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The political economy of industrial pollution control: environmental regulation in Swedish industry for five decades

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The paper analyzes the prerequisites for a regulatory-driven transition toward radically lower air and water pollution in industry. This is achieved in the empirical context of the Swedish mining and metals industry, and by investigating the environmental licensing processes during two regulatory systems. The paper derives an analytical framework that explores under what circumstances such licensing processes can result in radical emissions reductions without seriously jeopardizing the competitiveness of the industry. Archived material covering six environmental licensing processes, three during each system, is used to illustrate the various design and implementation issues. The results suggest that regulatory-driven green transitions benefit from trust-based bargaining procedures in which companies are involved in repeated interactions with regulatory authorities, and which extended probation periods permit tests of novel abatement technologies (including innovation). The findings also illustrate the importance of abstaining from simplified normative notions about policy instrument choice (e.g. taxes versus standards).

Keywords: environmental regulation; industrial pollution; competitiveness; technological change; mining; licensing processes

1. Introduction

This paper addresses the challenges involved in imposing very stringent regulations for air and water emissions in industrial sectors that compete in international markets. In such industries, environmental regulation involves multiple objectives and difficult tradeoffs. While emission taxes and standards have often led to incremental environmental improvements (Rogge *et al.* 2011; Similä 2002), governments increasingly face the challenge of imposing future emission reduction targets that cannot be met by sole reliance on existing, 'off-the-shelf', technologies (e.g. Bergquist *et al.* 2013; Krysiak 2011; Nentjes, de Vries, and Wiersma 2007; Sandén and Azar 2005). At the same time, though, stringent environmental licensing procedures and regulations can imply

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excessive compliance costs for the industry, and, in this way, jeopardize its future competitive strength.

In fact, while government regulations are necessary for reducing the environmental footprints of industrial production, inefficient licensing procedures and inflexible standards could also lead to increased uncertainty about the future business opportunities. This in turn would hamper the incentives to pursue sustainable technological change in various industries (Korhonen *et al*. 2015; Ulibarri, Cain, and Ajami 2017). For instance, the transition to a bio-based economy could provide the incumbent pulp and paper industry with novel business opportunities; instead of using the raw materials exclusively for the production of pulp and paper products, it could also produce zero-carbon transportation fuels, green chemicals and various bio-based materials (e.g. Hansen and Coenen 2017; Pätäri *et al*. 2016). In addition, the switch away from a fossil fuel-based to a renewable energy system hinges on the extractive industries supplying a wide range of critical metals out of which several are needed in the production of, for instance, wind turbines and electric batteries (Moreau, Dos Reis, and Vuille 2019; SweMin 2019).

Environmental licensing procedures have, however, occasionally constituted obstacles to novel green technologies such as renewable energy generation (Pettersson *et al*. 2010), but also new mining ventures involving the extraction of metals that are essential for such generation (e.g. Clagett 2013). Stringent environmental regulations can thus impose opportunities as well as threats for future sustainability transitions. For these reasons, it is critical to identify regulatory approaches that can maintain continuous incentives for emission reductions, while at the same time taking into account the risks of excessive compliance costs for the industrial plants affected by the regulations. In practice, this entails designing and implementing licensing processes that can promote technological change and innovation, and grant flexibility over time in identifying, developing and demonstrating new technologies.

Previous research in environmental economics asserts that market-based instruments, such as taxes on emissions, generally provide stronger incentives for green technology development than, for instance, performance standards in the form of individual, plant-specific emission limit values (Milliman and Prince 1989; Requate 2005). However, in most countries, performance standards, which typically result from plant-specific licensing processes, play a critical role in industrial pollution control, especially in regulating local pollution. Moreover, there is limited empirical evidence of some policy instrument being generally superior to others. Policy design, implementation, and various institutional preconditions (which have often evolved over several decades), are often equally important (Mohr 2006; Mickwitz, Hyvättinen, and Kivimaa 2008; Kemp and Pontoglio 2011; Bergquist *et al*. 2013). In the light of this, it is surprising how little attention previous work has devoted to the issue of how the environmental licensing processes can be improved. The present paper adds to the existing knowledge concerning how licensing procedures can be designed and implemented to facilitate radical reductions in industrial air and water pollution. As noted in Section 2, we address not only the design of the final regulatory conditions but also the entire process of negotiations, including any provisional conditions and company activities leading up to the final license.

The objectives of this paper are to: (a) analyze the prerequisites for achieving regulatory-driven transitions toward radical emission reductions in an industrial sector that faces intense global competition; and (b) provide an empirical illustration of some key design and implementation issues. We depart from an analytical framework, which is derived from the existing literature, and contributes with an increased understanding of how environment licensing procedures can help promote a radical greening of the industry without jeopardizing its competitiveness. Unlike most previous research on the economics of environmental regulation (see, however, Krysiak 2011; Nentjes, de Vries, and Wiersma 2007), this framework distinguishes between technical change emanating from the adoption of existing abatement technologies and that involving the development of new technology. The framework is illustrated and tested in the empirical context of the Swedish mining and metals industry during two regulatory regimes. We draw on archived documents exchanged between the companies and regulatory authorities during six different plant-specific licensing processes, three from each regulatory system.

The mining and metals industry has experienced significant growth since the turn of the century, both in the developed world as well as in emerging economies in Asia (Humphreys 2015) and Latin America (Bastida 2018). Our focus on this sector is of course also motivated due to its environmental footprints and the regulatory challenges facing new investments. The mining and metals industry poses significant environmental impacts, such as large volumes of waste rock, tailings, acid mine drainage, and airborne dust, but also emissions of sulfur dioxide and heavy metals in the smelting process of sulfide ores (e.g. Eggert 1994; Dudka and Adriano 1997). Mining ventures, including processing plants and smelters, therefore face increasingly stringent environmental regulations, and in many emerging economies, new regulations are underway.[1] Still, there are concerns about competitiveness; mining professionals have expressed fears that stringent regulations in combination with permitting delays could imply fewer investments (Cervantes, McMahon, and Wilson 2013). In addition, the existing environmental licensing processes are often claimed to be unpredictable, non-transparent, and lacking in coordination across the responsible authorities (Clagett 2013; SNL Metals & Mining 2015; Söderholm *et al*. 2015).

Our focus on the Swedish case is motivated in part because concerns about the efficiency of the existing environmental licensing procedures have been raised here as well (e.g. SweMin 2019; Swedish Energy Agency 2019). Still, more importantly, it allows us to contrast two regulatory systems in one country; these have had many similarities, but also subtle, and potentially very important, differences. These systems include an early period of industrial pollution control under the Swedish Environmental Protection Act (1969-1998), and the more recent system with the new Swedish Environmental Code representing the principal legislation for environmental licensing (1999 and onwards). With the advent of the Environmental Code, new legal rules and arenas (i.e. courts) were introduced. These rules were subordinated to the remaining central principles of the previous legislation, and the new arenas were essentially replicas of the old ones (Duit 2007). In spite of this stability in the regulatory framework, though, previous studies have pointed out important differences, not least in the way in which the legal rules have been implemented. Notably, the earlier system relied on a regulatory style seeking cooperation and consensus between the regulators and the industry, and in various ways providing opportunities for green technological innovation (e.g. Lundqvist 1980). This system also generated positive outcomes. For instance, during the 1970s and the 1980s, Swedish industry managed to achieve deep reductions in the emissions of a large number of pollutants. Nevertheless, during the same time period, production volumes increased significantly (Bergquist *et al*. 2013).

In the next section, we review the existing literature, and elaborate on the specific contributions of this paper. Section 3 introduces the analytical framework, which addresses three prerequisites for a regulatory approach that can achieve significant emission reductions without jeopardizing industrial competitiveness. Important trade-offs and challenges are also discussed. In Section 4, we present the research design. Given the paper's ambition to address the experiences from two regulatory systems, it is essential from a methodological perspective to address similarities and differences in the respective institutional contexts and introduce the six licensing process cases (Section 4.1). We present the empirical material and clarify how our analytical concepts have been detected in this material (Section 4.2). Section 5 illustrates the analytical framework empirically and outlines key experiences on how the above three prerequisites have played out in the selected licensing processes. In Section 6, we discuss these findings, not least by further elaborating on the conceptual contributions of the paper as well as by pointing out some practical implications. Section 7 concludes the paper and provides some avenues for future research.

