of regulatory institutions. Instruments such as monitoring, fines, and nonmonetary penalties are identified as optimal policy tools in a second-best setting. We analyze the applicability of the model using real case studies from the mining and energy industries. Finally, we present the policy implications of our theoretical analysis for the U.S.A. and Peru.

JEL Classification: D82, D73, D86, K21, K42, L40, L51, Q48, Q50

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INTRODUCTION

Since the end of the Cold War the world has experienced a dramatic series of changes that have reshaped the global economic panorama. Changes such as the improvement of communication systems and computing, the globalization of economic transactions, the increasing reliance on international trade to foster development, the geographical diversification of industrial and natural-resource production, the consolidation and concentration of many transnational industries, and the implementation of structural reforms to liberalize domestic markets have contributed to foster the development process of countries such as China, India, Brazil, Russia, as well as East European and Asian nations. Consequently, the demand for raw materials and natural-resource commodities such as oil, natural gas, and mining products (e.g., copper, silver, iron ore, rare earths, gold) in these economies has steadily grown (Radetzki 2006).

The increasing demand for mineral and energy commodities has stimulated investment projects to open new mines and oil fields, as well as to expand existing natural-resource deposits in different jurisdictions, especially Africa, South America, Canada, Southeast Asia, Australia, and the U.S.A. This trend is increasing the frequency of accidents involving sudden bursts of pollution (e.g., oil spills, gas leakages, oil rig blowouts, mining avalanches, power plant explosions, coal-bed methane explosions, accidental deforestation, and spills from hazardous-waste dumps such as mineral tailings ponds) with catastrophic consequences for the environment and human health in different mineral and oil producing countries. Two recent examples of accidents involving large discharges of pollution are the oil spill in the Gulf of Mexico after the Deepwater Horizon oil rig blowout and the red-mud alumina tailings spill in Hungary in 2010.

In addition, the consolidation process of the mining and energy industries during the recent commodity boom has increased the level of concentration in different commodity markets (Davis and Vasquez 2011).

The occurrence of accidental pollution and market power in the mineral and energy industries have raised concerns about economic efficiency, the quality of the environment, and human living conditions. The Internet boom has allowed common citizens and native communities to be aware of the adverse consequences of unregulated industrial activities. Hence, citizens are constantly demanding more regulations and governmental controls on the behavior of resource companies to protect them from "dirty activities" and high prices.

Description of the Problem

Regulating accidental pollution in the mineral and energy industries is difficult because accidental pollution involves four interrelated market failures: a) the uncertain external cost (random externality) that accidental pollution transmits to society, b) moral hazard, c) market power, and d) corruption.

Regarding the first market failure, the random nature of accidental pollution impedes a precise estimation of the magnitude of its external costs, making impossible the use of environmental policy instruments like emission charges, green taxes, subsidies, or permit trading, which are designed to deal with continuous sources of pollution that generate fairly predictable external costs. While these instruments affect economic behavior in the long run, they are not flexible enough to respond to short-run bursts of accidental pollution because their adjustment generally requires going through a legislative process in Congress. Even worse, many times the applicability of these instruments is not feasible due to political restrictions. The regulation of accidental pollution requires the use of flexible instruments that can be adjusted quickly to control short-run unpredictable external costs. Hence, traditional command-and-control instruments such as direct controls (e.g., monetary and nonmonetary penalties, detection, and monitoring) become the flexible tools needed to control the frequency of accidental pollution since environmental protection agencies can modify them depending on each particular case without the need to go to Congress (Baumol and Oates 1988).

Despite command-and-control instruments being very popular among regulators and practitioners, they are very unpopular amongst environmental economists who regard them as inefficient policy tools because they may fail to provide the right incentives to internalize pollution. However, the law and economics literature (Becker 1968, Polinsky and Shavell 2007) has pointed out that command-and-control tools such as fines and monitoring can induce incentives to comply with regulations provided they are well designed and implemented following economic principles that consider the economic rationality behind illegal behavior.

With respect to the second market failure, moral hazard occurs when mining and energy companies perform actions to reduce the occurrence of accidents (e.g., effort to comply safety and environmental standards), but these actions are not entirely observed by public regulators. This situation generates an informational asymmetry between the companies (which have an informational advantage) and the government (which does not observe firms' hidden actions). Moral hazard has been typically analyzed by means of hierarchical frameworks such as the principal-agent model in which the government (principal) oversees the behavior of a regulated party (the agent) empowered with more information. Implementing a regulatory scheme to control accidental pollution in a context plagued with informational asymmetries requires a detailed analysis of the incentives that drive the behavior of the participants of the "regulatory game" and the identification of the institutional organization under which regulatory policies are implemented (Laffont and Tirole 1993).

On top of random externalities and moral hazard, we have a two-fold problem of market power that can arise in mineral and energy markets. One form of market power is price setting. Resource companies can obtain a dominant position (e.g., monopolist or oligopolist) in domestic markets and become price setters by conducting anticompetitive practices (e.g., price discrimination, predatory pricing, dumping, and bid rigging) that have distorting effects in the allocation of resources. This is the conventional view of market power (Tirole 1988), and antitrust policy is the common mechanism to regulate this market failure (Viscusi, Vernon and Harrington 2005).

Another problem is the capability to control public institutions through regulatory capture (Stigler 1971). This kind of market power operates through the establishment of "private collusive deals" or "hidden side contracts" (involving transactions outside of the market) between regulated firms and public officials, seeking to corrupt regulators so as to obtain favorable regulations for the industry. The corruption of public regulators through bribes, framing, revolving doors, lobbying, and extortion actually generates a situation of bilateral monopoly between the interest group behind the hidden deals and the regulators. In this sense, interest groups can use their contractual power to affect market outcomes indirectly by capturing public officials (Laffont and Tirole 1993). Given the hidden nature of side contracting, moral hazard also arises in this context since the government (the principal) does not observe the behavior of regulated entities and public regulators (the agents) regarding the establishment of collusive deals. This problem exacerbates the informational asymmetries among the participant of a public institutional regulatory organization.

The occurrence of random externalities related to accidental pollution, the problem of moral hazard, the existence of market power, and the possibility of regulatory capture make the regulation of mining and energy industries challenging. This situation is worsened since public regulatory capabilities are being pushed to the limit in different jurisdictions. This is because of the lack of specialized human resources to deal with the regulation of multiple market failures occurring simultaneously, the complexities of mining and energy operations, tighter budget constraints, the intricacy of legal systems on which regulatory institutions are established, preexisting legal liability limits, and the institutional weaknesses of existing regulatory systems that make them fragile and predisposed to corruption (Laffont 2005).

The multiple market failures occurring in mining and energy markets also generate an important problem of policy coordination because environmental and antitrust regulators have different policy objectives. On the one hand, environmental agencies' main objective is to protect the environment by controlling pollution discharges. The implementation of this objective requires policy measures that finally increase the costs of production, contracting the

supply of these commodities. On the other hand, the antitrust commissions' main target is to foster competition and control abuses of market power in concentrated markets. In order to do that, the antitrust regulators use policies that stimulate more production, which increases supply. Hence, there is a fundamental tradeoff between antitrust and environmental policies for regulating mineral and energy markets. An improper management of this tradeoff may generate byproduct distortions that may adversely affect the functioning of the economy (Corden 1997). The existing literature has not analyzed this tradeoff in a context where the presence of moral hazard and the risk of regulatory capture are important.

