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1. Introduction

The scope of laws and regulations is wide-reaching and encompasses environmental laws and regulations, tax compliance, occupational health and safety, tax exemptions for owner occupied housing, insurance fraud, claims for social security benefits, misbehaviour by banks and financial advisors, and much more. This chapter focuses on compliance with environmental laws and regulations, although many of the lessons can be applied more broadly.

Effective laws and regulations require adequate monitoring and enforcement. Even the best designed environmental regulation can be ineffective if regulators fail to take steps to promote compliance. Yet this is costly and resources are limited. While systematic data on environmental enforcement is hard to find, Shimshack (2014) reports that between 1994 and 2011, the U. S. Environmental Protection Agency conducted approximately 19,850 federal inspections per year. Combined with the additional enforcement expenditures at the state level, it would appear that governments spend billions of dollars monitoring and enforcing environmental regulation each year. Policy makers therefore have incentives to find cost effective ways to improve compliance among firms and individuals. Increasing compliance will better achieve regulatory goals, such as cleaner air or fewer workplace accidents.

This chapter discusses the multiple ways that experimental economics can improve our understanding of the factors that affect compliance and lead to more effective use of limited enforcement resources. This includes testing theory, examining behavioural factors and the effectiveness of social observability, and test-bedding new methods in a low cost and low risk environment. We provide examples of all of these, and show that experiments are a useful complement to observational studies and are an essential methodology in the economics tool kit.

We demonstrate how experimental economics can improve our understanding of the factors affecting compliance in ways that are often impossible using naturally occurring data.

Experiments, of course, also set the gold standard for causal inference. Although they typically study simplified and somewhat artificial settings, experiments can nevertheless provide highly relevant empirical evidence, particularly when guided by clear theoretical principles. For example, experiments can help test theoretical conclusions regarding the benefits of relative auditing rules versus random auditing of firms or individuals. Grounding an experimental design in theory can help generalize the lessons beyond the specific setting considered in the experiment.

Why should firms and individuals comply with regulations? Beginning with Becker (1968), a rich body of literature has explored the economics of compliance.[i] Key in the canonical model is the tradeoff between the expected benefits and expected costs of compliance, where the benefits depend on both avoiding being detected as noncompliant and the potential penalty imposed if detected. While the empirical literature on compliance with environmental regulations demonstrates the importance of economic incentives (see for e.g., surveys of the evidence by Shimshack, 2014; and Gray and Shimshack, 2011), these authors also recognise the potential role of other "socio-behavioural" factors (Alm and Shimshack, 2014) such as reputation and moral costs.

Empirical studies can document general relationships between enforcement and outcomes such as pollution, but causality is harder to establish. One issue is that deterrence measures such as inspections are potentially endogenous; violators are more likely to be inspected, but for reasons that are unobservable to the analyst. In addition, assumptions need to be made and measures constructed regarding perceptions of key variables such as inspection probabilities and penalties. Furthermore, obtaining data on compliance for uninspected firms is difficult and often not available. Violators have a reason to stay silent. Firms' cost structures are also difficult for regulators to accurately observe. All of these issues, however, can be overcome with experiments.

A second major advantage of experiments in this context is the opportunity to investigate behavioural influences which are challenging to manipulate using naturally occurring data. Even if theory and empirical evidence exist, laboratory experiments can test the robustness of those results to behavioural factors, sometimes uncovering unanticipated behaviour that may undermine (or promote) the success of a policy. For example, experimental designs can observe or minimize reputation, social image, and other social motives and try to draw causal inferences. Experiments can also study the interaction between standard economic and behavioural factors.

Moving beyond understanding the basic determinants of compliance, a third significant advantage of experiments is their ability to trial (or, "test-bed") different enforcement strategies in a low cost and low risk setting. For novel policy approaches, the data required for empirical testing are simply unavailable, either in a timely fashion, or at all. Laboratory experiments provide perhaps the only opportunity to explore empirically different policy options and counterfactuals. Field experiments are also useful to explore new regulatory policies—but they can be more difficult to conduct. This chapter focuses on laboratory experiments.

Our aim is not to provide a comprehensive survey but to highlight some specific contributions and provide examples to illustrate how experiments can be used to investigate a range of applications on regulatory compliance, as well as suggesting areas for future study.[ii] Section 2 illustrates how experiments can help in designing tools of monitoring and enforcement based on standard economic incentives (e.g., state-dependent enforcement, probability of detection versus fines, competitive audit mechanisms, contracts). Section 3 considers a specific environmental application in greater detail: compliance in "cap-and-trade" markets for pollution permits. Section 4 discusses how leveraging behavioural economic insights (framing, information, social pressure, reciprocity) can improve compliance. These nonbinding incentives show promise for behavioural change and in affecting social norms. We

caution, however, against relying too heavily on such approaches intended to activate behavioural motivations in this compliance domain since the evidence is mixed. Section 5 concludes.

2. Standard Economic Incentives

This section describes how economics experiments can provide valuable empirical evidence on the standard economic tools of deterrence. This includes the basic levers such as the probability of detection and the penalties imposed. The main purpose of enforcement is to deter potential violators in the first place; so-called general deterrence. Experiments can be used to test theoretical predictions on the relationship between enforcement and compliance in a controlled way. Since enforcement is costly, understanding these relationships can inform budget constrained regulators on how to deploy their limited resources in the most effective manner. Note that almost all of the experiments in this section are neutrally framed and therefore not specific to an environmental context. We briefly discuss this feature of the experimental designs in the concluding section.