2. Literature review

The relationship between environmental regulation and industrial competitiveness has been the subject of considerable debate in the research literature since the turn of the century. The traditional view argues that regulations lead to additional costs, e.g. in the form of labor or capital, and these erode R&D investment and competitiveness (Jaffe *et al*. 1995; Calzolari 2001). Still, this view has been questioned, and one important point of departure for this discussion is the so-called Porter hypothesis (Porter and van der Linde 1995). This hypothesis states that *properly designed* environmental regulations will: (a) induce environmental innovation and technological change (the weak version of the hypothesis); and (b) increase not only the environmental performance but also the economic performance of the industry in terms of higher profits and productivity (the strong version) (Dechezleprêtre and Sato 2017). In other words, the strong version of the Porter hypothesis implies that environmental regulations could trigger innovations that fully offset the costs of complying with them.

The empirical literature testing the strong Porter hypothesis is rich, and typically investigates the relationship between the stringency of environmental regulations and productivity or profits at the company or plant level (for overviews, see Brännlund and Lundgren 2009: Ambec *et al*. 2013). This has been done on a wide range of industrial sectors, including mining. Overall, the results suggest meager support for the strong version of the Porter hypothesis; environmental regulations typically result in net costs for the affected companies. However, at the same time, there is little suggesting that existing regulations have had *profound* adverse effects on industrial competitiveness (Dechezleprêtre and Sato 2017; Söderholm, Bergquist, and Söderholm 2019).

There are likely several reasons for this. In some cases, the existing regulations have simply not been stringent enough to generate negative impacts, such as in the case of the so-called Cluster Rule (aimed at toxic releases) in the USA (e.g. Gray *et al*. 2014). Another reason is that the environmental regulations have influenced not only the adoption of existing ('off-the-shelf') abatement technologies, but also the development of novel and improved green technologies, in turn lowering the compliance costs. This signifies the weak version of the Porter hypothesis for which there is plenty of support in the empirical context of various industrial sectors (e.g. Weiss, Stephan, and Anisimova (2019) on the pulp and paper industry and Lindmark and Bergquist (2008) on the metal smelting sector).

In the case of the mining and metals industry, the related empirical research has focused on the relationship between environmental regulations and the locational choices of mining enterprises. Overall, this strand of the literature also finds evidence of modest negative impacts on the industrial competitiveness of such regulations. Environmental regulations have not constituted a major impediment to investment; this has been shown already by Peck, Landsberg, and Tilton (1992) who surveyed 32 multi-national mining companies. This is supported by more recent research (Wilkerson 2010; Tole and Koop 2011; McNamara 2009; Annandale and Taplin 2003). For instance, Tole and Koop (2011) present an econometric analysis of the locational choice of multi-national gold mining companies and report that such companies, rather than seeking out regions where environmental regulation is lax, they primarily search for countries that provide an overall stable government. Moreover, Annandale and Taplin (2003) study the effect of environmental permitting processes on proposed mine development projects internationally. Based on a survey among 200 mining company executives in Australia and Canada, they conclude that a substantive majority of the mining companies did not perceive the environmental licensing process as a major impediment to investment.

These empirical studies even suggest that instead of being intimidated by tough environmental regulations, companies tend to be attracted by the underlying factors that the existence of such regulations represent, namely stable political and legal institutions. Companies prefer to invest and operate in countries where the regulatory framework is predictable and non-discretionary (see also Rémy 2003). This notion, however, also sheds light on an issue that has largely been neglected in previous work. Specifically, existing research has primarily addressed the overall impacts of environmental regulations (on productivity, locational choice, etc.), but considerably less attention has been devoted to the specific design and implementation of these regulations, including the role of environmental licensing processes. This is in spite of the fact that Porter and van der Linde (1995) themselves stress the importance of "well-designed regulations".

Notable exceptions include a number of studies on the pulp and paper industry; these emphasize the importance of well-functioning innovation systems and compliance flexibility for emission reductions and green technological innovation (Weiss and Anisimova 2019; Bergquist and Söderholm 2011; Similä 2002).[2] However, this research typically addresses the role of single design features (e.g. compliance flexibility), and/or analyzes solely isolated instruments (e.g. performance standards) rather than the entire environmental licensing process. Moreover, a few studies on the mining sector present comparative analyses of environmental regulation across countries (Söderholm *et al*. 2015; Pettersson *et al*. 2015; McNamara 2009; Williams 2012). However, such studies typically struggle with considerable country heterogeneity in terms of, for instance, legal systems, regulatory approaches, political culture, etc., thus making it difficult to come up with generic conclusions.

This paper contributes to the existing research in primarily two ways. *First*, we investigate how the *design* and *implementation* of environmental licensing processes may significantly affect the prospects for radical emission reductions. Hence, the paper does not provide a test of the Porter hypothesis; instead, we ask how licensing processes can be designed and implemented to minimize the risk of such regulations counteracting industrial competitiveness. *Second*, our comparative-historical approach allows us to address and contrast a set of potentially important regulatory design and implementation issues in a single country context.

3. Analytical framework

3.1. The regulatory challenge

Figure 1 provides a graphical image of the transition toward radically lower emission levels in a given industrial sector, and the associated marginal abatement costs (MC_A). This simple model builds on Nentjes, de Vries, and Wiersma (2007) and Bergquist *et al*. (2013), and it has been used in other empirical contexts.[3] It allows us to identify a few important features of the challenge facing the regulatory authorities in this green transition. As such, it provides the basis for our conceptual contribution, the elaboration of various design and implementation features that can facilitate the transition toward deep emission reductions without jeopardizing competitiveness.

Figure 1 displays a situation where the regulator imposes an ambitious long-term emissions reduction target, $\bar{A}$. The three MC_A curves illustrate the marginal costs of available ('off-the-shelf') abatement technologies for a given cost-minimizing mining operation. The reduction target, though, requires that new technologies are also developed and diffused in the industry. The dashed straight lines therefore represent expectations about the (marginal) costs of future abatement technologies, which can only be adopted following future R&D efforts and pilot plant tests. Thus, in this case, the regulatory challenge is characterized by: (a) high uncertainty about future abatement costs (on the part of both companies and the regulator); and the fact that (b) the stipulated emission reduction requires a higher rate of pollution prevention than currently available 'off-the-shelf' technologies can offer (Nentjes, de Vries, and Wiersma 2007).

Figure 1 illustrates the importance of information, and how this is distributed across the relevant actors. In the companies' choice to adopt existing pollution abatement technology, significant information asymmetries are likely to exist in the sense that companies know far better than the regulatory authorities what it will cost to abate emissions.[4] Moreover, they generally have few incentives to reveal this information, and could even choose to signal high abatement costs to avoid the likelihood of more stringent regulations in the future (e.g. Kolstad 2000). In contrast, the process of developing novel, green technology is likely characterized by a *shared* uncertainty among the regulators and the companies (Bergquist *et al*. 2013).

This distinction between asymmetric information and shared uncertainty will have implications for the design and implementation of environmental regulations in industry, not least since it is essential to also consider the interaction between the objectives of the regulator and the cost-minimizing behavior of the firms. The presence of large shared firm-regulator uncertainty and concentrated industrial sectors in which the heterogeneity in pollution abatement technology is low, could facilitate a reliance on cooperative, trust-based, environmental licensing processes based on negotiations (Glachant 1999). Previous country case studies have confirmed that such negotiated regulation has often facilitated the implementation of efficient industrial pollution control (e.g. Jänicke 1992; Wallace 1995; Reinstaller 2008). Such consensual regulatory approaches also tend to facilitate information-sharing and knowledge transfer between industry and regulators (see further Section 3.2). This thus illustrates the importance of recognizing that studying regulatory approaches to

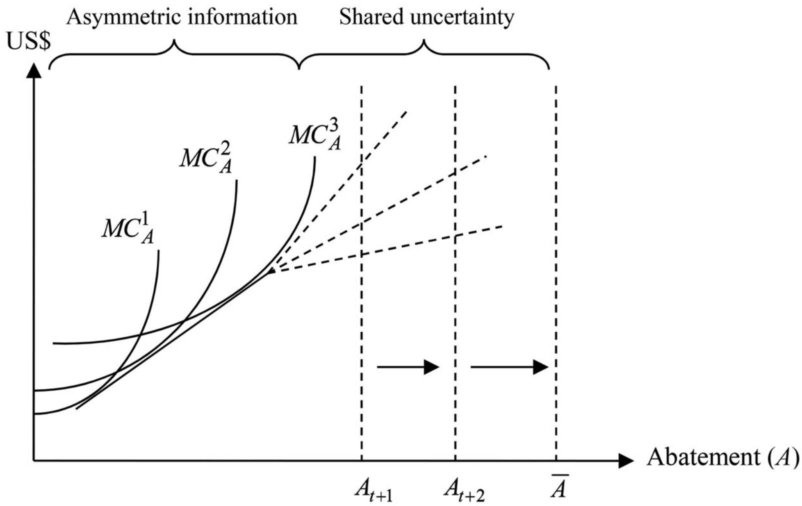

Figure 1. Marginal Abatement Costs Associated with a Transition toward Deep Emission Reductions.

industrial pollution needs to go beyond the consideration of individual policy instruments (e.g. taxes versus standards). In practice, the entire set-up of the regulatory system, including norms, trust, competence, knowledge accumulation and transfer, should be addressed.