Motivation and Objective of the Dissertation

Guaranteeing the viability of mineral and energy activities when several market failures occur and when more regulations to protect the environment and control anticompetitive practices are demanded motivates the study of a proper public governance system that balances the interests of the State (represented by the government), the mineral and energy companies, and the consumers (the civil society), that regulates the multiple market failures mentioned above, and that addresses several policy tradeoffs.

The purpose of this dissertation is to study how to organize and administer this kind of governance system by analyzing the way to achieve maximum social welfare given the interests of these different participants in the mining and energy industries. In order to attain this objective, the dissertation develops an optimal public governance system that simultaneously regulates accidental pollution and market power, taking into account the problems of corruption, moral hazard, the random nature of accidental pollution, and the organization of regulatory institutions.

Research Questions and Scientific Contribution

The existing literature provides useful insights on several issues that the dissertation covers, specifically the dynamic modeling of regulatory systems, the interaction of different players in a regulatory game, the control of random externalities, the modeling of corruption, and the optimal law enforcement of regulations under uncertainty. Nevertheless, none of the existing research in the literature deals specifically with developing an integrated optimal regulatory governance system to simultaneously regulate accidental pollution and market power in the mining and energy sectors. Our aim is to contribute to fill this gap. In order to do that, the dissertation examines the four research questions presented in the table below for the mining and energy industries. Research questions 3 and 4 are addressed for the cases of U.S.A. and Peru.

Research Questions of the Dissertation

- Which are the policy tradeoffs when administering antitrust and environmental enforcement actions inside a regulatory institutional organization affected by moral hazard and corruption?
- How can we analyze the interaction between antitrust and environmental enforcement policies in the mining and energy industries considering the complexities of the institutional organizations that administer them?
- What are the optimal policy instruments to regulate accidental pollution and market power? Do they differ from those applied in practice?
- How can the State use optimal policy instruments to enforce environmental and antitrust standards in the mining and energy industries?

Addressing these research questions requires a holistic approach that integrates different branches of economics and political science. The dissertation contributes to the existing literature by integrating and synthesizing in an

analytical regulatory framework the contributions of industrial organization and game theory, law and economics, contract theory and asymmetric information, political economy, and environmental economics in order to obtain new policy insights regarding the optimal way to regulate accidental pollution and market power in a context where failures in information and corruption are important concerns.

In this sense, the dissertation addresses the shortcomings of existing theoretical regulatory frameworks proposed in the literature by developing an integrated and consistent model to analyze what optimal policies can be used to control the occurrence of accidental pollution, the abuse of market power, and the effects of corruption on the performance of public regulation in natural-resource industries.

Organization of the Dissertation

The dissertation is divided into this introduction and seven subsequent chapters. Chapters 1 and 2 provide the background about the legal systems and the institutional organization ruling the regulation of environmental and antitrust affairs of mineral and energy industries in the U.S.A and Peru. The comparison of the environmental and antitrust regulatory systems in these countries will allow identifying the relevant institutional features that environmental and antitrust regulatory organizations exhibit in practice. These features will be used to develop a unified theoretical framework (performed in Chapters 3 and 4) to analyze the optimal way to regulate accidental pollution and market power in the mineral and energy industries.

Chapter 3 presents a review of the literature that is relevant to this dissertation and addresses our first research question. Along with a general background on the analytical tools to understand public law enforcement, random externalities, moral hazard and asymmetric information, market power exercise, and corruption, we take an in-depth look at how other research efforts have addressed the economic regulation of market power and random

externalities. Our approach to the literature is not only descriptive, but also critical, because we identify the contributions and limitations of the existing research in order to develop a synthesis on how to integrate the different branches of economics and political science that are necessary to understand the problem of regulating market power and random externalities in practice.

Using as building blocks the analysis performed in Chapter 3 and the lessons regarding the institutional features of environmental and antitrust regulatory systems in the U.S.A and Peru from Chapters 1 and 2, we develop in Chapter 4 a regulatory model to address the second research question of this dissertation. This model analyzes an institutional multi-tier hierarchy constituted by four principal-agent relations. The first relation is between the State (principal) and a mining/energy company (agent) that can generate accidental pollution and exercises market power in a resource commodity market. This relation is subject to informational asymmetries due to moral hazard. Given the assumption that the State is not capable of directly performing monitoring and law enforcement, it has to delegate to public regulators the responsibility to oversee the regulated company. Hence, the second principal-agent relation is between the State (principal), the environmental and antitrust regulators, and the courts of law (agents), which play a key role in the ultimate enforcement of public regulations. The third relation involves the company (principal), the public regulators, and the courts (agents). This relation is formalized by means of hidden collusive contracts between its participants, and it is through this relation that regulatory capture of public officials manifests. The final relation involves the company (principal) and a law firm (agent) that works as an advocate or lobbyist that aims to turn public regulations in favor of the interests of the company.

The model introduces elements of industrial organization, game theory, environmental economics, law and economics, and political economy in order to properly formalize the structure of a general regulatory institutional organization that we use to understand the optimal regulation of accidental pollution, market power, and corruption in regulatory systems such as those analyzed in Chapters 1 and 2 for the cases of the U.S.A. and Peru, respectively. The model is solved

using dynamic programming in order to identify the Nash equilibrium in the regulatory system and the optimal policy instruments that are necessary to regulate the different market failures mentioned above.

Chapter 5 addresses the third research question of this dissertation by comparing the policy instruments used in practice by environmental and antitrust regulatory agencies in the U.S.A. and Peru with the optimal policy tools identified in Chapter 4. In this chapter we identify that many of the traditional command-and-control instruments used in practice by environmental and antitrust regulators in both jurisdictions are theoretically inconsistent (i.e., their formulas do not correspond to the optimal instruments derived from our model). We provide policy recommendations about how to overcome the problem of having inconsistent instruments and improve current environmental and antitrust regulatory practices in both the U.S.A. and Peru.

Chapter 6 addresses the final research question of this dissertation by showing how public authorities can apply in practice the optimal regulatory framework developed in Chapter 4. The chapter illustrates the applicability of our framework using four relevant real-world cases that have recently occurred in the energy and mining industries: a) the oil spill in the Gulf of Mexico, b) the production water spills in the Peruvian rainforest, c) the red-mud tailings spills in Hungary, and d) a mineral tailings spills in a South American country. These are interesting case studies due to the large magnitude of the bursts of pollution released in each case, their catastrophic environmental consequences, the involvement of large mineral and energy companies with some sort of market power, and the corruption issues involved in the cases.

Finally, Chapter 7 summarizes the results of the first six chapters, presents the conclusions of the dissertation, and discusses the pending research agenda.

CHAPTER 7

CONCLUSIONS

In this dissertation we have developed a new economic model to analyze the regulation of mineral and energy activities that exhibit both a risky production technology for the environment and market power. The analysis of the simultaneous regulation of random externalities and market power using a hierarchical regulatory structure composed of different principals and agents, where moral hazard is widespread and incentives to corrupt public officials are strong, has been an elusive topic in the literature. Our theoretical analysis contributes to understand how the enforcement of environmental and antitrust polices can be achieved in an optimal way using a framework that takes into account key features of real-world regulatory regimes.