2.1 General Deterrence

The seminal economics of crime model of Becker (1968) provides a framework for the compliance decisions of firms subject to environmental laws and regulations. In particular, when deciding on their level of compliance, environmental managers compare the expected costs of compliance (e.g., pollution abatement costs) with the expected benefits of compliance. Typically, compliance benefits are determined by the avoidance of expected penalties. These expected penalties are comprised of the two key components: the probability of punishment and the severity of punishment if detected.

The most fundamental question that can be asked is whether polluters respond to these basic levers. That is, does general deterrence work, in that expected penalties deter violations

occurring in the first place? Friesen (2012) explores this question in the context of a regulatory compliance task where in each decision period participants in the experiment choose whether or not to comply with a generic regulation. Compliance incurs a certain cost, whereas violation entails a risk of being inspected and consequently incurring a penalty. The relevant parameters of compliance cost, likelihood of inspection, and penalty magnitude are varied systematically across 30 periods of choices. Friesen (2012) finds that the general deterrence hypothesis holds, as increases in either the probability of inspection or penalty (ceteris paribus) significantly increases compliance.[iii] She also compares the effectiveness of the two levers of probability and severity of punishment, finding that an increase in the severity of punishment is a more effective deterrent than an equivalent increase in the probability of punishment. This is consistent with risk averse expected utility maximization.

Anderson and Stafford (2003) ask similar questions, but in the context of a public good experiment with an option to use a third-party punishment mechanism (neutrally framed as an earnings adjustment) to probabilistically punish free riding. Consistent with Friesen (2012), they also find that compliance (here public good contributions) increases with both levers, and that subjects respond more to increases in punishment severity than to punishment likelihood.

These findings can give regulators confidence in the basic underlying theoretical framework of the deterrence approach, and they also provide information on the most effective lever to pull. The difference is that in Friesen (2012) violations do not cause harm to others, whereas in the public good setting of Anderson and Stafford (2003) a violation reduces the public good, arguably capturing an important aspect of environmental compliance. This difference in design is evident in later studies as well. Consistent findings across different settings increases confidence in the external validity of the findings.

2.2 Dynamic Enforcement

In contrast to random inspections, under conditional audit rules the regulator selects firms for inspection on the basis of certain characteristics. This kind of targeting is explicitly mentioned in the U.S. Environmental Protection Agency's "Next Generation Compliance" initiative which includes "Innovative Enforcement" approaches including data analytics and targeting as one of the five key and interconnected components to improve compliance.[iv]

In this subsection, we emphasize the characteristic of past compliance status. While the experiments discussed in the previous subsection involve repeated decision making, the enforcement parameters faced in a later period do not depend on earlier revealed compliance decisions. In contrast, many regulations invoke stricter penalties for repeat offenders, as well as increased scrutiny (likelihood of detection) for past violators. This can lead to stronger compliance incentives when individual penalty levels are limited by statute.

Theoretical models beginning with Harrington (1988) demonstrate the advantages of such dynamic enforcement. Specifically, Harrington (1988) models a simple approach where polluters are allocated into two groups based on their past compliance record, determined by their inspection outcomes. Polluters in the non-targeted group face a relatively low detection probability and penalty. However, polluters that are revealed via an inspection to be in violation are moved to the target group for the next period. This structure enhances (leverages) compliance incentives, because in the targeted group inspections are more frequent and penalties higher than in the non-targeted group. In addition, the opportunity to escape the target group (back to the less scrutinised non-target group) if found to be in compliance, gives polluters an additional incentive to comply. Harrington (1988) demonstrates theoretically how this approach can increase compliance without increasing the inspection budget, thereby leveraging enforcement resources. Friesen (2003) expands this case from what she labels as past compliance targeting to optimal targeting. Optimal targeting enhances compliance even

further by fully concentrating inspection resources on polluters in the target group, while also employing a random mechanism to move polluters into the target group. Targeting is optimal as the best transition parameters are derived rather than assumed.

Clark, Friesen and Muller (2004) provide an experimental test of the Harrington (1988) model in comparison to both Friesen (2003) and the baseline case of purely random inspections. The theoretical prediction is that the same level of compliance can be achieved as under random audits, but with fewer inspections using past compliance targeting and even less with optimal targeting. Clark et al.'s (2004) experimental results confirm this ranking of inspections although only the difference between optimal targeting and random inspections was statistically significant. Unexpectedly, however, compliance rates were significantly lower with optimal targeting than in either random or past compliance targeting.

Cason and Gangadharan (2006a) also test the Harrington (1988) model but using natural rather than neutral language. The various treatments test different parameter values for the cost of compliance and the probability of being released from the target group. While they find that participants respond to the parameters in the predicted direction, the responses are not as sharp as predicted by theory. Using a simple model of bounded rationality (noisy best response), Cason and Gangadharan (2006a) find that subjects are less likely to make errors that are more costly and that accounting for this pattern of decision errors significantly improves the model fit. This suggests how people act at the margin (where incentives to optimize are small) can influence the success of a policy.

