Improving Audit Mechanisms for Environmental Information Disclosure Programs

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RESEARCH REPORT

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Content

1. Introduction

Environmental information disclosure programs are an increasingly popular market-based instrument for environmental regulation around the world. This instrument creates market-based incentives for firms to voluntarily reduce their toxic emissions. Under environmental information disclosure programs ("disclosure programs"), the government typically requires firms to monitor, measure and catalogue their industrial pollution releases and their handling of certain toxic materials. The catalogued data in turn is shared with a regulatory body, which then makes the bulk of that information available to the general public. The theory is that the market pressure created by the firms' consumers and investors and the surrounding communities create incentives for firms to reduce their emissions. Examples of the application of such instruments include Canada's National Pollutant Release Inventory (NPRI), the U.S. Toxic Release Inventory program (TRI), and the recently introduced European Pollutant Emission Register (EPER).

The most essential component in the design of information disclosure programs for environmental protection is the ability to enforce compliance among the firms, e.g. the disclosure reports of the firms need to be truthful. Whenever the compliance level among regulated firms is low, the success of disclosure programs is at risk. Various studies have shown, that many firms do not truthfully report their emission levels, mainly because both audit probabilities and penalties for underreporting are usually low. (We define the audit probability as the probability that a firm is inspected and underreported emissions are detected).

Compliance among firms with disclosure programs can usually be achieved through an effective fine-based enforcement system operated by environmental regulatory agencies. E.g. enforcement agencies conduct inspections at the site of the firms and whenever the installation is found to have caused higher emission levels in comparison to the reported emissions by the firm, a fine needs to be paid on the undisclosed fraction of the emissions. Such an enforcement system chiefly relies on a sufficiently high audit probability to deter non-compliance by firms. However, conducting audits is costly for the agencies given the increasing complexity of some production processes and the significant amount of human and physical resources required to conduct inspections. Many environmental enforcement agencies around the world have insufficient budgets to carry out the required audits and this problem is compounded by ongoing budget cuts. (See textbox 1 for further details). It follows that using the scarce audit resources more effectively to improve the compliance levels among firms is critical for underfunded regulatory agencies.

This paper focuses on improving the effectiveness of existing and future inspection strategies (audit mechanisms) for disclosure programs. More effective audit mechanism not only protect the environment better by promoting higher levels of compliance among firms, but also enhance competitive fairness in the marketplace. Effective inspections help to 'level the playing field' within an industrial sector by ensuring that law-abiding companies are not competitively disadvantaged as a result of their compliance efforts. The goal of this paper is to review the auditing approaches for disclosure programs that have been discussed in the recent environmental economics literature, and to explain how they could be applied by under-funded environmental enforcement agencies in order to make optimal use of their available audit budget resources.

This paper is organized as following. Section two provides an overview of the theory underpinning disclosure programs, as well as of empirical studies that test the validity of the theory. Section three introduces the basic ideas of strategic decision theory which is the foundation of many contributions about auditing mechanisms in the environmental economics literature. Section four describes the commonly applied random audit mechanism and introduces two audit mechanisms that can lead to improved environmental performance: The dynamic audit mechanism and the competitive audit mechanism. Section five discusses some limitations of the analysis. Section six concludes and provides policy implications.

Example: Ontario. Compliance among firms can usually be achieved through an effective fine-based enforcement system implemented by environmental regulatory agencies. In Canada's largest Province Ontario for instance, the Sector Compliance Branch (SCB) of the Ministry of the Environment (MOE) conducts inspections of companies and sites in business sectors to ensure that these firms are in compliance with all of Ontario's provincial environmental laws and regulations. Such an enforcement system chiefly relies on sufficiently high audit probabilities to successfully deter non-compliance by regulated firms.