Our regulatory framework models the State's law enforcement problem as a *dynamic contracting game* in which several players (principals and agents) interact inside a hierarchical institutional organization. Using backward recursion, the solution of this contracting game is a sub-game perfect Nash equilibrium. The framework allows understanding the monitoring and enforcement of safety and antitrust standards in a consistent way, because: it takes into account the hierarchical structure of real-world regulatory systems; it considers the dynamic gaming nature of the interactions between principals and agents across the vertical structure; it analyzes conflicts between policy targets; it addresses the problem of market power in natural-resource markets; it makes explicit the role of the courts of law in the enforcement system; and it introduces the problem of corruption as an element that distort the regulatory framework.

These features have not been studied in an integrated and consistent way in the literature. Existing research on this subject only looks at specific aspects of the whole regulatory picture without integrating the different pieces involving the regulatory problem at hand and focusing only on one aspect of the problem at a

time. This tendency has led to partial theories with models that ignore important tradeoffs and relevant features of the regulatory problem at hand. To overcome this limitation, in this dissertation we adopt a holistic analytical approach that combines different aspects of several branches of economics: contract theory and the analysis of asymmetric information; industrial organization and game theory; environmental economics; decision theory; economic analysis of law and organization; and political economy. To the best of our knowledge, this dissertation constitutes the first attempt to integrate the contributions of these different economic fields to understand how to optimally regulate accidental pollution and market power in resource industries where asymmetric information and corruption constitute important problems.

The design of the optimal strategy to regulate random externalities presented in this dissertation has some similarities to the traditional analysis of optimal law enforcement. Nonetheless, this traditional analysis only constitutes a special case of the principal-agent model presented here, one in which social harm happens only if the agent (criminal) violates the law and each party involved in the enforcement system has symmetric information. On the contrary, in the case of stochastic pollution, social harm can happen even though the law breaker did not undertake any socially harmful action. For instance, a discharge from a tailings pond might be caused by an unforeseen weather-related circumstance and not by a negligent decision regarding safety effort undertaken by the mining company. In addition there is an intrinsic informational asymmetry between the parties involved in the enforcement system which generates a problem of moral hazard (i.e., the non-observability of firms' safety effort and production decisions).

We have shown that in the face of limited-liability constraints and decreasing returns to scale in monitoring effort, having an integrated ex ante and ex post regime is optimal. When safety violations happen prior to any accident, the safety agency's problem becomes one of conducting ex ante monitoring of the firm's activities to assess whether she is infringing the standards. Conversely, when socially harmful random pollution happens, there is a need to conduct ex

post inspections to assess whether an infringement of safety and environmental standards actually happened before the accident.

The courts of justice are crucial in a law enforcement system because they constitute the last instance of appeal in any conflict between regulated firms and regulators. The courts may authorize the application of fines or nonmonetary penalties or reject them according to the evidence provided by each party. Thus, there is a probability that penalties may be repealed by the courts, which weakens the effectiveness of the enforcement system. Our analysis has also taken into consideration the role of courts in the analysis of optimal law enforcement.

When a mineral or energy company also exercises monopoly power in a commodity market, the State needs to regulate any abuse of market power and simultaneously maintain the enforcement of safety standards. Tradeoffs between environmental and antitrust policies, between optimal deterrence and public efforts to maintain enforcement activities, as well as between limited liability and informational efficiency arise in this context. The early literature on the subject failed to correctly identify these tradeoffs, because it ignored the interaction between the agency problems and hidden side contracting associated with real-world regulatory systems (e.g., moral hazard and corruption), the dynamic nature of the relationships between the participants of the regulatory game, the random nature of pollution, and the price-setting behavior in imperfect market structures. This dissertation has filled this gap by answering the four research questions of this dissertation and providing a detailed analysis of these tradeoffs and the instruments necessary to balance them considering the features of real-world regulatory systems.

Optimal deterrence in a second-best setting, where asymmetric information is a key problem, requires that the State devise a penalty structure considering the effects of limited liability, the State's budget constraint, the ability of firms to participate in the State's enforcement regime, and incentive restrictions (i.e., incentive compatibility constraints). The elements that should integrate second-best penalties should be the probabilities of applying the fines and signals about the firm's safety and production performance. The social and private costs of temporarily shutting down the firm should be also considered in

case a nonmonetary penalty is assessed. The State should apply these penalties considering these elements to balance several tradeoffs arising in a regulatory hierarchy in a second-best setting. In this context, the penalties are maximal because a binding liability constraint under moral hazard makes the penalties to sum up to the maximum liability limit, $\overline{K}$.

The State needs to have a simple and transparent penalty structure that generates optimal deterrence subject to the constraints restricting his enforcement system in a second-best setting. If the State makes this penalty structure a public binding rule that his regulatory agencies have to obey, this rule will contribute to the objective of inducing the mining/energy firm to exert safety and production efforts that are consistent with the second-best optimal standards, u^{**} and Q^{**}.

The determination and application of the second-best penalties require that the safety, environmental, and antitrust agencies coordinate enforcement actions. This coordination is necessary because the regulatory agencies need to estimate in a consistent way the values of penalties, agree upon the value of the liability limit, and specify the density functions of random pollution, x, and the commodity price, p. An appropriate regulatory coordination policy will optimally balance the tradeoff between environmental and antitrust policies and induce the firm to abide by the State's standards in a second-best setting.

Nevertheless, the existence of a binding limited-liability constraint may inhibit the State's enforcement system to fully internalize the random externality and correct the deadweight loss of market power. Thus, the State can only apply restricted versions of the "monopoly- pay" and "polluter-pay" principles in a second-best setting.

Corruption (side contracting) and the possibility that regulated companies hire a law firm as an advocate in courts introduce informational distortions that spread all over the regulatory systems in a second-best setting, reducing its efficiency. When bribing happens, the State needs to pay wage premia to align the incentives toward his objectives. This "public compensation policy" works in a similar fashion as the compensation schemes offered to CEOs and top managers in private corporations to align their efforts to achieve profit maximization. A

compensation policy offering wage bonuses to public regulators for good performance against corruption avoids the destruction of monitors and judges' incentives to sustain the enforcement system. Although wage premia help fight bribing, they are costly to society. Thus, corruption is a critical problem when designing and implementing an optimal regulatory system because it reduces optimal deterrence and generates byproduct distortions associated with asymmetric information and salary compensations.

Our second-best system is not budget-balancing because it requires additional revenue to support the regulators' monitoring and enforcing activities. In addition, if the system requires more budgetary resources to maintain optimal deterrence, it will generate byproduct distortions associated with the collection of tax revenues to fund the regulatory agencies.