In general, these experimental findings provide support for the greater effectiveness of dynamic enforcement, through the mechanisms modeled by theory. However, they also suggest the need for caution when using more complex enforcement schemes to ensure these benefits are not undermined by bounded rationality and decision errors. More investigation of bounded rationality appears warranted in this context. Note that these experiments took considerable

care to describe the multi-group inspection regimes. In practice, firms and individuals regulated under these schemes may not be as well informed. This further complicates interpretation of the benefits of such schemes.

2.3 Relative Conditional Audit Mechanisms

A more recent literature explores conditional audit mechanisms that use relative comparisons with other polluters, rather than just a firm's own past compliance information. These mechanisms create competition among polluters to avoid being inspected, thus providing another means to leverage limited enforcement resources and increase compliance.[v] In particular, the probability of an audit depends on relative comparisons among peers, with inspections directed at polluters who are believed to be less compliant than other similar regulated entities.

Gilpatric, Vossler and McKee (2011) model a competitive audit regime where the regulator employs a rank-order tournament based on a noisy signal about compliance. Specifically, the regulator ranks facilities within a peer group based on a set of noisy signals and audits the facility expected to be the least compliant. Due to a strictly binding inspection budget, the regulator can only select a limited number of facilities to audit. The authors show theoretically that a rank-order tournament generates greater compliance than random audits using the same inspection budget. They then provide empirical support for this result in an experiment, and also find support for the model's comparative static predictions (e.g. the effect of increasing the penalty or audit cost).[vi]

In Gilpatric et al. (2011), compliance means the truthfulness of reporting emissions, with emissions themselves treated as fixed. While accurate reporting is clearly a desirable outcome, later experiments also consider the impact that audit tournaments have on pollution itself. For example, Cason, Friesen and Gangadharan (2016) report an experiment that considers both reporting and emissions choices. They find that audit tournaments lead to

significantly lower misreporting than random audits, and that the benefit of audit tournaments does not erode with experience. Importantly, they also find that the benefits of audit tournaments extend beyond encouraging truthful reporting, with a reduction in emissions and the negative externality they generate. While these findings confirm the basic mechanisms of the model work as expected theoretically, the impact on emissions is worthy of further exploration.

Gilpatric, Vossler and Liu (2015) combine both types of conditional audit mechanisms to create a dynamic tournament mechanism. The mechanism is based on the Harrington (1988) two group approach but with tournaments to govern the transitions between the two groups. Specifically, audited firms in each group compete in a rank order tournament, with the worst (largest violator) in the non-target group being moved to the target group, while the best escapes the target group for the next period. They compare this dynamic tournament mechanism to both static random audits and dynamic targeting based on a (non-competitive) standard. In the experiment, both dynamic mechanisms significantly increase compliance relative to random audits. However, while the results of the dynamic tournament mechanism are consistent with theory, the dynamic standards mechanism is not. Instead, compliance under the dynamic standards mechanism is insensitive to changes in either audit costs or the transition probabilities, which are both theoretically important parameters.

Gilpatric et al. (2015) suggest that the two dynamic tournaments perform differently because the incentives in the tournament mechanism are more obvious than in the dynamic standards mechanism, which requires individually solving a complicated dynamic problem. They argue that complexity might also explain the mixed findings in earlier experimental tests of targeting (Clark et al, 2004; Cason and Gangadharan, 2006a). In addition, Gilpatric et al. (2015) use a continuous choice setting compared to discrete choice in these two earlier studies, showing robustness to the choice of strategy space. Finally, note that while they also add

heterogeneity in (pre-determined) pollution levels in their model, the experiment uses homogenous emissions and the interaction of reporting and heterogeneous emission levels remains unexplored.[vii]

2.4 Underexplored Topics

One aspect largely unexplored in the experimental literature is the impact of the organizational structure in which regulatory compliance decisions occur. Specifically, while a manager might make a decision to comply, the actions of others in the organization (e.g. workers) significantly affect the actual outcome. In a recent paper, Cason, Friesen and Gangadharan (2020) explore regulatory compliance in social dilemmas with and without a principal-agent relationship. In their experiment, agents choose costly effort levels that can reduce the probability of an accident (regulatory violation) occurring. This intra-firm decision is embedded in an inter-firm social dilemma whereby an accident at any firm within the group harms all firms. In this setting, Cason et al. (2020) investigate whether the principal can design a contract that incentivizes the agent to take a desired (compliance) choice. Different treatments explore different contract forms: an unconditional wage plus a non-contractual bonus, a conditional (on outcome) wage, and a conditional wage plus a non-contractual bonus. These are compared to a baseline environment without an agent, so that the principal makes the compliance choice directly. Cason et al. (2020) find that principals use a combination of conditional wages and bonuses to help solve the agency problem. Hence, while the social dilemma still reduces overall welfare, the conditional contracts ensure that agency risk does not make this problem worse. In contrast, unconditional (gift exchange) contracts worsen the social dilemma; i.e. reciprocity is insufficient to incentivize the agent when there is outcome uncertainty. Future experiments can explore these issues more.