The probability with which a firm in a given industry in a given time period is inspected is determined by the agency's operating budget. Many environmental enforcement agencies around the world have insufficient budgets to carry out the required inspections at the sites of the firms and this problem is compounded by ongoing budget cuts. For example, MOE's operating budget decreased by 45% since 1992/1993, while at the same time the operating budget of the Ontario government increased by 72% (ECO (2011), p.81). Currently, MOE is responsible for the inspection of at least 125,000 facilities to ensure that they are complying with all of its provincial environmental laws and

regulations. However, MOE only has audit resources to conduct approximately 5,000 inspections each year and some facilities may go decades without inspections (ECO (2007), p.23-24). When MOE conducts inspections at polluting facilities, high levels of non-compliance are regularly found (ECO (2007), p.25-26).

2. Environmental Information Disclosure Programs

This section provides an overview of the theory underpinning environmental information disclosure programs ("disclosure programs"), as well as of empirical studies that test the validity of the theory. Disclosure programs are an increasingly popular market-based instrument for environmental regulation throughout the world. Bui and Mayer (2003) summarizes the advantages of disclosure programs in the following way:

> *"Using disclosure of private information as an "informal" regulatory tool is attractive because it is relatively low-cost. Theoretically, both the cash-starved regulatory agency and the "regulated" plant could face lower pollution abatement control expenditures. Instead of directly regulating plants and ensuring compliance, the enforcement agency only would be responsible for collecting and maintaining a public database, increasing community awareness, and penalizing firms for inaccurate reporting. A polluting firm would be free to choose how much to change its emissions and to use whatever abatement technology it wanted. Community policing would pressure firms to reduce actual emissions."*

According to economic theory, the provision of information by firms about their pollution enhances the environmental performance of self-reporting firms (Arora and Gangopadhyay 1995, Maxwell et al. 2000, and Khanna 2001). In an empirical study by Koehler and Spengler (2007), it was found that emissions of toxic chemicals listed in the the U.S. Toxic Release Inventory program (TRI) fell by over 45% in the first two decades following the inception of the program in 1987. This decreasing trend in toxic chemicals led to the widespread conclusion that informational regulation is effective.

Konar and Cohen (1997) explain information disclosure programs this way:

> *"If consumers, community groups, or investors care about a firm's emissions, providing more firm-specific environmental information may cause consumers to adjust their purchase decisions, community groups to pressure firms to reduce pollution beyond that required by federal laws, or investors to change their portfolios. Thus, mandatory disclosure requirements might be viewed as a form of "market-based incentive" for firms to change their behavior. In theory, each firm will independently weigh the costs of public disclosure of "bad" information against the costs of taking actions that will put the firm in a more favorable light. Firms will voluntarily go beyond any legally mandated regulatory standard if it is in their interest to do so. This will only work, however, if the "public" cares enough*

about the information being released to "punish" firms that are bad actors."

There are three main ways in which disclosure programs spur improved environmental performance (based on Powers (2011)):

1. ***Output market pressure:*** Disclosed information may affect the demand for firms' goods
2. ***Input market pressure:*** Disclosed information may affect the demand for firms' securities and their ability to hire and retain employees
3. ***Community pressure:*** Disclosure may encourage private citizens to sue polluters

Output market pressure. Firms with a market base of consumers who are environmentally conscious have an incentive to reduce their emissions voluntarily, as their consumers may avoid buying their products if they produce high emissions. In an empirical study Antweiler and Harrison (2003) analyze the effectiveness of green consumerism in response to the publication of Canada's National Pollutant Release Inventory (NPRI). The study considers different release media (air, water, land, subsoil, and offsite transfers). Their study finds empirical evidence that companies respond most strongly to consumer pressure by reducing their releases of easily visible pollution (e.g. air), and increasing their releases of less easily visible pollution (e.g. subsoil).

Input market pressure. Hamilton (1995) and Khanna, Quimio, and Bojilova (1998) find that capital markets show a significant negative reaction to firms with high emissions published in the U.S. TRI. Specifically, Hamilton (1995) finds that the higher the pollution figures are in a firm's TRI reports, the more likely print journalists are to write about the firm's toxic releases and the more likely the firm is to have abnormal negative stock returns shortly after the figures are released.