The analytical results obtained in this dissertation for the second-best enforcement system have not been identified by previous research. The literature has basically focused on characterizing first-best penalty structures ignoring important elements (e.g., liability, informational, and budget constraints, etc.) which actually affect real-world enforcement systems. However, the evidence from the American and Peruvian experiences regarding the regulation of energy and mining industries shows that these elements are indeed very important, so it is not possible to use first-best enforcement regimes to regulate very risky mining and energy activities in practice as the current literature would suggest. Our second-best enforcement system would be the correct analytical framework to understand the functioning of heavily constrained real-world regulatory regimes for very risky energy and mining activities. The complete development of a second-best enforcement system to regulate risky activities in the energy and mining industries is, therefore, the most important contribution of this dissertation.

We have also characterized the properties of a first-best enforcement regime. Our analysis showed that there are closed-form solutions for the first-best penalties. The ex post environmental and antitrust fines are proportional to the social damage generated by the firm's misbehavior and adjusted by the inverse of the probability of applying the penalties. This result implies that the first-best

enforcement system actually fully incorporates the "polluter pays" and "monopoly-pays" principles in the ex post and antitrust penalties.

A first-best ex ante fine is only needed when no ex post inspections are allowed; otherwise, the first-best ex ante fine is equal to zero (a corner solution). In a situation where the State is restricted to using only ex ante monitoring, the first-best ex ante penalty is based on the illicit benefit (avoided or delayed costs) that the firm obtains from shirking. When no social damage occurs in an ex ante scenario, the use of gain-based ex ante fines is enough to deter illicit behavior.

Administering a first-best penalty system does not require institutional coordination because the independent application of ex post and antitrust penalties is enough to bring about the compliance of the State's standards. This result is explained by the fact the limited-liability constraint is not binding in first-best setting. Hence, in this scenario, there is no tradeoff between environmental and antitrust policies.

The first-best penalty system may be adequate to regulate a small mining or energy activity that is not very risky and not so dirty. For instance, if a mining/ energy firm uses a technology with a low risk of producing a large burst of pollution, it is likely that the firm will generate small discharges of accidental pollution most of the time. So, in general, this company can be charged the full value of the random externality and the deadweight loss from anticompetitive practices in the ex post and antitrust penalties without exposing her to the risk of bankruptcy.

It is important to notice that the effects of corruption are incorporated in our first-best penalty system by supplementing the optimal fines with wage premia. This recommendation assumes that public regulatory entities do not receive any compensation for corruption before the occurrence of infringements and that the public compensation mechanism for corruption shows up "on the spot" when the illegal behavior is detected and punished. That is, wage bonuses to prevent regulatory capture only appear when the fine is paid in a first-best setting. This scheme constitutes an efficient way to transfer wage premia to the regulatory authorities, since it does not generate byproduct distortions associated with the collection of tax revenues to support the corruption control policy. This

constitutes an application of the "briber-pay" principle discussed in Chapter 4 by which the violator is directly overcharged for the problem of regulatory capture when detected. However, this may generate perverse incentives for regulators to over-penalize the company in order to collect more wage bonuses. In this sense, collecting wage premia from the fines may generate excessive deterrence that is beyond a socially desirable level.

The comparison of the actual penalty systems used in the U.S.A. and Peru with the optimal penalty system developed in Chapter 5 has identified the shortcomings of these frameworks and has provided interesting policy insights to improve them. In the case of the U.S.A., we identified that neither environmental nor antitrust penalty rules are consistent with the second-best optimal penalties obtained in Chapter 4.

The environmental penalty system used in the U.S.A. also fails to clearly distinguish between ex ante and ex post scenarios, a feature that is very important to regulate accidental pollution. Different penalty instruments have to be used in ex ante and ex post scenarios. The U.S. environmental penalty system ignores this consideration. In addition, U.S. regulatory authorities use guidelines that make their penalty rules not binding. This issue worsens the penalty administration in the U.S.A. by making it discretionary, which reduces its effectiveness.

It is likely that environmental and antitrust penalties applied through civil proceedings in the U.S.A. are not providing the right incentives to deter illegal behavior, internalize random environmental externalities, and control market power. For instance, it may be the case that biased environmental penalties are increasing the frequency of accidental pollution by not providing enough incentives for firms to exert an optimal level of safety effort. To improve this situation, it would be necessary to clearly differentiate ex ante and ex post environmental enforcement regimes and use different penalty instruments in each case. Likewise, it would be important to use in the actual U.S. penalty systems the elements characterizing the second-best penalties identified in this dissertation to guarantee an optimal level of deterrence. Making clear, transparent, and binding the rules governing penalty systems in the U.S.A. would

be important too so as to improve the predictability of the environmental and antitrust regulatory policies and reduce the discretion of regulators.

In the case of Peru, we showed that the environmental authorities are not using a second-best penalty structure as well. However, the authorities clearly distinguish between ex ante and ex post scenarios, so they apply different penalties for each case. The environmental regulator uses binding first-best rules which makes her policies predictable and transparent. Our policy recommendation for the Peruvian authorities evaluate the adoption of the elements characterizing second-best ex ante and ex post penalties to improve the effectiveness of their penalty policy.

With respect to antitrust affairs in Peru, the antitrust regulator has not made explicit its penalty formulas to calculate antitrust fines, so the antitrust penalty policy is not transparent and probably nonbinding. It seems that the Peruvian antitrust regulator has discretion to calculate fines without following a clear rule. The recommendation in this case would be to include in the Peruvian antitrust penalty assessment the elements characterizing the second-best antitrust penalty and to make binding the rule to promote the transparency and predictability of the application of antitrust policy.

Regarding the issue of controlling corruption, none of the penalty systems used in the U.S.A. and Peru explicitly control for corruption effects. In the case of Peru, the Peruvian Energy and Mining Regulatory Commission (OSINERGMIN) receives a regulatory royalty from the regulated community to afford its institutional budget and pay higher salaries than the average wage in Peru to its employees. This royalty is conceived to guarantee its political and financial autonomy from the central government and to control corruption. Although this way to control for corruption may not be the most efficient one as discussed above, it allows OSINERGMIN to be, to some extent, shielded from corruption. Likewise, the royalty allows OSINERGMIN to have a nonbinding budget constraint which strengthens her overall law enforcement policy. In contrast, the Peruvian Antitrust Agency (INDECOPI) is a public self-financing institution that is not shielded from corruption, because it does not receive any regulatory royalty. Given that it faces a binding budget constraint and that it is

not properly shielded against corruption, the effectiveness of its antitrust enforcement actions is probably weak.

In the case of the U.S.A., it is unclear how the EPA, the DOJ, the FERC, and the FTC handle the problem of corruption based on official information. What is clear is that they take direct appropriations from the federal government. This means that they are more exposed to the influence of political decisions and/or the influence of lobbying, so it is likely that they are not shielded enough to properly control for corruption. State regulators also get direct appropriations from their corresponding state governments, but it seems that these regulators face tighter budget constraints than federal regulators given the recent budget cuts at the state level after the economic crisis of 2008. It is unclear how these state regulators manage the issue of corruption, but it is likely that they are more exposed to the risk of corruption considering the tighter budgets they face.