The experiments described above all involve inspection probabilities and penalties that are known and announced to participants. In reality, regulated firms must form beliefs of both

the likelihood of being detected and the penalty if caught in violation. While legal scholars have long espoused the benefits of enforcement uncertainty (e.g., Harel and Segal, 1999), only two laboratory experiments specifically explore this topic, neither in an environmental compliance context. DeAngelo and Charness (2012) find that uncertainty about the enforcement regime (due to participants' failure to understand a more complex enforcement regime) significantly reduces violations in a laboratory experiment framed as speeding. On the other hand, in a study of tax compliance, Salmon and Shniderman (2019) find limited evidence of ambiguity aversion, which suggests that ambiguous enforcement might not improve compliance, and that instead it might be beneficial to reveal the parameters of the enforcement regime rather than conceal them. Given the prevalence of enforcement uncertainty in practice, this is clearly an important aspect for future study, and laboratory experiments are ideal to study such topics in a controlled manner.

3. Enforcement in Emissions Permit Markets

Considerable experimental research has investigated compliance in emissions permit markets. In this type of environmental regulation, sometimes referred to as "Cap-and-Trade," the regulator sets a limit on the total volume of pollution allowed, and allocates property rights over this allocation by distributing thousands of individual permits. A permit typically conveys the right to emit a specific amount of pollution over a specific time period; e.g., one tonne of CO_2 during calendar year 2021. The initial allocation for each time period can be auctioned, providing a source of government revenue, but sometimes a portion of the allocation is "grandfathered" to existing polluters at no cost. The government often reduces the number of permits allocated over time to achieve additional reductions in emissions.

A key distinguishing feature of this regulatory approach is that it provides flexibility for meeting pollution control goals, since individuals and firms can trade the emissions permits

amongst each other. In many trading schemes parties can bank unused permits for future use, or even borrow from future allocations. This flexibility means that firms face the same tradeoff on the margin of incurring their marginal cost of an additional amount of pollution abatement or paying the market price for a permit to avoid the abatement. Firms with low marginal abatement costs can undertake abatement and sell permits, while those with high abatement costs can avoid abatement and buy permits. In a competitive market with zero transactions costs this equates all firms' marginal abatement costs—at the common permit price—and this minimizes the overall cost of meeting the original limit the regulator set for the total pollution allowed (Montgomery, 1972).

The first large-scale permit trading scheme was implemented in Title IV of the 1990 Clean Air Act Amendments in the U.S., which effectively cut in half the amount of SO_2 released by large sources (e.g., coal-fired electricity generators). Emissions trading is particularly suited for uniformly-mixed pollutants (i.e., where the geographic location of the emissions source is not relevant to address the environmental problem), so the most important permit markets today are used to regulate greenhouse gas (GHG) emissions. The largest is the European Union Emissions Trading Scheme (EU ETS). Markets also exist in Australia, New Zealand, and many other countries, as well as regionally in the U.S. (such as the Regional Greenhouse Gas Initiative, RGGI, in the U.S. northeast, and a large GHG market in California).

Stranlund (2017) provides a comprehensive review of theoretical and empirical research on regulatory compliance in emissions permit markets. For the same reasons noted earlier regarding the difficulty of studying compliance with naturally-occurring field data, many empirical studies of enforcement in permit markets have employed laboratory experiments. Laboratory experiments have also provided empirical evidence on other design features of emissions permit markets other than enforcement, as surveyed in Friesen and Gangadharan (2013a) and Cason (2010).

3.1 Measurement and Penalties

Measurement is the first challenge facing any regulatory scheme that is based on the quantity of pollution produced. Firms and the regulator must have some measurement or credible estimate of emissions. In some cases Continuous Emissions Monitoring (CEM) is feasible.[viii] This approach, however, is not feasible for other types of pollutants, and when individual sources are smaller or more numerous. For some important GHG emissions, accounting-based approaches are feasible. CO_2 emissions, for example, are approximately proportional to fossil fuel input, with the total emissions per unit of input depending on the fuel type. Therefore, CO_2 emissions can be estimated based on the amount of fuel use and this can be the basis of self-reported emissions. These emissions reports are then subject to auditing, such as in the EU ETS and the California GHG market, analogous to the requirement that financial records require certified audits for tax and financial market regulation.[ix]

A firm whose emissions in a particular time period exceed current permit holdings can simply buy additional permits. Effective enforcement, therefore, requires that any (marginal) penalty must exceed the permit price for each "unit" of emissions that exceeds the permits held. Emissions trading markets often also require that excess emissions must be covered in subsequent years, either through a reduced future allocation or a requirement that the firm buy extra permits to account for prior year excess emissions. This makes part of the penalty market-based, as it is dependent on future permit prices. In some cases, permit violations require future period offsets or reduced allocations at a multiple of the violation size. For example, violations in California's GHG market are punished with a four-to-one offset (California Air Resources Board, 2011). These types of future year permit reductions make the most environmental sense for a cumulative pollutant such as GHG emissions, where the time dimension—at least the year to year variation—is not too relevant.

3.2 Unique Aspects of Permit Market Compliance

Given perfect enforcement, no market power and zero transaction costs, firms minimize regulatory compliance costs by choosing emissions such that their marginal abatement costs equal the permit price. As noted above, these choices minimize aggregate abatement costs (Montgomery, 1972). If enforcement is imperfect, however, a firm that chooses to violate will hold enough permits so that the expected marginal penalty for noncompliance equals the permit price. Thus, the permit price endogenously determines the marginal compliance choice. Nevertheless, the marginal incentive is still the same for all firms when they face the same permit prices, so the aggregate abatement costs are still minimized even with imperfect enforcement (Malik, 1990). Stranlund, Murphy and Spraggon (2013) provide experimental support for this prediction, using laboratory markets with eight traders exchanging permits through a continuous double auction.[x] Although violations were lower than predicted in treatments when compliance incentives were weak, individual emissions control was distributed approximately as predicted.