3.2. Regulatory design and implementation: compliance and competitiveness

Based on the regulatory challenge introduced in the previous section, we identify three different prerequisites for environmental regulatory approaches that can facilitate the transition toward deep emission reductions without jeopardizing the competitiveness of the industry.[5] This, in turn, involves the provision of strong and continuous incentives for emission reductions, taking into account the risk of excessive compliance costs for affected operations. It also encompasses providing incentives for environmental R&D and technology demonstration activities.

The first prerequisite is *flexibility* and it concerns how the regulatory requirements are designed. There are two elements of flexibility. The regulations need to grant firms flexibility in terms of the choice of specific compliance measures (so-called 'what-flexibility'), and time for adjusting the production processes to the new requirements ('when-flexibility'). What-flexibility implies, for instance, the adoption of performance standards rather than technology-based standards. By design, the latter provide no leeway to undertake other (low-cost) measures, and technology standards could even force investments into suboptimal technologies (Lindmark and Bergquist 2008). This is particularly likely in the presence of firm-regulator information asymmetries. In contrast, performance standards will provide what-flexibility, and permit firms to experiment with different pollution abatement technologies and choose the most efficient mix of these.

In environmental regulations, when-flexibility could be accomplished by employing extended probation periods (Nentjes, de Vries, and Wiersma 2007).[6] In Figure 1, this is illustrated by first assuming that in period t, the regulator imposes a performance standard, A_{t+1}, which cannot be met by employing the abatement technologies available in that period. However, mining companies are allowed to develop, adopt and test new technology until time period $t+1$. In the presence of technological progress, the regulator can impose a yet stricter standard, e.g. A_{t+2}, but again in combination with another probation period. This type of regulatory design permits companies to coordinate environmental and productive investments, learn from the results of R&D projects and avoid errors in the technology development process (see also Kamien and Schwartz 1982; Viscusi, Vernon, and Harrington 2005). For the capital-intensive mining industry, this is important since replacing industrial equipment will typically be a time-consuming and uncertain process. Still, introducing such probation periods is difficult, as this regulatory design relies on high regulatory competence, including government officials who can push for stringent long-term emission reduction targets without, however, invoking excessively high short-term costs on the industry (see more on this below).

The second prerequisite concerns *predictability* with respect to the timeliness of the regulatory process, and the transparency in terms of how the legal rules are interpreted in practice. Capacity expansions (including replacements) are important for the future competitiveness of mining and metals ventures. The timeliness of the regulatory decision is also important, since this industry typically faces rather narrow investment windows, i.e. periods characterized by high prices and thus favorable conditions for loan financing. Moreover, during the last two decades, intense competition in the global commodity markets has increased the need for improved capacity utilization rates and efficiency, thus leading to the adoption of lean manufacturing techniques and just-in-time inventory systems (Humphreys 2000). For this reason, it has become essential for the companies to demonstrate themselves as reliable suppliers; delays in the environmental licensing processes – due to appeals and lack of staff and resources at the regulatory authorities – would jeopardize this reputation. Clearly, this also applies to other process industries.

However, while the foundations of competitive strength in the mining and metals industry tend to force particular timetables (and outcomes), tight time plans could also have opportunity costs. During recent decades, there has been increased demand for more inclusive mining ventures that involve more direct participation in the decision-making processes taking place at the local level (Söderholm and Svahn 2015; Ranängen and Lindman 2018). For these reasons, several companies in the mining and metals industry have embraced the need for mineral ventures to earn a so-called 'social license to operate', i.e. broad acceptance of society that goes beyond the requirements of formal licenses (Prno 2013; Humphreys 2015). In other words, companies must acknowledge the business risks associated with tense community relations, and engage in early and constructive dialogues with key stakeholders, including local citizens' groups. Such deliberative practices typically *have to* take time, but they also help avoid future appeals and delays in the licensing process.

As noted above, predictability also relates to transparency in terms of how legal rules will be interpreted in individual cases (e.g. concerning the regulatory requirements). If the legal rules only provide vague guidelines for how to assess specific mining ventures, there is greater scope for late appeals and lengthy processes. It should be noted that the legal rules will quite often be deliberately vague, in part since this makes it possible to balance environmental protection and economic development in individual cases. In other words, while these rules must clarify "what applies" in a particular situation, the profitability as well as the environmental impact of mining projects are typically highly context dependent. This, in turn, speaks against the use of uniform performance standards and other regulatory requirements across various ventures. Even though such a harmonization would increase the predictability of the regulatory requirements, it would also make it considerably harder – if not impossible – to balance the forcing of improved environmental performance on the one hand and maintaining the competitiveness of individual mining ventures on the other.[7]

Finally, the third prerequisite for enabling radical emissions reductions without compromising industrial competitiveness, concerns *know-how* on the part of the regulator about technical opportunities and their costs. If such expertise exists, including the transfer of knowledge between different actors, consensus-based – yet tough – negotiations between the regulatory authorities and the companies can take place. Thus, establishing efficient regulatory approaches goes beyond selecting individual instruments, e.g. technology versus performance standards. The entire set-up of the regulatory system matters, and previous studies have shown that countries tend to have different styles and cultures in terms of industrial pollution control (e.g. Löfstedt *et al*. 2001). Distinct national institutions, including historically shaped firm-government relations, will lead to specific contexts shaping the design and implementation of environmental regulations. This is an important remark given that such regulations, e.g. performance standards, are the outcomes of case-by-case licensing procedures, thus involving direct negotiations between the regulator and the owners of the polluting plant. These firm-regulator interactions concern issues about information asymmetries and knowledge transfer, but also social trust and informal norms (e.g. Bergquist and Söderholm 2011).

In the regulatory process, information asymmetries make it difficult to implement performance standards that are not based on either an underestimation or an overestimation of the compliance costs. The gradual tightening of standards over time will therefore have to build on substantial investment in engineering competence on the part of the regulatory authorities. Moreover, the accumulation and transfer of knowledge are also important when new abatement technology needs to be developed and tested. As noted above, research also suggests that the presence of shared firm-regulator uncertainty will facilitate the reliance on consensus-based regulatory approaches (Glachant 1999). In such situations, there will be a strong case for joint private-public R&D efforts, including intense knowledge transfer between these efforts and technology adoption choices at the plant level.

In fact, the emergence of trustful and expert-based negotiations over the content and the timing of environmental regulations is in some way a necessary condition for realizing the previously discussed conditions. As noted above, the incentive effects of flexible performance standards will deteriorate over time, e.g. as less costly abatement technologies are introduced. For this reason, there is a need for a gradual tightening of standards over time. These decisions require tough and knowledge-based negotiations on what future emission limit values are realistic, and what timeframes for complying with these are reasonable. As indicated above, previous country case studies have illustrated that the presence of negotiated regulations, thus building on a consensual regulatory approach, has facilitated the implementation of effective environmental regulations

Finally, our analytical framework has addressed three prerequisites for well-designed licensing processes, and to some extent, we have also discussed the interrelationship between these three prerequisites. The remainder of the paper attempts at illustrating and testing this framework, but the empirical case studies also provide an opportunity to elaborate further on these relations, including on important tradeoffs and challenges.