Community pressure. Disclosure programs may also increase local community pressure against firms in order to force firms to lower their emissions. However, Bui and Mayer (2003) studies how local communities react to information about emissions disclosed through the TRI. This study shows that there is no significant broad-based community response to the data disclosed through the TRI, and it questions the ability of the public to process complex information on hazardous emissions.

In conclusion, empirical evidence supports the theory that disclosure programs are an

effective market-based instrument for improving the environmental performance of firms with respect to certain pollutants, and that the main impetus for the improvement is through input and output market pressure.

Greatest Challenge for Disclosure Programs: Compliance by Firms

The greatest challenge for disclosure programs is that the programs rely on firms truthfully reporting their emissions. If a firm truthfully reports its emissions, it may face negative repercussions such as input and output market pressure. At the same time, firms may decide not to reduce their emissions given the costs of abatement. Hence, when the fine for underreporting emissions is relatively low, the firm may decide to underreport some or all of its emissions and face the fine for not reporting truthfully. The empirical evidence showing that some firms underreport their emissions is extensive:

Marchi and Hamilton (2006) show for the case of air emissions in the U.S. chemical industry, that some regulated plants frequently decide not to report accurate estimates of their actual air emissions. Wolf (1996) shows that up to one-third of facilities regulated by the TRI fail to comply with reporting requirements in a given year. Williams et al. (2002) assess the semiconductor industry emissions and show that TRI levels are significantly lower than those reported to other national toxic chemical release databases, indicating significant underreporting in the TRI.

The empirical studies summarized above show that the failure of firms to comply with reporting requirements is a significant issue. Compliance among firms can usually be achieved through an effective fine-based enforcement system implemented by environmental regulatory agencies. The fines for non-compliance in such a system are capped at a level that is determined by the policy-maker to be in the public interest given considerations such as, acceptable pollution levels, business interests, the economy and jobs.

With capped fines, an enforcement system relies heavily on sufficiently high audit probabilities to successfully deter non-compliance. However, conducting audits is costly for the regulatory agencies, given the complexity of production processes and the human and technological resources required to carry out the audits. Therefore, the probability of a regulated firm being audited is determined by the inspection agency's ability to conduct audits. This ability, in turn, depends on the operating budget of the inspection agency, which is often limited (see text box 1 for an example).

Using the scarce audit resources more effectively (i.e. better audit strategies) to improve the compliance levels among firms is critical for underfunded enforcement agencies in Canada and around the world. Several environmental economists have suggested improved audit mechanisms for disclosure programs. Their studies often take into account the strategic behavior of firms facing such a regulation. In so doing, these studies apply microeconomics theory, especially strategic decision theory. The next section outlines the basic ideas of this theory.

3. Strategic Decision Theory

A fundamental principle of microeconomics is that firms respond to incentives. An incentive is something that encourages or discourages firms to make certain operational choices, such as how much money to invest in emissions abatement. Because of the important role that incentives play in modifying a firm's behavior, they should be taken into account when designing environmental policies.

Environmental economists increasingly use strategic decision theory (game theory) to improve the design of environmental policies. According to strategic decision theory, firms respond strategically to incentives created by interactions between institutions, customers and other firms (Dixit and Skeath, 2009). Furthermore, strategic decision theory teaches us "how to deal with someone who knows more than you do." For example, regulated firms typically know more about their own emission levels in comparison to the regulatory authority. Analyzing such a "game" provides some general principles of the behavior of firms. Once it is understood how firms respond to certain incentives with the help of strategic decision theory, this knowledge can be used to design policies that align firms' incentives with the underlying goals of the policy maker.