Another implication of this common marginal incentive to comply, given by the prevailing permit price, is that a firm's compliance decision is independent of its individual characteristics. All firms are affected by the same margin (Stranlund and Dhanda, 1999). The policy implication of this theoretical result is clear: The regulator has no reason to target specific firms for more or less aggressive enforcement.[xi] Murphy and Stranlund (2007) provide support for this implication using a laboratory experiment, by showing that cost effectiveness of enforcement would not improve if enforcement stringency was based on the firms' heterogeneity in abatement costs. Although these experimental markets appear to be competitive, this experiment also provides evidence of non-trivial transactions costs. In particular, those firms with higher marginal abatement costs, who should buy larger quantities of permits in equilibrium, buy fewer permits than predicted. They are therefore less compliant than firms with lower abatement costs who are net permit sellers.

Another unique aspect of compliance in emissions permit markets is that enforcement stringency affects the permit price. Murphy and Stranlund (2006) study the implications of this both theoretically and experimentally. They show that enforcement has a direct effect on prices: more enforcement, such as through a greater penalty for noncompliance, increases compliance rates and this increases permit demand; consequently, this raises the permit price. The higher permit price has a countervailing, but smaller impact, reducing compliance. Because permits are more expensive this raises the cost of compliance since this is achieved by buying more permits. Their experiment is able to decompose these direct and indirect impacts, providing valuable empirical evidence that the compliance benefits of increased enforcement are tempered in permit markets due to the resulting increase in compliance costs.

3.3 Intertemporal Complications

Another feature that makes emission permit markets unusual is banking, which links compliance across periods. When banking is allowed, firms can carry over unneeded permits from the current compliance period for use in later compliance periods. In some cases, such as in the EU ETS, firms can also borrow against future permit allocations if they hold insufficient permits (e.g., Chevallier, 2012). This ability to redeem permits for compliance in different time periods leads the potential for intertemporal arbitrage to limit price differences over time, as is the case for any durable asset.

Because banking smooths out permit prices across time, it can help promote the price stability needed to properly incentivize investments in new abatement technologies. Volatility can arise, for example, from the correlation of emissions with weather, since emissions increase directly with greater heating and cooling demands. Price variation can also arise from discrete changes in total permit allocations, and this can also motivate banking. For example, Phase I of the U.S. SO_2 trading scheme featured extensive banking in the late 1990s prior to the pre-announced reduction in total permits introduced in Phase II (in 2000).

Cason and Gangadharan (2006b) study compliance in a laboratory experiment with permit banking, and emissions variability. Enforcement had a dynamic component, based on a two-group version of Harrington's (1988) model of history-dependent performance. This experiment provides support for the theoretical prediction that banking smooths out permit price variability. Underreporting emissions, however, increases the size of a firm's permit bank. Banking therefore increased noncompliance, because it provides the incentive for even compliant firms to underreport actual emissions in order to bank permits that maintain considerable value in future periods.

Stranlund, Murphy and Spraggon (2011) use an experiment to study the role of self-reporting emissions in a dynamic market with permit banking, drawing a distinction between permit violations (i.e., not holding enough permits to cover emissions) and reporting violations (i.e., underreporting actual emissions). Although a permit registry provides the regulator with perfect information about the number of permits held by the firm, the regulator does not learn actual emissions without auditing. A firm that holds sufficient permits to cover emissions in the current period may choose to under-report emissions to increase the size of its permit bank. Consistent with the theoretical results in Stranlund, Costello and Chavez (2005), higher permit violation penalties have little deterrence value in these markets with banking. Reporting violation penalties are more important to improve compliance and limit emissions.

3.4 Underexplored Topics

Several of the enforcement strategies discussed earlier in this chapter, such as dynamic enforcement and competitive audit mechanisms, have not been investigated for enforcement in emissions markets, either theoretically or experimentally (except to a limited extent in Cason and Gangadharan, 2006b). Another new enforcement approach that needs more investigation ties monitoring or fines to the level of permit prices. This approach has rarely been implemented in the field, but it featured prominently in some federally-based emissions trading

programs proposed in the U.S. in the 2000s.[xii] Stranlund, Murphy, Spraggon and Zirogiannis (2019) report the only experiment conducted to study how this type of dynamic enforcement performs. While a treatment where the audit rate varied with permit prices effectively eliminated noncompliance as predicted, an alternative based on a fine level that varied with the price level was less successful.

Permit markets in practice have often been implemented with administrative price floors and ceilings, and they are often expected to be binding (Borenstein, Bushnell, Wolak and Zaragoza-Watkins, 2019). While the price and efficiency consequences of such price controls have been explored in experiments (Stranlund, Murphy and Spraggon, 2014; Perkis, Cason and Tyner, 2016; Friesen, Gangadharan, Khezr, and MacKenzie, 2020), and the enforcement implications of price controls have been studied in theory (Stranlund and Moffitt, 2014), compliance and enforcement implications of price controls have not been considered in experiments.