4. Research design

The analytical framework in the previous section pinpoints three overall conditions under which environmental regulations are likely to facilitate a transition toward radical emission cuts in industries that face intense competition. In the remainder of this paper, we will address these conditions in the empirical context of the environmental licensing of a selection of mining and metal operations. Since one important component of our research design is to analyze licensing cases from two regulatory regimes in one country, it is necessary to briefly present the regimes employed in Sweden from the 1970s onwards (Section 4.1). The paper then introduces the nature of the empirical material as well as how this has been screened in the research process (Section 4.2).

4.1. Context and case selection

In Sweden, government involvement to address industrial pollution has existed since the late 19th century, e.g. the Public Health Act of 1874 and the Water Rights Ordinance of 1880. Occasionally, such legislation had far-reaching consequences for industrial polluters, including relatively stringent technology standards in the pulp and paper industry already during the early 20th century (Söderholm 2009). In the 1940s, more stringent environmental legislation was introduced, and resulted in the establishment of the Swedish Environmental Protection Agency (EPA) in 1967. In 1969, the Environmental Protection Act (EPAct) was enacted. This Act represented the first uniform legal framework for the regulation of emissions to air, water pollution, noise and other disturbing activities from Swedish industrial plants. A semi-judicial administrative body, the so-called Licensing Board for Environmental Protection (LBEP), was assigned the task of issuing plant-specific licenses in accordance with the different legal rules in the EPAct (Lundqvist 1980).

The conditions in the licenses, such as the stringency of performance standards, were based on what was considered technologically feasible, i.e. Best Available Technology (BAT), at the time, and on what could be considered economically reasonable and justified from an environmental perspective. In practice, the LBEP possessed substantial discretion when it came to balancing these three rules of consideration against each other (Duit 2007). A key feature of the LBEP directorate was that, apart from a chairperson who was qualified as a presiding judge, it had to include an industrial representative, thus ensuring the industry's influence at the very heart of the institution, one person with "technical competence", and one person with "experience from the domains of the EPA." As a result, the engineering competence of the LBEP was high. The Swedish EPA and the County Administrative Boards were in turn central consultation bodies during each licensing process. The consultations were carried out within this relatively exclusive group; the general public thus had no access or direct influence.

The environmental licensing system during the 1970s and the 1980s was based on a regulatory philosophy that emphasized the importance of collaboration, trust and consensus between the LBEP and industry representatives (Lundqvist 1980). This philosophy was in turn derived from a corporative political culture that had emerged in Sweden during the 20th century (Rothstein 1992). A major vehicle for the regulatory approach was also the transfer of information among industrial firms, government authorities and research institutes. Rational decisions could, it was perceived, only be reached if each of the negotiating actors knew exactly what the others wanted and why. Still, over time – and with the adoption of new environmental legislation – the system became difficult to survey. Inconsistencies and overlaps across the various environmental laws were identified and discussed.

With the aim of coordinating some of the key environmental laws, a commission was appointed in 1989, and the development of the Swedish Environmental Code began. This Code came into force in 1999; it incorporated 16 environmental laws, including the EPAct, now under the umbrella of the overarching goal of sustainable development. An important procedural novelty in this reform was the establishment of Environmental Courts (today Land and Environmental Courts) that replaced the LBEP. Moreover, the right to appeal was offered to (a certain selection of) environmental NGOs, and appeals are dealt with in the so-called Land and Environmental Court of Appeals.

When Sweden joined the European Union (EU) in 1995, this implied the advent of new legal obligations, not least in the industrial pollution control area. Notably, in 1996, the EU adopted Directive 1996/61/EC on Integrated Pollution Prevention and Control (IPPC), which, among other things, did require a regular reassessment of licenses and, if applicable, an update of the existing licensing conditions. However, in this respect, Swedish environmental legislation has lagged behind, not least with regard to licensing process for industrial plants. Specifically, the possibilities for reassessing any existing licenses have been limited (Government Bill 2001/02:65; Government Bill 2004/05:129). This holds true also for reassessments of the requirements as to what should be included in the original application. EU legislation also brought an increased demand for environmental impact assessments (EIAs), including opportunities for consultation and public participation in the relevant decision-making procedures. EIA requirements were not a new feature in Swedish environmental law, but in order to comply with EU law, the rules had to be made more stringent in the Environmental Code (Government Bill 1997/98:45).

In the mid-2000s, the conditions for environmental assessments of industrial activities had thus changed in significant ways compared to the situation before the advent of the Environmental Code. For our purposes, it is however important to note that the substantive rules concerning the balancing of BAT, economic costs, and environmental impacts have essentially not changed during this long time period. Moreover, one arena for the consultations taking place prior to the plant-specific licensing decisions, has been replaced by another. Nevertheless, requirements for integrated and comprehensive assessments of the environmental impacts of industrial plants, considering the objective of sustainable development, have influenced the interpretation and application of both new and existing legal rules. There is also greater scope for the involvement of various stakeholders in the relevant decision-making processes. One key aspect of this is that the discretion of the Land and Environmental Courts when it comes to balancing the three rules of consideration have likely become more limited compared to the corresponding discretion of the LBEP. Still, overall, the corporatist model of state-industry collaboration has remained an important component of Swedish policy, e.g. in climate policy (Kronsell, Khan, and Hildingsson 2019), although some claim that its importance decreased during the 1990s (Rothstein and Bergström 1999).

In the light of these legal developments, and the existence of two regulatory regimes (one before the advent of the Environmental Code and one after), we have

Table 1. Licensing processes for mining and metals projects during two regulatory systems.

	Time period	Description
Early System (1969–1998)		
Boliden-Rönnskär	1974–1986	Production increase at the company's metal smelter plant Rönnskär. This included the regulation of several pollutants, such as arsenic, cadmium, sulfur dioxide, and mercury.
Boliden-Laisvall	1974–1986	Production increase in the Laisvall mine (lead, zinc and silver) and in the nearby concentrating plant. The regulations concerned the discharges of mine water into one lake and of enrichment water into another lake.
LKAB-Kiruna	1975–1979	Production increase in the ore processing (pelletizing) plant in Kiruna. The emissions regulated include airborne dust, sulfur and fluorine.
Current System (1999–)		
Boliden-Hötjärn	2004–2011	New tailings pond at Hötjärn supporting several mine operations by the company. Concerns emissions of metals into water, as well as acidifying and nitrogenous substances.
LKAB-Gruvberget	2008–2013	The opening of a new iron mine (Gruvberget), and where the licensing process came to focus on the appropriate scope of the environmental assessment.
Boliden-Rönnskär	2009–2014	Production increase at the company's metal smelter plant Rönnskär. This included the regulation of several pollutants, not least sulfur dioxide.

selected six mining licensing processes (Table 1). Three of these processes are from the early regulatory regime while three have taken place since the turn of the century. This selection is based on the fact that, during the relevant period, the licensing processes in Table 1 represent the most significant production increases at existing mining and metal smelting operations in the two biggest mining companies in the country: LKAB and Boliden.

The Boliden-Rönnskär smelter plant is particularly interesting since it allows the analysis of two licensing processes for the same industrial plant during two regulatory systems. Moreover, this smelter has had a history of being the biggest Swedish hot spot for emissions of several pollutants such as arsenic, sulfur dioxide, cadmium, and mercury. It should also be noted that a few of these licensing processes have been presented in greater detail in previous studies (Bergquist 2007; Söderholm and Viklund 2019), typically employing narrative and/or technical focuses. Still, this research has not had any ambitions to provide in-depth comparative analyses of the design and implementation issues that could facilitate a transition toward deep emission reductions.