Controlling the risk of corruption in both the U.S.A. and Peru requires implementing an adequate wage compensation scheme to induce public officials to exert enough effort to guarantee the correct functioning of law enforcement regimes and counteract the incentives to establish private collusive deals with the regulated community. The experience of OSINERGMIN in Peru is illustrative of a way to fund this kind of scheme by means of a regulatory royalty that deserves a more detailed study. Another alternative is to apply the "briber pays" principle and supplement monetary fines with wage premia in case a first-best setting is considered. However, it would be necessary to evaluate for each particular case what alternative is more efficient and what alternative is politically feasible to implement before deciding for one of them.

An important policy that can also help fight the effects of corruption is the division of regulatory tasks in separate regulatory institutions. As Hiriart et al. (2009) point out, having separate regulators for each regulatory task increases the transaction costs of side contracting, making more difficult for regulated parties to capture public officials. Nonetheless, it would be necessary to establish coordination mechanisms among separate regulatory authorities in order to

control tradeoffs such as the one between antitrust and environmental policies that has been analyzed in this dissertation.

Many of the research papers on optimal enforcement have proposed theoretical but impractical (or unfeasible) systems to enforce the law, for the majority of this literature is sterile in terms of policy applications and empirical analysis (Posner 2006). In contrast, our analysis in Chapter 4 provides a theoretically consistent second-best enforcement system that can be applied to different real-world regulatory scenarios. What is necessary is that public regulatory administrations coordinate efforts to develop a cost-effective practical methodology to assess second-best penalties, taking into account statutory deadlines that usually accompany the regulatory process. However, it is likely that the resulting methodology be subject to measurement and transference errors that may affect the calculation of optimal penalties. Thus, public regulators should take into consideration this problem when assessing penalties and should make publicly available the degree of statistical confidence in order to make transparent their penalty assessment methodology.

Another advantage that our model has with respect to the existing literature is that it is suitable to empirical analysis. Our policy analysis in Chapter 4 has revealed some empirical propositions regarding the effects of the exogenous parameters in the model (e.g., the liability limit, the budget endowment, and other exogenous parameters in Table 4.2) on the penalty structure, the level of deterrence, and expected welfare. An important proposition is the one pointing that a government failure may show up when distortions in the flexibility of the enforcement system become relevant. The government failure may lead to a suboptimal level of deterrence that may induce firms to deviate from the optimal safety and quantity standards. That deviation may generate a suboptimal increase in the frequency of accidental pollution and in the frequency of the commodity price (which may constitute an abuse of market power).

The blowout of the Deepwater Horizon oil rig in the U.S.A, the red-mud tailings spill in Hungary, and the production water discharges in the Peruvian Amazonia have been used in this dissertation as cases studies to illustrate how the theoretical framework developed in Chapter 4 can be used to understand real-

world policy scenarios. The first and third cases have shown that failures in the enforcement systems are in fact real problems that can erode their effectiveness and might generate catastrophic burst of pollution in a short period of time. These cases illustrate how liability limits, budget cuts, and bribing interact to create government failures that deteriorate the efficacy of ex ante and ex post regulatory systems. This result may be behind a suboptimal increase in the frequency of accidental pollution, enlarging the expected value of pollution size.

The Peruvian case study has shown a successful application of an ex post environmental fine to control production water spills from oil extraction in the Amazon rainforest. OSINERGMIN applied a monetary fine and a nonmonetary penalty (i.e., the temporal suspension of oil extraction) that were close to the first-best penalties, because the infringing oil company internalized the environmental externality by investing during five years in a water reinjection system. The case is interesting since it illustrates how penalties that are conceived to alter behavior in the short run can actually have long-run effects on corporate behavior, an effect that is commonly associated with economic tools such as taxes and permit trading. The case also illustrates how an ex post enforcement system can properly correct externalities.

The last case study, the mining tailings spill in the Andes of South America produced by a copper cartel, has illustrated how coordination and separation of regulatory tasks are relevant to guarantee optimal deterrence and control corruption.

To conclude, it is important to say that the dissertation is not exempt of limitations. First, the dissertation has mainly focused on the interactions among the State, public regulators, a mining/energy company, and a law firm inside an institutional regulatory hierarchy. Our approach to analyze this hierarchy has been the study of the sequential interactions among these "players," which allowed us to analyze the nature of these interactions using dynamic programming (backward recursion) and game-theoretic techniques. Thus, the source of dynamics in the model is *strategic*, arising from the interrelations of the different participants in the regulatory game. We simplified the already complex problem at hand by ruling out another important source of dynamics that is

relevant in the mineral and energy industries: the extraction of nonrenewable natural resources and its associated depletion effects. According to Perloff et al. (2007), this constitutes a *fundamental* source of dynamics because of the presence of resource constraints related to the finite nature of nonrenewable natural-resource deposits. Introducing this source of dynamics would make difficult the analysis of optimal enforcement because this will imply integrating both the strategic interactions of the participants in the game and the decision of the regulated company regarding the optimal extraction of nonrenewable resources over time. This would be an interesting extension of our model that would help analyze the long-run effects of enforcement policy tools over time.

Second, the dissertation has analyzed the regulation of a mineral/energy monopolist (or cartel). This approach has greatly simplified the analysis by abstracting the issue of having different resource companies in the regulatory structure. Analyzing a regulatory framework considering an oligopolistic market structure is challenging because this would require considering how oligopolists react to the decisions of their competitors and how they interact to corrupt public officials. This would require building a model of an *overlapped dynamic game* that considers the oligopoly game and the bilateral collusive side contracts between public officials and the oligopolists. A model like the one described would be particularly useful to extent the theoretical framework developed in this dissertation and to better understand the strategic reasons behind the pursuit of an illegal competitive advantage and the occurrence of random externalities in an oligopolistic setting.

Third, our analysis has abstracted public-finance issues by assuming an exogenous budget endowment available to fund regulatory activities. In reality, affording the budget of regulatory agencies requires to raise revenues from different source like public bonds or taxes. The difficulty to introduce the financing of regulators' public budgets implies the study of the byproduct distortions associated to taxation, public debt, and the marginal cost of public funds. This would make necessary to understand the interactions of the different market failures studied in this dissertation with the distortions generated by public finance.

Fourth, the dissertation has focused on a second-best penalty scheme. It would be interesting to delve into the analysis of this system to evaluate its practical applicability. Our analysis in Chapter 4 provides information on the components that should constitute the optimal fines and on how to control for policy tradeoffs. Given that we do not have closed-form solutions for the second-best penalties, an interesting extension of our analysis would require specifying functional forms for the probabilities of detection and the probability density functions of random pollution (x) and the commodity price (p) in order to conduct a simulation exercise to determine numerically second-best penalties under different scenarios.

Fifth, exploring other ways to control for corruption would also be an interesting extension of the model presented in this dissertation.[160] Our analysis has concentrated on direct monetary transfer to control for corruption that can be included in the optimal penalties themselves (i.e., the briber-pay principle in a first-best penalty regime). This is an efficient way to control the risk of regulatory capture, but it may not be politically feasible to implement. Another way to control for corruption that has been discussed in the thesis is through the collection of regulatory royalties. However, we have not analyzed how compensation mechanisms can be implemented *inside* regulatory agencies. Extending the analysis to address this issue would involve the study of principal-agent relations inside each particular regulatory agency. The paper of Segerson and Tietenberg (1992) provides a starting point to delve into this topic.