Permit markets are also likely to become increasingly linked, internationally and across different states. This will change the compliance incentives in different jurisdictions as it will affect prices (see Stranlund, 2017, for a discussion). Different regions will also have variations in penalties and enforcement. Although some initial experiments have explored the implications of linking markets in different ways (Cason and Gangadharan, 2011), none have explored the effects of linking on compliance.

4. Behavioural Levers

While many studies focus on the monetary incentives inherent in complying with regulatory programs, firms and individuals may also be motivated by additional factors such as status, reputation, prevailing social norms, shame, and corporate social responsibility, which may influence their incentives to comply.[xiii] These extrinsic, intrinsic, and reputational motives

have been studied extensively in the literature and studies have also shown that in some situations increasing monetary (extrinsic) incentives may crowd out intrinsic motives and dilute reputational effects (Benabou and Tirole, 2006). The combination of extrinsic, intrinsic and reputational motives may be particularly important in the sphere of compliance with environmental programs in the field (Brent et al., 2016 provides a comprehensive review). In this section we highlight several papers that introduce non-monetary motives into the study of environmental compliance, using laboratory experiments.

4.1 Social Observability

Information disclosure strategies have been considered as a "third wave" of environmental regulation, in many cases replacing or supplementing traditional command-and-control and market-based instruments. The desire for social approval, leading to the positive impact of social observability on compliance rates could be effectively leveraged by regulators, especially if the costs associated with public disclosure are mostly negligible. The U.S. Environmental Protection Agency's "Next Generation Compliance" initiative includes information disclosure ("Transparency") as another key important component to tackle compliance.

Cason, Friesen and Gangadharan (2016) compare the effectiveness of traditional audit mechanisms and social information policies, in an environment where members in a group may impose direct negative externalities on others depending on their decisions. The externality introduces an important feature into the audit literature, which has traditionally focused on individual decision making; it makes the setting more relevant for studying environmental issues and provides a platform to investigate non-monetary motives. Social observability policies, for example, rely on the premise that increasing the visibility of actions and audit outcomes can lead to improved compliance, which due to the externality benefits others.

The audit treatments examined in Cason et al. (2016), as discussed above in Section 2, include a random audit treatment, in which firms are randomly inspected with a constant and exogenously determined probability, and the tournament audit treatment, in which firms are ranked based on their self-reporting. In the tournament firms have an incentive to compete with each other in terms of compliance, since lower underreporting compared to others in the regulatory group results in lower chances of an audit. The audit treatments include two levels of information disclosure. In the low information condition only the reporting choices of other participants are revealed, whereas in the high information scenario participants see digital photographs of everyone in the group and also learn the actual output and compliance of the inspected group members.

Revealing identities along with additional information about detected underreporting may increase the stigma from noncompliance compared with the low information treatment. The additional information, however, could also provide a signal about the proportion of evaders in the population, which might cause individuals to update their beliefs about the social norm and the cost of deviating from that norm. Depending on the norm in the group, one could observe lower or higher compliance. The audit tournament treatment presents further challenges. While making reporting choices visible has no effect on others in the random treatment, greater underreporting in the tournament treatment leads to positive externalities for other group members as it reduces their probability of being audited. This positive effect could reduce the social stigma from underreporting.

As noted earlier and consistent with theoretical predictions, the treatment with audit tournaments leads to higher compliance levels as compared to the random audit treatment. Competition to avoid being audited reduces misreporting by 60 to 80 percent on average. Reliance on the relative perceived performance amongst regulated individuals leads to improved efficiency by both reducing negative externality generating output and by increasing

truthful reporting. Interestingly, however, social observability does not affect output or reporting significantly in either of the audit treatments. The offsetting incentives in the tournament mechanism apparently counteracts any social stigma that might exist for misreporting. The findings suggest that social information could interact in unexpected ways with competitive schemes and needs to be examined closely before it can be considered an effective enforcement strategy in the field.

When individuals have different capacities to be compliant, then this heterogeneity could influence the formation of norms relating to compliance. Those with higher endowments or higher abilities to comply may place different weights on the principles of group efficiency and equality as compared to those with lower capacity. Brent, Gangadharan, Mihut and Villeval (2019) evaluate the effectiveness of monetary and non-monetary approaches to improve environmental compliance in situations where agents are heterogenous. Their monetary mechanisms focus on tax and redistribution policies to improve compliance with extraction limits in a non-linear common pool resource setting. Agents vary in their ability to extract a resource from a common pool. In one of their tax policies, each unit consumed is taxed, with the tax reflecting the scarcity of the resource. The other policy proposes higher rates for higher successive blocks of consumption, similar to the increasing block rate tariffs commonly used to price electricity and water use. Both policies also have an inequality reduction dimension, achieved through an equal redistribution of the tax revenue toward all the group members.