4.2. Methods

For our purposes, it is important to contextualize the licensing processes. The environmental regulations emerge through repeated case-by-case licensing negotiations, and there exists no simple, one-directional (stimulus-response) link between regulations and company responses. In this paper, we therefore employ case study methodology (Flyvbjerg 2006), and the licensing cases will help reveal how choices were made in situations of uncertainty and mutual influence between the affected companies and the regulatory authorities. In order to achieve this, we first need to build on case law and analytical jurisprudence for determining the content and function of the legislation, including assessments of the final verdicts of the LBEP and the Land and Environmental Courts, respectively. However, given the scope of our analytical framework, we need to consider the (often long) negotiating processes that led to these decisions. For instance, the flexibility perspective requires attention to the use of probation periods and any associated provisional standards, and the extent to which these have allowed the companies to develop and test novel solutions for pollution abatement. In order to address the predictability perspective, we need to learn about any delays and appeals during the process, including how the companies have responded to, for instance, unclear interpretations of the existing legal rules. In addition, the know-how perspective implies a focus on the content and the role of joint consultations, and the knowledge shared during these.

All in all, this implies that we have screened the full material generated and exchanged during the entire licensing processes (all six cases). This material provides information about: (a) the companies' license applications for the operations, including various technical specifications (e.g. production process, emissions, etc.); (b) evaluations and (provisional) decisions from the authorities; (c) accounts (minutes) of the negotiations between the authorities, the company and the consultative bodies (e.g. the Swedish EPA) during the processes; and (d) subsequent reports over related tests (of prospective pollution abatement technologies), and (e) the final regulatory conditions in the verdict. The relevant documents are kept at the National Archive of Sweden, and at the archives of the County Administrative Boards (in the counties where the respective mining ventures are located).

The screening process is based on the paper's ambition to illustrate our analytical framework, i.e. investigate how the three prerequisites have played out in the context of the selected mining licensing processes. Given this focus, and the fact that the original source material is extensive (several thousand pages), we need to clarify how our analytical concepts can be detected in the material. Table 2 therefore clarifies this by outlining the specific questions that have guided this screening process.

5. Empirical illustration

In this section, we employ the case study material to investigate the environmental licensing of the Swedish mining and metals industry during two regulatory systems. Each case is addressed to the extent that it provides important illustrations of how our three analytical concepts have played out in real-life licensing processes, as well as how they could offer (good and bad) lessons in the context of the prerequisites for well-designed environmental regulation

5.1. Flexibility: Compliance strategies and probation periods

Our cases show that overall, the importance of flexibility and firm discretion in identifying the most suitable abatement technology for efficient compliance outcomes (what-

Table 2. Questions guiding the screening of the empirical material.

Analytical concepts	Questions asked to the empirical material for each mining licensing process
Flexibility	
What-flexibility (compliance strategies)	• How have the licensing conditions been designed, e.g., the use of performance versus technology standards, including any provisional (temporary) standards? • How were the decisions on the design of the licensing conditions motivated by the licensing authorities? • How did the chosen standards affect the companies' search for – and choice of – pollution abatement solutions?
When-flexibility (compliance and probation periods)	• To what extent have compliance and probation periods been employed in the licensing conditions, including any extensions? • How were the decisions to grant probation periods motivated by the licensing authorities, as well as influenced by the negotiations with the companies? • How did the probation periods affect the companies' search for – and choice of – pollution abatement solutions, including efforts to pursue technological innovation?
Predictability	
Timeliness (licensing delays, e.g. due to appeals)	• To what extent have the licensing processes been characterized by delays, and what has been the major cause of these delays? • How have these delays affected the involved companies, and what measures (if any) have been undertaken to address the delays and their consequences?
Transparency (clarity regarding how the legal rules are interpreted)	• To what extent have the licensing processes involved uncertainty and differences in opinion on how the legal rules should be interpreted and applied in each case? • How have such unclarity affected the involved companies, and what measures have been undertaken to deal with uncertain interpretations of the legislation?
Know-how	
Consensual negotiations (regulatory competence and negotiations on equal terms)	• To what extent have the licensing processes involved continuous joint consultations between the regulatory authorities and the company? • What has characterized these consultations and knowledge-sharing activities, not least in the presence of shared uncertainty about potential abatement technologies? • How have the negotiations dealt with the task of balancing environmental versus economic outcomes, not least in the presence of uncertainty (e.g., about the legal interpretations)?

flexbility), have been recognized during both regulatory systems. In other words, the regulatory approach in Sweden has maintained a strong emphasis on performance rather than technology standards in the licensing conditions. This is illustrated in the more recent Boliden-Rönnskär case (2009-2014); it includes new emission limit values for, for instance, sulfur dioxide (see further below).

Nevertheless, the emphasis on what-flexibility was often particularly evident during the 1970s and the 1980s. The negotiations at the LBEP involved intense deliberations concerning what could be considered BAT (see also Lundqvist 1980). While the regulatory conditions – both the provisional and the final ones – relied on BAT requirements, the Board consistently avoided the use of technology standards. This regulatory approach was important for the companies, not least since it did not lock-in these to certain (potentially inefficient) technological pathways. For instance, the LKAB-Kiruna case shows how the company allocated considerable resources to reduce the emissions of fluorine compounds from its pelletizing plant. This included tests in a pilot plant of the so-called Dry method, a technology that was endorsed by the Swedish EPA (Söderholm and Viklund 2019). In the end, LKAB chose to comply with the standards using a mix of various measures (e.g. phosphorus removal).

The Boliden-Rönnskär (1973-1986) case is another apt illustration of the importance of 'what-flexibility'. The use of performance standards – in combination with extended probation periods – permitted the company's engineers to select, develop and test new technology suitable for the existing production processes. In the early 1980s, the LBEP recommended the plant owners to invest in so-called flash smelting technology (in line with what a Japanese reference plant had done already). Still, Boliden had the discretion to pursue other solutions as long as it complied with the stipulated performance standards. In the end, the company rejected flash smelting, and instead invested in several structural process alterations that enabled both productivity gains and emission reductions at lower costs than those associated with a new smelting unit.

It can be noted that the significant attention devoted to compliance flexibility in the Swedish regulatory system, is in contrast to the regulatory approaches adopted in many other countries. For instance, Lindmark and Bergquist (2008) remark that the North American regulations have often relied on technology standards (e.g. according to the US Clear Water Act). In addition, Yarime (2007) investigates mercury regulations in Japanese chlor-alkali plants, and concludes that technology standards mandated these plants to adopt abatement technologies that generated lower-quality products even if more efficient alternatives were available.

The most profound difference in terms of flexibility between the two regulatory regimes used in Sweden, concerns the use of probation periods (providing when-flexibility). Since the advent of the EPAct in 1969, there has been no legal obstacle to imposing such periods. Nevertheless, the cases studied suggest that this approach was employed more consistently during the earlier regulatory approach.[8] In fact, all three earlier licensing processes involving LKAB and Boliden show clear evidence of such inter-temporal flexibility.

In the LKAB-Kiruna licensing case, the company was granted a probation period of two years with the requirement that it needed to investigate in what ways the emissions of dust could be reduced following the production increase at the pelletizing plant. The LBEP motivated its decision by noting that this issue could not be entirely resolved until the rebuilt plant had been tested in practical operation. Even in the presence of the economic downturn in 1978, when LKAB had to put the pelletizing plant

Table 3. Metal output and environmental emissions at the Rönnskär Smelter during 50 years.

		Emissions into air and water				
	Metal production (kton per year)	Sulfur dioxide (S02) (kton per year)	Arsenic (As) (ton per year)	Copper (Cu) (ton per year)	Lead (Pb) (ton per year)	Mercury (Hg) (ton per year)
1967	119	36	2232	355	898	8.7
1972	136	46	1814	267	692	3.1
1977	136	28	815	236	251	1.5
1982	170	14	88	85	203	1.1
1987	192	11	20	53	75	0.4
1992	188	4.9	5.2	26	33	0.2
1997	213	3.3	1.1	7.0	7.8	0.15
2002	277	4.2	1.3	1.8	3.6	0.16
2007	277	4.2	1.2	1.7	2.8	0.10
2012	269	3.8	0.8	1.3	2.4	0.04
2018	285	3.5	0.3	1.5	2.5	0.02

Sources: Bergquist (2007), Swedish Environmental Protection Agency (2019) and Boliden annual reports.

on standby, the LBEP instructed the company to continue with the investigations. It even requested LKAB to expand these to also include the emission of fluorine and sulfur compounds. Provisional performance standards were introduced, but the Board also made clear that in the light of the uncertain economic prospects at the time, it was not reasonable to tighten the relevant standards any further. Instead, the probation period was extended for another two-year period. In the end, from having emitted 4.5 kg dust per ton of pellets produced, about four years later, the final performance standard could be set at 0.5 kg dust per ton (thus indicating an emission reduction of over 80 percent).