Finally, it would be important that future research test the empirical propositions of our model to assess its consistency with reality. The case studies presented in Chapter 6 illustrated how our model can be used to study practical scenarios and provided some empirical support. However, these case studies constitute a small sample. A large sample of case studies would be necessary to validate our model relating the frequency of accidents and antitrust law violations to the regulatory policies in place. In addition, an empirical assessment

[160] A recent paper of Harstad and Svensson (2011) can shed light on the choice between bribing and lobbying that can provide an initial basis to consider particular characteristics of the corruption phenomenon in developed and developing countries in our model.

of a counterfactual scenario that measures the value of environmental damage generated by accidental pollution and the deadweight loss related with market power, given the use of an optimal penalty system, would be interesting in order to evaluate how optimal the enforcement regimes in the U.S.A. and Peru are. This exercise could be conducted using a simulation model based on our theoretical framework in Chapter 4.

REFERENCES

ABA (2009) *Energy Antitrust Handbook* (Chicago, IL: ABA Section of Antitrust Law)

Ades, Alberto, and Rafael Di Tella (1999) 'Rents, competition, and corruption.' *American Economic Review* 89(4), 982 – 993

Aidt, Toke S. (2003) Review: 'Economic analysis of corruption: A survey.' *Economic Journal* 113(491), F632 – F652

Al-Qahtani, Ayed (2008) 'A model for the global oil market: Optimal oil production levels for Saudi Arabia.' PhD dissertation, Colorado School of Mines, Golden, CO

Andersen, Lykke (1997) 'A Cost-Benefit Analysis of Deforestation in the Brazilian Amazon.' Discussion Paper IEA 455, IPEA

Andrews, David (1971) 'Antitrust law meets the environmental crisis: An argument for accommodation.' *Ecology Law Quarterly* 1(4), 840 – 865

Andrianova, Svetlana, and Nicolas Melissas (2009) 'Corruption, extortion, and the boundaries of the law.' *Journal of Law, Economics, and Organization* 25(2), 442 – 471

Ardila, Sergio, Ricardo Quiroga, and William Vaugham (1998) 'A review of the use of contingent valuation methods in project analysis.' Working Paper, The Inter-American Development Bank

Armstrong, Mark, and David E. M. Sappington (2006) 'Regulation, competition, and liberalization.' *Journal of Economic Literature* 44(2), 325 – 366

Armstrong, Mark, and David E.M. Sappington (2007) 'Recent developments in the theory of regulation.' In *Handbook of Industrial Organization,* ed. M. Armstrong and R. Porter, vol. 3 (Elsevier) Chapter 27, pp. 1557 – 1700

Armstrong, Mark, Simon Cowan, and John Vickers (1994) *Regulatory Reform: Economic Analysis and British Experience* (Cambridge, MA: MIT Press)

Bardhan, Pranab (1997) 'Corruption and Development, A Review of Issues.' *Journal of Economic Literature* 35(3), 1320 – 1346

Barrett, Scott (1994) 'Strategic environmental policy and international trade.' *Journal of Public Economics* 54(3), 325 – 338

Baumol, William J., and Wallace E. Oates (1988) *The Theory of Environmental Policy,* 2nd ed. (Cambridge, MA: Cambridge University Press)

Beavis, Brian, and Martin Walker (1983) 'Random wastes, imperfect monitoring and environmental quality standards.' *Journal of Public Economics* 21(3), 377 – 387

Becker, Gary, and George Stigler (1974) 'Law enforcement, malfeasance, and compensation of enforcers.' *Journal of Legal Studies* 3(1), 1 – 19

Becker, Gary S. (1968) 'Crime and punishment: An economic approach.' *The Journal of Political Economy* 76(2), 169 – 217

Benchekroun, Hassan, Gerard Gaudet, and Ngo Van Long (2006) 'Temporary natural resource cartels.' *Journal of Environmental Economics and Management* 52(3), 663 – 674

Bolton, Patrick, and Mathias Dewatripont (2005) *Contract Theory* (Boston, MA: MIT Press)

Bullard, Alfredo, and Alejandro Falla (2011) 'Peru.' In *The International Handbook on Private Enforcement of Competition Law,* ed. A. Foer (American Antitrust Institute) pp. 462 – 474

Calabresi, Guido (1970) *The Costs of Accidents* (New Haven: Yale University Press)

Cameron, Samuel (1988) 'The economics of crime deterrence: A survey of theory and evidence.' *KYKLOS International Review of Social Sciences* 41(2), 301 – 323

Carson, Richard T., Robert C. Mitchell, Michael Hanemann, Raymond J. Kopp, Stanley Presser, and Paul A. Ruud (2003) 'Contingent Valuation and Lost Passive Use: Damages from the Exxon Valdez Oil Spill.' *Environmental and Resource Economics* 25(3), 257 – 286

Cavnar, Robert L. (2010) *Disaster on the Horizon* (White River Junction: Chelsea Green)

Chiang, Alpha C., and Kevin Wainwright (2005) *Fundamental Methods of Mathematical Economics,* 4 ed. (New York: McGraw-Hill Irwin)

Choe, Olivia S. (2003) 'A missed opportunity: Nonprofit Antitrust Liability in Virginia Vermiculite, Ltd. v. Historic Green Springs, Inc.' *Yale Law Journal* 113, 533 – 540

Clemen, Robert T., and Terence Reilly (2001) *Making Hard Decisions with Decision Tools* (Pacific Grove, CA: Duxbury)

Coase, Ronald H. (1960) 'The problem of social cost.' *Journal of Law and Economics* 3(1), 1 – 44

Cohen, Mark A. (1987) 'Optimal enforcement strategy to prevent oil spills: An application of a principal-agent model with moral hazard.' *Journal of Law and Economics* 30(1), 23 – 51

Considine, Timothy J. (2001) 'Markup pricing in petroleum refining: A multiproduct framework.' *International Journal of Industrial Organization* 19(10), 1499 – 1526

Corden, W. Max (1997) *Trade Policy and Economic Welfare,* 2nd ed. (Oxford: Oxford University Press)

Cowling, Keith, and Dennis C. Mueller (1978) 'The social costs of monopoly power.' *The Economic Journal* 88(352), 727 – 748

Crone, Timothy J., and Maya Tolstoy (2010) 'Magnitude of the 2010 Gulf of Mexico Oil Leak.' *Science* 330(10), 634

Davis, Graham A., and Arturo L. Vasquez Cordano (2011) 'International trade in mining products.' *Journal of Economic Surveys,* forthcoming

Davis, Graham A., and Robert D. Cairns (1999) 'Valuing petroleum reserves using current net price.' *Economic Inquiry* 37(2), 295 – 311

De la Fuente, Angel (2000) *Mathematical Methods and Models for Economist* (Cambridge: Cambridge University Press)

Desvousges, W., F. Johnson, and H. Banzhaf (1998) *Environmental Policy Analysis with Limited Information* (Cheltenham: Edward Elgar)

Ehrlich, Isaac (1973) 'Participation in illegitimate activities: A theoretical and empirical investigation.' *Journal of Political Economy* 81(3), 521 – 565

_____ (1996) 'Crime, punishment, and the market for offenses.' *Journal of Economic Perspectives* 10(1), 43 – 67

Epple, Dennis, and Michael Visscher (1984) 'Environmental pollution: Modeling occurrence, detection and deterrence.' *Journal of Law and Economics* 27(1), 29 – 60

Esworthy, Robert (2008) 'Federal pollution control laws: How are they enforced?' CRS Report for the U.S. Congress, Congressional Research Service

European Commission (2000) *XXIX Report on Competition Policy* (Brussels: Commission of the European Communities)

Figueroa, Adolfo (2010) 'The intergenerational consumption frontier.' Working Paper, CENTRUM - Pontifical Catholic University of Peru

Froehlich, Mary A., and John F. Bellantoni (1981) 'Oil spill rates in four U.S. coastal regions.' In *1981 Oil Spill Conference Proceedings,* ed. American Petroleum Institute

FTC (2004) 'The petroleum industry: Mergers, structural change, and antitrust enforcement.' FTC Staff Study, Federal Trade Commission, Bureau of Economics, Washington D.C.