With regards to compliance issues under disclosure programs, the regulated firms typically know more about their own emission levels in comparison to the regulatory authority, but might be reluctant to share this information. The question addressed in the next section is how to design audit mechanisms that make firms reveal their pollution levels to the regulatory agency even if the revelation of this information is costly for the firms (because they anticipate negative market reactions by consumers or investors), audit probabilities are low (because agencies are often underfunded) and fines for non-compliance are capped (at some level of appropriateness).

In an analysis using strategic decision theory, the enforcement agency and the regulated firms are described as "players" in a "compliance game". To keep the analysis tractable, several simplifying assumptions need to be made in such a model. It is assumed that a firm can either truthfully report all of its emissions or not. Reporting emissions is assumed to have the same per-unit cost for the firm. This cost of reporting emissions can be avoided by underreporting emissions.

In this model, the agency can find out the true level of a firm's emissions through a costly audit (inspection at the site of the firm). The agency's ability to conduct audits depends

on its budget for auditing. For example in Ontario, MOE is responsible for 125,000 firms, but it can only audit 5,000 of them.

If the agency decides to audit the firm, the firm has to pay a fixed per unit penalty if the agency discovers that the firm has underreported its emissions. The agency is rewarded for every period that the firm reports truthfully, because truthful reporting is essential to the success of disclosure programs. The agency is penalized whenever the firm underreports emissions. Thus, the agency's goal is to minimize the frequency of underreporting given its enforcement budget.

The best strategy for the firm, according to strategic decision theory, is clear: The firm is better off truthfully reporting all of its emissions to the public if the expected cost of truthfully reporting is lower in comparison to the expected costs of underreporting emissions and being fined by the agency. If the expected cost of truthfully reporting is higher than the expected costs of underreporting emissions, the firm under-reports its emissions. Therefore, the main reason that firms choose not to report truthfully under environmental information disclosure programs is due to low audit probabilities and fines.

4. Auditing Mechanisms for Disclosure Programs

4.a. The Random Audit Mechanism

It is common for environmental enforcement agencies not to disclose their audit strategy publicly, which means that regulated firms do not know how audit resources are allocated among them. According to strategic decision theory, the rational assumption is that audit resources are allocated equally among all regulated firms. The agency's strategy to split the available audit resources equally between all firms in the industry is called the random audit mechanism. The random audit mechanism typically serves as the benchmark in academic studies, as it is believed to be the most commonly applied audit strategy by agencies.

An example is stated next referring to textbox 1. MOE has audit resources to conduct approximately 5,000 inspections each year while it is responsible for the inspection of at least 125,000 facilities. Hence, the audit probability is 5,000/125,000 = 4%. If the expected negative market reaction of a firm for truthfully reporting the emission level of some pollutant is $10,000 and the penalty for underreporting is $100,000, then the firm weighs the cost of truthfully reporting, which is $10,000, against the expected cost for underreporting, which is $4,000 (4%*100,000). Since underreporting is the cheaper option for the firm, it clearly has an incentive to underreport.

The question that will be addressed in the reminder of this paper is: *Is there be a better way to apply the available audit resources to the regulated firms than through the random audit mechanism?* The next sections of the paper present two alternative mechanisms to the commonly applied random audit mechanism: the dynamic audit mechanism and the competitive audit mechanism. It is shown that the dynamic audit mechanism and the competitive audit mechanism achieve better results for the environment than the random audit mechanism, and consequently that the random audit mechanism is not optimal in terms of the incentives it creates for abating emissions when the enforcement agency is under-funded.

4.b. The Dynamic Audit Mechanism

Many research papers promote the use of dynamic audit mechanisms, which use the information obtained through past audits to inform the probability of future audits (Harrington (1988), Greenberg (1984), Livernois and McKenna (1999), Heyes and Rickman (1999), Friesen (2003)). The basic idea is a system with two enforcement groups. Firms found to violate regulations in the current period are placed in an enforcement group with tougher sanctions in the next period. In general, it is shown that firms that do

not have incentives to comply under the random audit mechanism have incentives to comply under the dynamic audit mechanism. The reason for this that firms in the tougher sanctions group have an additional incentive to comply with the environmental policy, namely the reward of being transferred to the lower sanction group in the next period. Therefore, the compliance history of firms can be used as a basis for allocating audit resources that lead to more effective audit decisions in comparison to a random allocation of audit resources among the firms.