Along the non-monetary dimension, observability is implemented such that each individual's extraction decision and payoff are publicly revealed to her group members. The authors find that both the tax and redistribution mechanisms significantly improve compliance by reducing extraction, while also increasing efficiency and reducing inequality, as compared to a baseline treatment with no policy. Social observability, interestingly, reduces compliance in the absence of a combined tax and redistribution mechanism. With a tax and redistribution

mechanism, the negative effect of social information and observability disappears and there are no significant differences in compliance with or without observability. This means that social observability on its own encourages people to extract more. In particular, a majority of high-type subjects extract at their maximum capacity level knowing that their decision will be made public. The authors conjecture that the decisions of the high-types may be self-serving, to signal that they would not subsidize the low types and act to install a norm of high extraction to mitigate any potential guilt in case others in the group show intentions to comply.

4.2 Encouraging Honesty

As mentioned in Section 3, compliance in many environmental programs is measured with self-reports by individuals and firms. Self-reporting can improve compliance (as in some programs it offers lower penalties for those who voluntarily report environmental non-compliance) and reduce enforcement costs (EPA, 2000). Honesty, however, is an important part of this regulatory framework.[xiv] Self-reporting regimes can be designed in different ways that can consequently influence intrinsic motivations to be honest. Friesen and Gangadharan (2013b) examine the effectiveness of voluntary and compulsory self-reporting. Keeping economic incentives constant, theoretically one should not observe any difference between voluntary and compulsory reporting. Behavioural influences, however, may affect these regimes differently. This is because distinct differences may exist between failing to voluntarily submit a report (an act of omission) and telling an outright lie (an act of commission: knowingly submitting a false report). If agents are averse to blatant lies, this could result in greater reporting of violations in the compulsory self-reporting scenario than in the voluntary one. Conversely, being compelled to submit a report could lead to crowding out of the intrinsic motivation to voluntarily report violations and therefore may lead to less reporting in the compulsory case.

To examine the effectiveness of the two regimes, Friesen and Gangadharan (2013b) design a production task with self-reporting of environmental accidents where some participants faced compulsory reporting while for others reporting was voluntary. They find that reporting of accidents was significantly more frequent with compulsory than with voluntary reporting. The aversion to overt lying therefore had a stronger effect than any potential crowding out of the intrinsic motivation to voluntarily report. Importantly, the compulsory regime led dishonest people (measured using an individual level matrix task, designed by Mazar, Amir and Ariely, 2008) to be more truthful and report accidents more often. Many programs in the field use voluntary self-reporting systems and this research suggests that the choice of self-reporting scheme can be critical in improving compliance in environmental programs. With increased use of online reporting, monitoring may become easier; but on the other hand, this kind of reporting reduces social distance, which could increase dishonesty.

4.3 Underexplored Topics

Overall, the literature suggests that regulators need to exercise care when implementing policies that rely on behavioural motives to enhance compliance. The two policy levers from standard economic models of deterrence, frequency of inspections and magnitude of fines, appear to be less sensitive to context. In contrast, the experimental literature finds that environmental policies that rely on social information, norms, crowding out and morality produce mixed results.[xv] In some cases, they may also have perverse effects and can interact in unexpected ways with other features of the compliance policy. The next generation of experiments in this area could focus on identifying the underlying reasons for these mixed results.[xvi]

5. Summary and Conclusion

Compliance with laws and regulations is inherently difficult to study empirically, since agents have the incentive to hide their illegal activity or over-report costly actions. While important lessons can be learned from studying detected violations, the presence of undetected violations means this leads to an incomplete picture of overall regulatory compliance. For over 50 years economists have developed models of enforcement and how agents should react to different compliance incentives. The combination of a solid, micro-founded theoretical framework and the inherent challenges of observing a complete picture of the key compliance choices using naturally-occurring field data makes experimental studies in this area particularly useful.

The experiments we have summarized in this chapter investigate responses to differing inspection rates and penalties, testing some of the basic implications of the seminal model of Becker (1968). They also investigate alternatives that can improve on random inspections, including dynamic enforcement that applies greater scrutiny towards firms with past violations, and rank-order tournaments that inspect firms that are more likely to be non-compliant. We also provide an overview of a range of experiments that study compliance in markets for emission permits, and the use of social norms, triggered by transparency, to promote compliance.

Most of the experiments we describe were carried out in dedicated experimental economics laboratories on university campuses using college students as subjects. While this methodology is standard in this field, it raises the question of generalizability. Individuals and consumers sometimes make compliance decisions, but the most relevant population of decision-makers for regulatory compliance choices is firms and their managers. The theoretical models that motivate the research questions and the experimental designs discussed here do not make assumptions about the detailed characteristics of the relevant decision makers; for

example, they are silent about the amount of industry experience required before the models make relevant empirical predictions.

The use of a narrow class of subjects who are accustomed to making decisions in a controlled setting provides some benefits. Theory-oriented experimental studies, even those that have policy implications such as those considered here, can benefit from having a relatively homogeneous subject pool (Cason and Wu, 2019). Reducing the nuisance variation across treatments arising from subject heterogeneity increases experimental control—and the lower variance helps improve statistical power.

Another design feature of these laboratory studies that increases experimental control at the potential cost of generalizability is their use of neutral framing. Subjects in these experiments typically saw no references to the environment or pollution, although the experiments that study compliance often employ "inspections" and "penalties" and other enforcement terms. The experiments avoid environmental terminology because individuals may have different attitudes towards environmental protection, which could influence behaviour in an uncontrolled way (Cason and Raymond, 2011). These attitudes are not part of the theoretical models that guide the experimental designs, with the exception of some experiments described in Section 4 that explore behavioural factors. Avoiding environmental terminology can help reduce variance that is beyond the models' scope. Additional research would be useful to determine how much framing affects behaviour in these types of experiments.