The two early licensing processes involving Boliden even show some evidence of regulation-induced technological innovation. In the Boliden-Laisvall case, the company investigated new as well as improved existing purification methods for its waterborne emissions. In addition, at the request of the consulting bodies of the LBEP, Boliden also tested the possibility of recovering the wastewater. Ultimately, in 1986, when the LBEP issued the final permit, it would prove that the proposed treatment plant – based on, for instance, sulfide precipitation, and in part tested and developed by engineers at the company – implied very low levels of heavy metals in the fish. In fact, it was no longer justified to consider the possible recovery of the wastewater (see also below). In this case, the total length of the probation period was as long as ten years.

The licensing of the Boliden-Rönnskär plant (1973-1986) was very complex. In spite of this, however, the licensing process led to radical improvements in the plant's environmental performance. This outcome is illustrated in Table 3. It shows that over the period 1970-2000, the emissions of sulfur dioxide decreased by 90 percent, while the discharges of a number of heavy metals (such as mercury and lead) decreased by as much as 99 percent. During the same period, the smelter's metal output (primarily copper) more than doubled.

The complexity of the environmental adaptation process at the Rönnskär smelter was much due to closely integrated production processes. These made it difficult for both the authorities and the company to identify low-cost and timely pollution abatement measures. In other words, the lack of 'off-the-shelf' abatement technologies implicated the presence of shared knowledge in the early phases of the licensing process. To address this, Boliden was granted two consecutive five-year-long probation periods, one in 1975 and yet another in 1981. Intensive experimental activities at the company level characterized the first period, and these proved productive. An integrated wastewater purification facility was invented by the company's engineers (Bergquist 2007). In fact, Boliden became a world leading company in the case of mercury and arsenic abatement technology as well as in the abatement of heavy metals from water (Solbu 1986).

5.2. Predictability: Timeliness and transparency

During recent decades, licensing delays have been a frequently debated issue in the mining and metals industry, globally as well as in Sweden (Behre Dolbear 2014; SweMin 2012). In Sweden, the average time for mining cases administered at the Land and Environmental Courts (thus excluding the time needed for a concession permit) was about two years over the time period 2002-2011, but it also varied a lot across single cases (reaching more than six years in one case) (SweMin 2012).

These periods, though, do not include appeals during the licensing process, e.g. any additional negotiations taking place at the Land and Environmental Court of Appeal. The Boliden-Hötjärn (2004-2011) case is a good illustration of how appeals could aggravate delays in the licensing process. This process concerned the construction of a new tailings pond supporting Boliden's mine operations. In 2004, the original application was submitted to the Land and Environmental Court, and the license was granted in 2007. Still, the EPA appealed this decision on the grounds that additional pollution abatement requirements were justified. This in turn led to further legal proceedings during the period 2008-2010, and only in 2011, the Court rejected the last appeals (e.g. Granberg 2013). The most significant consequences of the delay included reduced output from the mining operations of Boliden, including foregone economic opportunities to benefit from the booming metal prices during the first decade of the 2000s.

Even though there is little specific information about the timeliness of mining licensing cases during the 1970s and 1980s, our empirical cases suggest that these processes were overall faster. One important reason for this outcome, though, was that these projects (e.g. the LKAB-Laisvall case), concerned production increases rather than greenfield-investments. Provisional standards were set in combination with often extended probation periods, something that made it possible to avoid delays in production. Moreover, the consultations taking place at the LBEP involved a relatively exclusive group of experts, and the public had no access (e.g. Lundqvist 1980). As noted above, though, public participation in the licensing decision-making processes has much higher priority in the prevailing regulatory system, and Swedish mining enterprises will often have an incentive to outperform legal requirements on this account (i.e. to gain a social license to operate). Thus, even if the earlier system's focus on expert-based negotiations attempting to balance environmental and economic performance facilitated the transition to radical emission reductions, such closed negotiations would not be considered legitimate in the contemporary licensing processes. Indeed, deliberations with stakeholders *must* typically take time in order to be meaningful. In order to save time and avoid late appeals, it is essential for mining companies to establish close relations with key stakeholders at an early stage in the licensing process (e.g. Ranängen and Lindman 2018).

Over the recent decade, measures have been undertaken to shorten the durations of the mining licensing processes in Sweden, not least through the allocation of more resources (staff) to the authorities involved.[9] Still, the issue of the timeliness of licensing processes is not only a matter of having more staff at the various regulatory authorities. It also concerns the predictability of the process, not least relating to how the legal rules should be interpreted in specific situations and projects. Vague guidelines do create uncertainties and may lead to late appeals, thus further extending the timeframes involved in obtaining an environmental license.

An illustrative example of such uncertainty is the licensing of the LKAB-Gruvberget operation. In 2008, LKAB submitted its original licensing application to the Land and Environmental Court, and a license was granted two years later. Still, the Swedish EPA appealed this decision, essentially arguing that the new iron ore mining operation had to be assessed in conjunction with already existing (refining) facilities at the same geographical location (in line with the legal requirement for so-called integrated environmental assessments). The case was brought to the Environmental Court of Appeal whose members expressed support for the argument put forward by the EPA. For this reason, the Court rejected the company's original application since it was considered too narrow in scope. LKAB had to prepare a new application, and enter into a repeated licensing process, in turn resulting in a three-year investment delay. While integrated environmental assessments are often necessary in order to obtain a comprehensive picture of the total environmental load in an area (Swedish Geological Survey 2013), Swedish legislation provides few guiding principles for how to decide on the scope of the environmental licensing application in individual cases (see also Pettersson and Söderholm 2014). From the perspective of LKAB, this made it difficult to anticipate the two Courts' diverging assessments concerning the planned operations.

The licensing processes from the early regulatory system displayed less evidence of uncertainty over the interpretation of the legal rules. This could primarily be attributed to the long-term and consensus-seeking regulatory approach of the LBEP. Specifically, the combination of stringent emission reduction targets and extended probation periods provided the involved actors with the time needed to make use of existing knowledge and sort out any differences in opinion in equal – yet tough – negotiations. At the same time, production activities could commence. This was evident in the Boliden Rönnskär (1973-1986) case where the interpretation of the rules of the EPAct was uncertain but could be resolved through joint information-search efforts (see also below). In addition, as noted above, the EPAct provided the LBEP with a lot of discretion in terms of weighing the different rules of consideration against each other. In contrast, the current regulatory system has often been questioned on the ground that licenses can be rejected on largely procedural and formalistic bases. This regulatory system therefore devotes, it is often argued, less attention to weighing the technical, environmental and economic considerations against each other over time (Granberg 2013; see also below on 'excessive' costs).

5.3. Generation and transfer of know-how in a consensual regulatory approach

The experiences from all of the three early licensing processes, display how the LBEP was able to gradually implement increasingly stringent performance standards over time without this having serious negative impacts on production performance. This required, though, substantial investments in expertise on industry-specific pollution abatement technologies on the part of the LBEP and the Swedish EPA; this in order to reduce any existing information asymmetries.

The empirical cases also indicate clear evidence of shared uncertainty about future pollution-abatement opportunities. In such instances, the EPA planned the investigation efforts during the probation periods in collaboration with the owners of the plants. It monitored and enforced the development efforts through frequent plant visits, including visits at similar plants abroad. In this way, knowledge could be exchanged between the regulatory authority and the company, and then used effectively throughout the entire licensing processes. In the LKAB-Kiruna case, the company initially (in 1978) had to comply with a performance standard for airborne dust emissions at 1.2 kg dust/ton sinter, but the investigations carried out by LKAB in collaboration with the Swedish EPA displayed that considerably more stringent standards could be feasible. In the end, the final license decision resulted in a much more stringent emission limit value, 0.5 kg dust/ton sinter, imposed on the company.