Frisen (2003) explains the dynamic audit mechanism this way:

An enforcement agency can enhance deterrence by dividing regulated firms into two groups according to their past compliance record. Inspection resources are concentrated on firms in one of the groups, the target group, where surveillance is more frequent and the penalty is larger than in the non-target group. Firms inspected and found in violation are moved into the target group. Once there, being moved back into the non-target group rewards firms found in compliance. The "stick" of stricter enforcement and "carrot" for compliance combine to create stronger incentives to comply than a simple random auditing framework. As a result, a firm may comply even when their compliance cost exceeds the expected current penalty. Alternatively, the same level of deterrence can be achieved with the expenditure of fewer monitoring resources.

One of the biggest limitations of the dynamic audit mechanism is that it requires the agency to have access to the compliance history of the firms subject to the environmental policy. New environmental policies often lack this base of information.

4.c. The Competitive Audit Mechanism

Competitive audit mechanisms can lead to better results for the environment even if the enforcement agency has no information about the compliance history. The basic idea of competitive audit mechanisms is that under this audit strategy the agency allocates more of the available audit resources to the firms with the lowest emissions reports compared to the other firms. The agency's comparison between the firms' reports generates a reporting competition between firms. This gives firms the incentive to more accurately report their emissions in order to avoid being audited by the agency under certain conditions.

Gilpatric et. al (2011) introduces the competitive audit mechanism when the agency is

able to predict the true level of any firm's true emission level relatively accurately. Specifically, the authors suggest that the agency should focus their audit efforts on those firms that deviate in their report from the expectation of the agency. The agency's expectation of the emission level of a firm may be informed by a number of factors, including observation of changes in ambient air or water quality in the vicinity of firms' plants, and contact with industry insiders who know which firms are in compliance and which are not. The more that the firm's emissions report deviates from the agency's expectations, the higher the audit probability of the firm will be. The authors state: "In the equilibrium of the game, high levels of compliance are predicted even in some circumstances where purely random audits would yield zero compliance effort." Accordingly, such an audit mechanism has advantages compared to the random audit mechanism.

In the analysis in Gilpatric et. al (2011), it is assumed that emissions are fixed and that the agency is able to predict the firms' levels of emissions relatively accurately. Because the authors focus on firms' reporting behavior and assume emissions are fixed, the firms' incentives for emission abatement remain unclear. Since most environmental policies aim to control emission levels, it is important to include the firms' incentives for abating emissions under a competitive audit mechanism.

Oestreich (2012) compares the effectiveness of various audit mechanisms when firms are allowed to choose both actual emissions and reported emissions. In order to implement the audit mechanism in this study, the enforcement agency does not need to be able to predict the firms' emissions. The agency's inspection strategy is as follows:

1. The agency uses information about the firms that is provided with the firm's emissions report (such as the firm's number of employees, size, types of products it produces, etc.). This process of collecting observable characteristics of subjects is called profiling.[1]
2. Firms with similar profiles are matched together in groups. The main assumption is that these firms benefit from causing emissions in a similar way.
3. In each group, the agency focuses audit resources on the firms with lower emissions reports in comparison to other firms in the same group.

1 Profiling is a feature of sophisticated audit mechanisms applied by some agencies. In this process, subjects with similar profiles are matched and their reports are compared by the agency. For example, Australia's tax authority estimates the tax evasion potential of small firms through a computer-based scoring system that evaluates the evasion potential of a firm based on a comparison of that firm to other declarations given by firms sharing the same profile (Australian Taxation Office (2008) found in Bayer and Cowell (2009), footnote 9).