Fudenberg, Drew, and Jean Tirole (1991) *Game Theory* (Cambridge: MIT Press)

Gallardo, Jose, and Santiago Davila (2003) 'Concentraciones horizontales en la actividad electrica: El caso peruano.' Working Paper 2, OSINERGMIN

Garoupa, Nuno (1997) 'The theory of optimal law enforcement.' *Journal of Economic Surveys* 11(3), 267 – 295

Gellhorn, Ernest, William E. Kovacic, and Stephen Calkins (2004) *Antitrust Law and Economics in a Nutshell,* 4th ed. (St. Paul, MN: Thompson West)

Ginsburg, Douglas H. (2005) 'Comparing Antitrust Enforcement in the United States and Europe.' *Journal of Competition, Law, and Economics* 1(3), 427 – 439

Grossman, Sanford J., and Oliver D. Hart (1983) 'An analysis of the principal-agent problem.' *Econometrica* 51(1), 7 – 45

Hamilton, Stephen F., and Till Requate (2004) 'Vertical structure and strategic environmental trade policy.' *Journal of Environmental Economics and Management* 47(2), 260 – 269

Hanley, Nick, Jason H. Shogren, and Ben White (2007) *Environmental Economics in Theory and Practice* (New York: Palgrave Macmillan)

Harford, Jon D. (1978) 'Firm behavior under imperfectly enforceable pollution standards and taxes.' *Journal of Environmental Economics and Management* 5(1), 26 – 43

Harrington, Joseph E., Jr. (2004) 'Cartel pricing dynamics in the presence of an antitrust authority.' *RAND Journal of Economics* 35(4), 651 – 673

Harris, Milton, and Artur Raviv (1979) 'Optimal incentive contracts with imperfect information.' *Journal of Economic Theory* 20(2), 231 – 259

Harstad, Bard, and Jacob Svensson (2011) 'Bribes, Lobbying, and Development.' *American Political Science Review* 105(1), 46 – 63

Heintz, Roebyem, and Richard Tol (1996) 'Secondary benefits of climate control policies: Implications for the global environment facility.' Working Paper GEC 96-17, CSERGE, London

Hiriart, Yolande, David Martimort, and Jerome Pouyet (2009) 'The public management of risk: Separating ex ante and ex post monitors.' Working Paper, Toulouse School of Economics, Toulouse

Holmstrom, Bengt (1979) 'Moral hazard and observability.' *The Bell Journal of Economics* 10(1), 74 – 91

Hueth, Brent, and Tigran Melkonyan (2009) 'Standards and the regulation of environmental risk.' *Journal of Regulatory Economics* 36(3), 219 – 246

Jain, Arvind K. (2001) 'Corruption: A review.' *Journal of Economic Surveys* 15(1), 71 – 121

Jewitt, Ian (1988) 'Justifying the first-order approach to principal-agent problems.' *Econometrica* 56(5), 1177 – 1190

Judge, William Q., D. Brian McNatt, and Weichu Xu (2011) 'The antecedents and effects of national corruption: A meta-analysis.' *Journal of World Business* 46(1), 93 – 103

Kaplow, Louis (1990) 'A note on the optimal use of nonmonetary sanctions.' *Journal of Public Economics* 42(2), 245 – 247

Kolstad, Charles D. (2010) *Environmental Economics* (New York: Oxford University Press)

Kolstad, Charles D., Thomas S. Ulen, and Gary V. Johnson (1990) 'Ex post liability for harm vs. ex ante safety regulation: Substitutes or complements?' *American Economic Review* 80(4), 888 – 901

Laffont, Jean-Jacques (1988) 'Hidden gaming and hierarchies: Facts and models.' *Economic Record* 64(187), 295 – 307

_____ (1990) 'Analysis of hidden gaming in a three-level hierarchy.' *Journal of Law, Economics, and Organization* 6(2), 301 – 324

_____ (2005) *Regulation and Development* (Cambridge: Cambridge University Press)

Laffont, Jean-Jacques, and David Martimort (2001) *The Theory of Incentives: The Principal-Agent Model* (Princeton: Princeton University Press)

Laffont, Jean-Jacques, and Jean Tirole (1993) *A Theory of Incentives in Procurement and Regulation* (Cambridge, MA: MIT Press)

Lehner, Peter, and Robert Deans (2010) *In Deep Water: The Anatomy of a Disaster, the Fate of the Gulf, and Ending our Oil Addiction* (New York: The Experiment)

Leibenstein, Harvey (1966) 'Allocative efficiency vs. "X-Efficiency".' *American Economic Review* 56(3), 392 – 415

Levy, Brian, and Pablo T. Spiller (1996) *Regulation, Institutions, and Commitment: Comparative Studies of Telecommunications* (New York: Cambridge University Press)

Macho-Stadler, Ines, and David Perez-Castrillo (1997) *An Introduction to the Economics of Information: Incentives and Contracts.* (Oxford: Oxford University Press)

Martin, Stephen (2002) *Advanced Industrial Organization,* 2 ed. (Oxford: Blackwell Publisher)

Mas-Colell, Andrew, Michael D. Whinston, and Jerry R. Green (1995) *Microeconomic Theory* (New York: Oxford University Press)

Mattei, Hugo (1998) *Comparative Law and Economics* (Michigan: Michigan University Press)

McAfee, R. Preston, Hugo M. Mialon, and Sue H. Mialon (2008) 'Private v. public antitrust enforcement: A strategic analysis.' *Journal of Public Economics* 92(10-11), 1863 – 1875

Mirrlees, James A. (1999 [1975]) 'The theory of moral hazard and unobservable behavior: Part I.' *Review of Economic Studies* 66(1), 3 – 21

Montero, Juan Pablo (2009) 'Market power in pollution permit markets.' *Energy Journal* 30(Special Issue 2), 115 – 142

Montero, Juan Pablo, and Juan Ignacio Guzman (2010) 'Output-expanding collusion in the presence of a competitive fringe.' *Journal of Industrial Economics* 58(1), 106 – 126

Motchenkova, Evgenia (2008) 'Determination of optimal penalties for antitrust violations in a dynamic setting.' *European Journal of Operational Research* 189(1), 269 – 291