In a corresponding manner, the LBEP granted Boliden-Laisvall a one-year probation period to investigate options for the treatment of the mine water. These investigations were also pursued in collaboration with the Swedish EPA, and the objective was to present a proposal for more high-grade purification of the mine water. The LBEP maintained that this should be technically possible (e.g. through precipitation), as well as reasonable from an economic standpoint given the scale of production and the environmental status of the recipient (see also Söderholm and Viklund 2019). One year later (in 1976), Boliden presented a proposal for a purification plant based on sulfide precipitation, but the company also expressed a wish to pursue this investment in two phases, this in order to attain better coordination with other productive investments. The LBEP endorsed this suggestion, in part since Boliden could then gain important experiences from operating the new plant (which was inaugurated in 1979). However, the LBEP required the company to pursue more in-depth investigation of the enrichment water – and any associated pollution abatement options – during an additional three-year probation period. In 1984, the Board concluded that the emission levels into the two lakes had been reduced by 90-95 percent compared to the peak levels prior to the beginning of the licensing process in 1974.

The differences between the old and the current regulatory system in terms of cooperation and knowledge transfer also become quite clear when comparing the two licensing processes for the Rönnskär smelter plant. As noted above, the licensing of this plant during the 1973-1986 period, involved several extended probation periods, largely motivated by the presence of significant shared uncertainty about technological solutions. During this process, Boliden was required to consult the relevant authorities, in particular the EPA and the regional County Administrative Board. These so-called 'joint consultations' provided an opportunity for the company to report on potential solutions as well as any problems encountered in the development activities. At the same time, the regulatory authorities remained updated about the status of these activities.

In contrast to other industries, such as pulp and paper, the LBEP could not base its assessment on the experiences of reference plants in the domestic industry. Instead, several plant visits were undertaken jointly by professionals from Boliden, the EPA, the County Administrative Board and the LBEP. In the case of sulfur dioxide emissions, one study trip to Japan revealed that the regulations facing the Japanese smelters were overall the most stringent, and the EPA referred to these when the final license negotiations took place in 1986. The LBEP stipulated long-term emission reduction targets for sulfur dioxide emissions; the annual emission levels were not allowed to exceed 10,000 and 5,000 tons in the periods 1987-1989 and 1992-1993, respectively (compared to over 45,000 tons in 1970). Since 1991, the actual emissions of sulfur dioxide have not exceeded the 5,000-ton target (Table 3). This history of the environmental adaptation of the Rönnskär smelter reveals plenty of shared uncertainty about pollution abatement opportunities on the part of the regulator and the company. In other words, the licensing process very much involved a collective undertaking during which the marginal abatement cost curve had to be jointly discovered over time.

This long-term cooperative approach was less visible in the more recent regulation of sulfur dioxide emissions at the Rönnskär plant (2009-2014). In this case, the Land and Environmental court decided (in 2011) on an emission limit value of 4,500 tons per year until the year 2016, and thereafter 3,500 tons. The company appealed this verdict, and contended that these standards were too stringent. In the negotiations that took place at the Land and Environmental Court of Appeals, the EPA argued for even stricter standards. Still, the Court rejected both proposals, and the emission limit values for sulfur dioxide remained unaltered. Table 3 shows that Boliden has been able to comply with the new and more stringent standards. It is worth noting, though, that in this recent licensing process, no joint investigations were initiated and the company was not allowed to benefit from extended probation periods.

Instead, the deliberations in the Courts very much concerned what the costs of achieving a more stringent performance standard would be. In most developed countries, the environmental licensing process involves an assessment of the presence of 'excessive' costs, but often there exists limited well-established guiding principles upon which such impacts can be assessed in individual cases (Sorrell 2002). The Boliden-Rönnskär (2009-2014) case is an apt illustration of this in that the negotiations during the licensing process involved ambiguities – and even inconsistencies – concerning what should be considered 'excessive costs' in line with the rules of the Swedish Environmental Code (Söderqvist *et al.* 2015). Specifically, the deliberations tend to rest on a mix of – at least – two key points of departure for this type of assessment, i.e. one involving comparisons with the marginal costs of sulfur dioxide abatement in other sectors of the Swedish economy, and the other building on a comparison between the economic value of the marginal damage of sulfur pollution at the site. Interestingly, though, in the Boliden case, the verdict of the Land and Environmental Court of Appeal essentially combined the first of these approaches with yet another rationale, namely Boliden's ability to afford environmental investments in general. Overall, such ambiguities lead to difficulties for companies to anticipate the outcome of future verdicts on 'excessive' costs.

The two Boliden-Rönnskär licensing processes illustrate how the early, very much consensus-based, regulatory approach resembled an iterated and trust-based bargaining game in which the mining and metals companies were engaged in repeated interactions with the core regulatory authorities. In these processes, the approach to the assessment of 'excessive costs' was more long-term, involving stringent targets, extended probation periods, and intense experimentation. In contrast, the corresponding licensing processes from 2009 and onwards can be characterized as 'one-shot' games, i.e. involving one appeal but no joint investigations and relatively limited benchmarking activities. In part, the latter can be linked to a number of factors, such as limited resources (staff) at the regulatory authorities, the lack of regulatory competence and knowledge transfer concerning industry-specific abatement technologies, and a more narrow sense of trust between the involved actors (see also Bergquist *et al*. 2013).

Mining and metals companies worldwide have recently expressed concerns about the lack of professionalism of regulatory authorities, and difficulties in communicating with these (e.g. Söderholm *et al*. 2015). In Sweden, this critique has focused on the key consultative bodies, such as the Swedish EPA. In this respect, it can be noted that during the period 1995-2006, the total number of employees at the EPA increased from 517 to 544. Nevertheless, the number of employees with expertise in engineering and process industries decreased from 72 to 69, this in spite of the fact that the number of corresponding licensing cases involving industrial plants increased. During the same period, the number of social scientists and lawyers increased from 130 to 176 (SOU 2008, 62, Table 3.5). Concerns have also been expressed about the lack of engineering competence at the environmental courts, which tend to be dominated by experts on the legislation and on assessing the impacts on the natural environment (e.g. biologists).[10]

This can in part explain the above mentioned concern expressed by Swedish mining companies, namely that regulatory processes have frequently been characterized by a too strong emphasis on legal principles. The decisions taken by the courts may not even, it is sometimes argued, have environmental relevance in the context of the individual licensing cases;[11] too little weight has been placed on technological competence and engineering knowledge. Again, the reliance on consensus and long-term cooperation has been less frequent and far-reaching in the current system compared to the one that prevailed during the 1970s and 1980s.

5.3. Comparative summary

Unlike previous research, we compare two regulatory systems for industrial pollution control in one country, and by studying six environmental licensing processes in the Swedish mining and metals industry. This permits a consistent comparison of key design and implementation issues in an otherwise relatively stable national institutional setting. Table 4 summarizes some of the key differences between the two main industrial pollution control approaches used in Sweden since the advent of modern environmental policy in the late 1960s.

Our findings suggest that the early Swedish regulatory approach comprised many key elements of a well-designed regulation-induced transition toward radically lower emissions in industry. One key to making such a transition possible, involved the combination of stringent long-term performance standards and extended probation periods. This, in turn, relied on high regulatory competence, and provided significant incentives for technological change at the plant level. The existing system has involved several appeals and delays in the licensing processes. It has also occasionally been characterized by unpredictable licensing conditions, e.g. vague guidelines on how to interpret the legal rules in individual cases. In brief, the balancing act of pushing for improved environmental performance on the one hand and avoiding negative competitiveness impacts on the other, was therefore overall, better managed in the early system compared to the prevailing one.

Table 4. Environmental regulation of swedish industry during two regulatory systems.

	Previous system (1969-1998)	Current system (1999 and onwards)
Key industrial pollution control legislation	*Environmental Protection Act*	*Environmental Code*
Regulatory arena	The Licensing Board for Environmental Protection (LBEP)	The Land and Environmental Courts (five courts distributed across the country)
Flexibility granted firms in identifying the measures to comply with regulations, and the time allowed for adjusting to new conditions.	Consistent use of performance standards allowed by existing BAT rather than technology standards. Frequent use of extended probation periods (2-5 years), as well as adaptation to existing market conditions.	Frequent use of performance standards (based on BAT) rather than technology standards. The legal rules permit extended probation periods, but these are generally shorter and used less frequently (compared to earlier).
Predictability with respect to the timeliness of the regulatory process, and the transparency regarding how the rules will be interpreted.	Licensing – and production – delays are generally not considered a key problem. Public participation relatively restricted. Expert-based and consensus-seeking dialogues implied less uncertainty about the final licensing conditions.	Frequent concerns over delays in licensing process, in part due to late appeals. Public participation important part of EIA. Concerns about unpredictable licensing conditions, including vague guidelines on how to interpret specific legal rules.
Know-how on the part of the regulatory authority about pollution abatement technologies and their costs.	Substantial regulatory knowledge about abatement opportunities, and an intense exchange of information among actors. Iterated and trust-based bargaining game involving repeated interactions between the key actors.	Concerns over lack of regulators' technical competence and calls for expert-based and consensus-seeking regulatory approach. Regulatory approach more of a one-shot game, involving appeals, and limited joint investigations and knowledge transfer.