Oestreich (2012) compares the random audit mechanism (available audit resources are split equally between the firms), to two types of competitive audit mechanisms: (1) The Tullock audit mechanism, i.e. the allocation of audit resources can be influenced to some degree by firms' reports – but not completely. This audit mechanism is named after Gordon Tullock, because the algorithm with which the audit resources are allocated was first introduced in Tullock (1980). (2) The auction audit mechanism, i.e. the agency allocates all of the audit resources to the firm with the lowest report, i.e. the higher reporting firm is "rewarded" with lenient treatment by the agency, while the lower reporting firm is "punished" with the full audit probability.

Table 1 provides an example of the audit probabilities under each of the three audit mechanisms under comparison for two identical firms. In this example, the agency has no information about the true level of emissions caused by firm 1 or 2, but knows that they caused the same level of emissions. Firm 1 reports to have released 3 Mio liters of a toxic substance in a given year while firm 2 reports 9 Mio liters of the same substance. Under the random audit mechanism both firms face an audit probability of 4% regardless of their emissions report. In contrast, competitive audit mechanisms take the reports of the firms into account when allocating audit resources. Under the Tullock audit mechanism the lower reporting firm (firm 1) faces an increased audit probability of 6% while the higher reporting firm (firm 2) faces an audit probability of 2%.[2] Under the auction audit mechanism, the lower reporting firm (firm 1) attracts the highest possible audit probability of 8% while the higher reporting firm (firm 2) faces an audit probability of 0%. Note, that the combined audit probability is the same in all three cases, e.g. the money spent on auditing is identical for the agency in all three cases.

[2] The audit probability under the Tullock audit mechanism is calculated as following: the audit probability of the lower reporting firm 1 is calculated as: 4%*9/(3+9)*2=2%. The audit probability of the higher reporting firm 2 is calculated as: 4%*3/(3+9)*2=6%. For details refer to Oestreich (2012).

	Firm 1	Firm 2
Report (Example):	3 Mio	9 Mio
Audit Probability under: **Random audit mechanism**	4%	4%
Audit Probability under: **Tullock audit mechanism**	6%	2%
Audit Probability under: **Auction audit mechanism**	8%	0%

Table 1: Allocation of audit resources under the three audit mechanisms of interest

The Tullock audit mechanism leads to more accurate reporting by firms compared to the random audit mechanism. Under the Tullock audit mechanism, firms have an additional incentive to report truthfully as it enables them to lower their audit probability. In example 1, firm 1 would have an incentive to more truthfully report in order to lower its own audit probability and increase the audit probability of firm 2. This competition results in more truthful reports by both firms compared to under the random audit mechanism. At equilibrium, the audit resources are split equally between the two firms, because the two firms report the same amount of emissions. However, the amount of emissions that they report is higher than the amount they would have reported under the random audit mechanism, even though the audit probability is the same.

Interestingly, the Tullock audit mechanism not only leads to more accurate reports compared to the random audit mechanism, but also it also achieves bester results for the environment. It provides the strongest incentives for firms to lower their emissions among the three audit mechanisms under comparison. Under the Tullock audit mechanism, when firms make a decision about the amount of emissions to create during the production process, they take into consideration the competition resulting in more accurate reports and the potential degree of negative market reaction to more accurate reports. Since the firms know that they are going to report and pay for a larger share of their emissions than they would under the random audit mechanism, the effective cost of emissions has been increased. Therefore, the firms reduce their emissions.

The auction audit mechanism also leads to more accurate reporting by firms compared to the random audit mechanism. Just as under the Tullock audit mechanism, firms have an additional incentive to report truthfully as it enables them to lower their audit probability. However, the auction audit mechanism leads to higher emission levels compared to the other two audit mechanisms. A characteristic of the auction audit mechanism is that a firm does not always make the same reporting and emission choices at equilibrium, nor does it always make the same reporting and emission choices as the other firm. Therefore at equilibrium under the auction audit mechanism, the two firms could have different emissions, yet the firm with the lower emissions will be "punished" with the full audit capacity for accurately reporting, because it reports lower emissions as compared to the firm that produces higher emissions. On the contrary, the audit auction mechanism "rewards" the firm that produces and reports higher emissions compared to the lower-reporting firm, even if the higher-reporting firm significantly underreports its emissions. As a result, the auction audit mechanism leads to higher emission levels compared to the random audit mechanism.