Motta, Massimo (2004) *Competition Policy: Theory and Policy,* 1 ed. (Cambridge: Cambridge University Press)

Navrud, Stale, and Richard Ready (2007) 'Review of methods for value transfer.' In *Environmental Value Transfer: Issues and Methods,* ed. Stale Navrud and Richard Ready, vol. 9 (Dordrecht: Springer) pp. 1 – 10

North, Douglass (1990) *Institutions, Institutional Change, and Economic Performance* (Cambridge, MA: Harvard University Press)

OECD (2004) 'Competition law and policy in Latin America: Peer reviews of Argentina, Brazil, Chile, Mexico and Peru.' Report, Inter-American Development Bank and Organization for Economic Co-operation and Development

OECM-EPA (2003) 'Identifying and calculating economic benefit that goes beyond avoided and/or delayed costs: The white paper.' Technical Report, U.S. Environmental Protection Agency (EPA), Office of Enforcement and Compliance Monitoring (OECM)

Perloff, Jeffrey M., Larry S. Karp, and Amos Golan (2007) *Estimating Market Power and Strategies (*Cambridge: Cambridge University Press)

Pindyck, Robert S. (1979) 'The cartelization of world commodity markets.' *American Economic Review* 69(2), 154 – 158

Polinsky, A. Mitchell, and Steven Shavell (1979) 'The optimal tradeoff between the probability and magnitude of fines.' *American Economic Review* 69(5), 880 – 891

_____ (1984) 'The optimal use of fines and imprisonment.' *Journal of Public Economics* 24(1), 89 – 99

_____ (1994) 'Should liability be based on the harm to the victim of the gain to the injurer?' *Journal of Law, Economics, and Organization* 10(2), 427 – 437

_____ (2000) 'The economic theory of public enforcement of law.' *Journal of Economic Literature* 38(1), 45 – 76

_____ (2007) 'The theory of public enforcement of law.' In *Handbook of Law and Economics,* ed. Mitchell Polinsky and Steven Shavell, vol. 1 (Amsterdam: North-Holland) pp. 403 – 454

Posner, Richard (1972) *Economic Analysis of Law* (Boston: Little)

_____ (1985) 'An economic theory of criminal law.' *Columbia Law Review* 85(6), 1193 – 1232

_____ (2006) 'A review of Steven Shavell's "Foundations of Economic Analysis of Law".' *Journal of Economic Literature* 44(2), 405 – 414

Radetzki, Marian (2006) 'The anatomy of three commodity booms.' *Resources Policy* 31(1), 56 – 64

Rasmusen, Eric (2006) *Games and Information: An Introduction to Game Theory,* 4 ed. (Wiley-Blackwell)

Rogerson, William P. (1985) 'The first-order approach to principal-agent problems.' *Econometrica* 53(6), 1357 – 1367

Ross, Stephen A. (1973) 'The economic theory of agency: The principal's problem.' *American Economic Review* 63(2), 134 – 139

Segerson, Kathleen, and Tom Tietenberg (1992) 'The structure of penalties in environmental enforcement: An economic analysis.' *Journal of Environmental Economics and Management* 23(2), 179 – 200

Shavell, Steven (1979) 'Risk sharing and incentives in the principal and agent relationship.' *Bell Journal of Economics* 10(1), 55 – 73

_____ (1984a) 'A model of the optimal use of liability and safety regulation.' *RAND Journal of Economics* 15(2), 271 – 280

_____ (1984b) 'Liability for harm versus regulation of safety.' *Journal of Legal Studies* 13(2), 357 – 374

_____ (1985) 'Criminal law and the optimal use of nonmonetary sanctions as a deterrent.' *Columbia Law Review* 85(6), 1232 – 1262

_____ (2004) *Foundations of Economic Analysis of Law* (Cambridge, MA: Harvard University Press)

Shleifer, Andrei, and Robert W. Vishny (1993) 'Corruption.' *Quarterly Journal of Economics* 108(3), 599 – 617

Stavins, Robert N. (1998) 'What can we learn from the grand policy experiment? Lessons from SO2 allowance trading.' *Journal of Economic Perspectives* 12(3), 69 – 88

Stigler, George J. (1970) 'The optimum enforcement of laws.' *Journal of Political Economy* 78(3), 526 – 536

_____ (1971) 'The theory of economic regulation.' *Bell Journal of Economics* 2(1), 3 – 21

Teece, David J., David Sunding, and Elaine Mosakowski (1993) 'Natural resource cartels.' In *Handbook of Natural Resource and Energy Economics,* ed. Allen V. Keese and James L. Sweeney, vol. 3 (Amsterdam: North-Holland) chapter 24, pp. 1131 – 1166

Tirole, Jean (1986) 'Hierarchies and bureaucracies: On the role of collusion in organizations.' *Journal of Law, Economics and Organization* 2(2), 181 – 214

_____ (1988) *The Theory of Industrial Organization* (Cambridge: MIT Press)

Train, Kenneth (1991) *Optimal Regulation: The Economic Theory of Natural Monopoly* (Cambridge, MA: MIT Press)

UNEP-PNUE (2001) 'Tailings dams: Risk of dangerous occurrences.' Bulletin 121, Commission Internationale des Grands Barrages

Vasquez Cordano, Arturo L. (2006a) 'Sistemas de sanciones por daños ambientales para la fiscalizacion de la industria de hidrocarburos en el Peru.' Working Paper 20, OSINERGMIN - Peru, Lima

_____ (2006b) 'La organizacion economica de la industria de hidrocarburos en el Peru: El mercado del gas licuado de petroleo.' *Revista de la Competencia y de la Propiedad Intelectual* 2(3), 63 – 131

Vasquez Cordano, Arturo L., and Edward J. Balistreri (2010) 'The marginal cost of public funds of mineral and energy taxes in Peru.' *Resources Policy* 35(4), 257 – 264

Vasquez Cordano, Arturo L., and Jose D. Gallardo (2006) 'Sistemas de supervision y esquemas de sanciones para el sector hidrocarburos.' Working Paper 10, OSINERGMIN - Peru, Lima

Viscusi, W. Kip, Joseph E. Harrington, and John M. Vernon (2005) *Economics of Regulation and Antitrust,* 4 ed. (Cambridge, MA: MIT Press)

Weitzman, Martin L. (1974) 'Prices vs. quantities.' *Review of Economic Studies* 41(4), 477 – 491

White House (2011) 'The Macondo well and the blowout.' Final Report, National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling

Williamson, Oliver E. (2000) 'The new institutional economics: Taking stock, looking ahead.' *Journal of Economic Literature* 38(3), 595 – 613

Wittman, Donald (1977) 'Prior regulation versus post liability: The choice between input and output monitoring.' *Journal of Legal Studies* 6(1), 193 – 212

World Bank (2002) *World Development Report: Building Institutions for Markets* (Washington D.C.: World Bank)

Xepapadeas, A. P. (1991) 'Environmental policy under imperfect information: Incentives and moral hazard.' *Journal of Environmental Economics and Management* 20(2), 113 – 126

Zener, Robert V. (1974) 'Antitrust and pollution control: An EPA perspective.' *University of Pittsburg Law Review* 36, 705 – 714