Compliance in environmental markets is studied mostly using a classical economic lens. Would social concerns about environmental issues influence the behavioural norms relating to compliance in these markets, or would competitive market forces dilute the impact of these norms (e.g., Bartling, Weber and Yao, 2015)? Would their impact differ depending on the direct harm caused by pollution? Would organisational structure affect compliance

decisions? If managers can delegate compliance to another employee, does this give them some moral wiggle room and what does this imply for compliance in these markets? These open questions would be fruitful to explore in the future.

As resources for regulatory enforcement continue to remain stretched, we anticipate research in environmental compliance will grow and an experimental approach would provide the scope for investigations that are systematic, rigorous and rely on causal inferences.

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End Notes:

[i] Polinsky and Shavell (2000) survey the early theoretical literature.
[ii] Recent survey papers providing more detail regarding laboratory experiments addressing specific environmental issues include Cason and Wu (2019), Friesen and Gangadharan (2013a), and Cason (2010). Surveys for relevant field experiments include Brent, Friesen, Gangadharan, and Leibbrandt (2016), List and Price (2016), and Price (2014).
[iii] Other laboratory experiments also confirm that the basic deterrence predictions hold including DeAngelo and Charness (2012) in a task framed as speeding, and Salmon and Shniderman (2019) with respect to audit probabilities in a tax compliance experiment.
[iv] See https://www.epa.gov/compliance/next-generation-compliance, accessed 16 May, 2020.
[v] Even compliant firms prefer to avoid inspections as they are costly regardless of their compliance status.
[vi] Gilpatric et al. (2011) also study a more general relative evaluation mechanism, which applies when the audit budget is not fixed. Under this mechanism, the probability of an audit depends on the entity's estimated compliance relative to its peer group. They demonstrate, both theoretically and experimentally, that this mechanism also increases compliance.
[vii] In theoretical work, Oestreich (2015) models the impact of competitive audit mechanisms (using a Tullock-style contest, which nests random audits and perfectly discriminating audits as limiting cases) on actual emissions, as well as the reporting of these emissions. Interestingly, he finds that excessive competition can actually backfire by increasing emissions, while still improving the truthfulness of reporting.
[viii] For example, the emissions permit scheme implemented in the 1990 U.S. Clean Air Act Amendments applied to large sources, and "smokestack based" monitors were used to quantify each source's SO_2 and NO_x emissions. Emissions data were transferred to the regulator in real time, so this simplified measurement and reporting compliance essentially to maintenance and accuracy of the CEM devices.
[ix] The certification of emissions reports is a potential source of noncompliance, and Shen, Betz, Ortmann and Gong (2020) report an experiment in which the regulated firm may make side payments ("bribes") to a third party tasked with verifying report accuracy. They find that rotating both verifiers and inspection officials reduces corruption and improves truthful reporting.
[x] In this trading institution, which is used for many laboratory studies of emissions permit markets, traders wishing to buy permits can submit bid prices to buy or accept sellers' offer prices in continuous time. Symmetrically, those wishing to sell permits can submit offer prices to sell or accept buyers' bid prices at any time. This centralized, multilateral negotiation process creates relatively competitive market conditions even with a relatively small number of traders.
[xi] This result does not hold in the presence of market power, however (van Egteren and Weber, 1996), nor does it hold in the presence of transaction costs. Transactions costs drive a wedge between what buyers pay for permits and the price that sellers receive (Stavins, 1995). Consequently, since buyers face a higher "effective" price they are more likely to violate than sellers.
[xii] Fines were also tied to permit prices in pilot programs implemented in China (Zhang, 2015). For example, in the Beijing pilot the fine for excess emissions ranged between three and five times the prevailing average permit price in the previous six months. The rate depended on the extent of noncompliance, with the higher fine rate (5) applied to firms with emissions more then 20 percent over their permit holdings.
[xiii] Research using psychological measures and self-reports of emotions, shows that emotional arousals are strongly associated with the likelihood of being compliant (e.g., Coricelli, Joffily, Montmarquette and Villeval, 2010; Khadjavi, 2014). This may be one channel through which individuals take non-monetary factors (such as moral and social dimensions), into account when making compliance decisions. Additionally, limited evidence exists that affirmative motivations, such as belief that honest emissions reporting is appropriate or that levels of permit endowments are "fair," increase compliance (Raymond and Cason, 2011).
[xiv] Using data from more than 90 experimental studies, Abeler, Nosenzo and Raymond (2019) show that the main reasons for truth-telling in different contexts include a preference for being honest and a preference for being seen to be honest.
[xv] Slemrod (2019) also reports this mixed evidence of the effectiveness of intrinsic motives in the area of tax compliance.
[xvi] Research using field data lend some support to these mixed effects. For example, while evidence from the field indicates that social information might change behavior by triggering conformity to a social norm (e.g., Allcott and Mullainathan, 2010; Ferraro and Price, 2013), researchers also find that economic incentives provide much larger and more persistent effects as compared to intrinsic measures such as moral suasion, which showed a diminishing effect when the interventions were repeated (Ito et. al. 2018).