5. Empirical Confirmation of the Theoretical Predictions

In order to inform the efficient design of environmental policies, the theoretical predictions regarding the performance of the audit mechanisms outlined in this paper should be confirmed with real-world data. In particular, given the paucity of reliable and available field data in the case of environmental compliance by firms, it would be informative to test whether the qualitative predictions derived from the models introduced in this paper hold true in a laboratory computer experiment which tests how participants respond to incentives.

Some of the theories mentioned in this paper have been tested empirically. Cason and Gangadharan (2006) report a laboratory experiment based on the dynamic audit mechanism. "The laboratory evidence presented in this article shows that, in a broad sense, participants' behavior is consistent with the theoretical predictions of this dynamic enforcement model." However, the authors also find that the compliance behavior by firms does not change as sharply as the model predicts. Gilpatric et. al (2011) broadly confirm the theoretical predictions of the competitive audit mechanism using an experimental design that allows for the identification of the effects of changing the audit probability, fixed audit cost, and marginal penalty. These two empirical studies mainly support the theoretical predictions.

6. Conclusions and Policy Implications

Environmental information disclosure programs create market-based incentives for firms to voluntarily reduce their toxic emissions, but they rely on compliance by firms in order to successfully achieve their objective. Compliance among firms can usually be achieved through an effective fine-based enforcement system by environmental enforcement agencies. Such an enforcement system chiefly relies on sufficiently high audit probabilities so that it successfully deters non-compliance by firms. However, conducting audits is costly for the agencies. Since, many environmental enforcement agencies around the world have insufficient budgets to carry out the required audits, innovative methods are required in order to make optimal use of the available audit resources.

It is common for environmental enforcement agencies to not disclose their audit strategy publicly. Where this is the case, regulated firms do not know how audit resources are allocated among them. Accordingly, the regulated firms behave as though the enforcement agency splits the available audit resources equally among the firms. This audit strategy is called the random audit mechanism, and economists believe that it is the most commonly applied audit strategy by regulatory agencies.

This policy background paper shows that this commonly applied random audit mechanism is not optimal in terms of the incentives it creates for abating emissions when the enforcement agency is underfunded. Instead, it is shown that there are two different audit strategies that lead to more efficient use of audit resources and better results for the environment compared to the random audit mechanism. These strategies are called the dynamic audit mechanism and the competitive audit mechanism.

The dynamic audit mechanism takes into account the compliance history of firms as a basis for allocating audit resources. This leads to more effective audit decisions in comparison to a random allocation of audit resources among regulated firms. The competitive audit mechanism takes the firms' current reports into consideration when allocating audit resources. Some types of competitive audit mechanism lead to more accurate reporting and fewer emissions compared to the random audit mechanism. Some of these audit strategies have also been shown to perform better than the random audit mechanism when tested in computer-mediated laboratory experiments.

More effective audit mechanisms not only protect the environment better by promoting higher levels of compliance among firms, but also enhance competitive fairness in the marketplace. Based on economic theory, the presented dynamic audit mechanisms and some of the presented competitive audit mechanisms have the potential to make better use of scarce audit resources than the commonly applied random audit mechanism. However, further research is required, in order to completely assess the potential for improving the effectiveness of current and future audit mechanisms for disclosure programs, including in the disciplines of law and political science.

While this paper focuses on the environmental field, the audit strategies discussed have potential for application in regulatory areas as diverse as tax collection, banking regulation, health and safety regulations, besides others.

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