6. Discussion

Industrial pollution control through the environmental licensing of individual plants, and any associated regulatory requirements, plays a key role in modern environmental policy. Licensing processes are not only important for regulating the environmental impacts of existing industries, but also for enabling investments in novel, sustainable industrial projects. For this reason, it is important to identify the conditions under which environmental regulations can promote deep emission reductions and green technological change without jeopardizing the competitiveness of industrial sectors that compete in global markets. Environmental licensing processes should not represent significant obstacles to green industrial transformations. Still, so far, the literature has devoted very limited attention to how these processes can be designed and implemented.

In this discussion, we elaborate on the conceptual contribution of the paper. Some implications of the analysis for the research community are outlined, and we contrast our findings to earlier research (Section 6.1). We then discuss practical implications for policy-making (Section 6.2).

6.1. Implications for research

The key message of this paper is that the significance of the environment-competitiveness tradeoff will depend on the design and the implementation of the environmental licensing processes, and there will often be scope for achieving positive environmental outcomes without seriously jeopardizing the long-term competitiveness of industrial enterprises. The theoretical contribution of the paper consists of an analytical framework, which addresses three prerequisites for 'well-designed' environmental licensing processes. This framework was developed by drawing on various strands of the existing literature (e.g. environmental economics, law, environmental politics, institutional economics, etc.), and then illustrated and tested empirically in the context of six licensing processes in the Swedish mining and metals industry.

Figure 2 displays this analytical framework; it illustrates the roles of flexibility, predictability, and know-how for providing strong and continuous incentives for emission reductions while at the same time addressing concerns about competitiveness. Our empirical case studies validated and illustrated this framework and showed how these three prerequisites helped to promote the green transition. In particular, the empirical findings suggest that such transitions benefit from trust-based bargaining procedures in which companies are involved in repeated and knowledge-based interactions with regulatory authorities, and in which extended probation periods permit tests of novel abatement technologies (including innovation).[12]

The empirical illustration also sheds additional light on how the three prerequisites may interact during the licensing processes, something which is also indicated in Figure 2. Specifically, the experiences indicate that these processes are often characterized by difficult tradeoffs relating to flexibility and predictability, respectively. For instance, while the use of probation periods (providing when-flexibility) creates an opportunity for the regulatory authorities to maintain control over the industrial pollution control efforts, it may add to the uncertainties about what any upcoming licensing conditions could look like. The results clearly display how regulatory competence (know-how) helps resolve this tradeoff; it provides a necessary condition for trust- and expert-based negotiations over the content and the timing of environmental regulations.[13] In other words, the balancing act of providing strong incentives for lower emissions on the one hand and avoiding negative impacts on competitiveness on the other, becomes very difficult in the absence of high regulatory competence and intense knowledge-sharing.

Our findings are well in line with previous literature illustrating the importance of regulation-induced green technological change in various industrial sectors (Weiss, Stephan, and Anisimova 2019; Bergquist and Söderholm 2011). However, the paper also adds to this literature by scrutinizing the notion of 'well-designed' environmental regulations, and highlighting the significance of key design and implementation features. Furthermore, the analysis displays the often-complex institutional mechanisms through which environmental compliance and green technological change appear to unfold (Burtraw 2013; Kemp and Pontoglio 2011). In the case of environmental regulations that

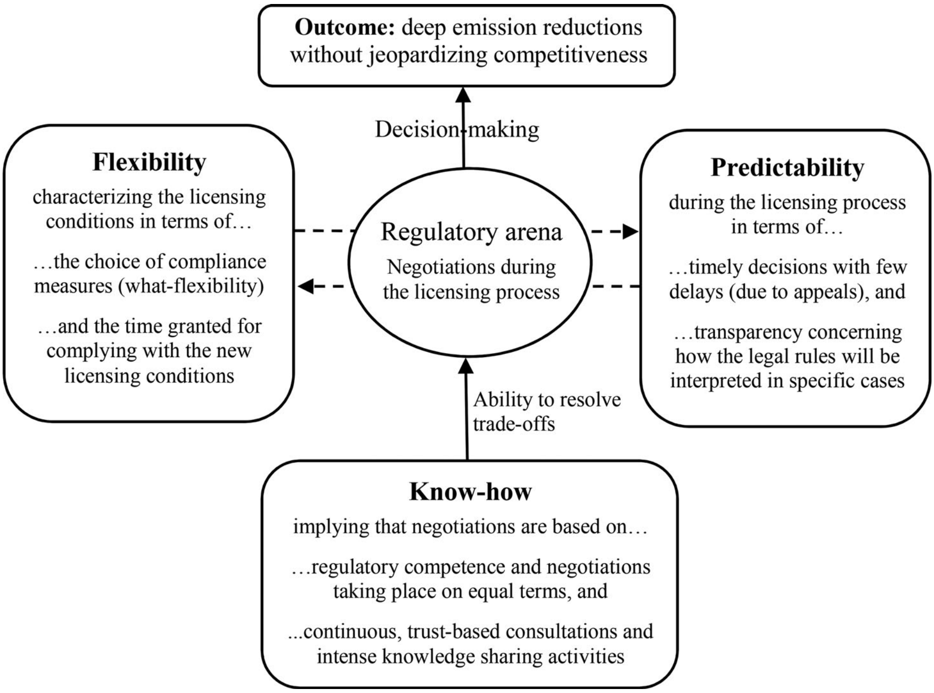

Figure 2. Designing and Implementing Efficient Environmental Licensing Processes: A Framework.

emerge from case-by-case licensing procedures, there exists no simple, one-directional (stimulus-response) link between the regulator and the affected industry. The Swedish mining and metal cases also illustrate these points. The cooperative approach of seeking consensus and sharing information implied that new knowledge was advanced in close interaction between industry, environmental authorities and research institutes before the final licenses were issued. Unlike much previous work, which tends to focus on single design features or instruments (e.g. Weiss, Stephan, and Anisimova 2019; Similä 2002), we have addressed the characteristics of the entire licensing process. Finally, our historical comparative approach permitted an illustration of how the same legal rules, e.g. the BAT requirement, can be implemented in different ways depending on the institutional and organizational context, in turn leading to varying outcomes for the affected companies. This adds to the existing studies that have conducted country comparisons.

6.2. Practical implications

The results presented in the paper imply some important implications for policy-making in the industrial pollution control domain. First, there are lessons concerning the choice of different types of environmental policy instruments. Our findings suggest that regulators need to abstain from simplified normative arguments about policy instrument choices regardless of context. One important example is the choice between economic instruments and various administrative instruments, such plant-specific performance standards. Notably, the environmental economics literature typically concludes that taxes and tradable allowance schemes will be superior to performance standards in terms of inducing green technological change (Goulder and Parry 2008).

The main reason is that in the latter case, the polluter has fewer incentives to perform beyond the standard, while a pollution tax will induce polluters to conduct low-cost abatement beyond the current level (since this reduces total tax payments).

However, there are other issues that need to be taken into account. Kemp (1997) shows that in a situation where the regulator needs to consider impacts on competitiveness, performance standards could have profound advantages over pollution taxes. The political economy suggests that, in this case, the regulator is likely to implement a comparatively low tax level. As a result, companies will then undertake less green R&D than in the standards case. In other words, the additional costs that a tax will impose on firms, withhold the regulator from implementing the long-term targets that it could have undertaken if the non-abated emissions had been free (see also Johansson 2006).

Our empirical analysis of the Swedish mining and metals industry support this notion; it shows clear evidence of performance standards promoting (demand-driven) green innovation (e.g. at the Boliden-Rönnskär smelter). This result is also consistent with the notion that there is meager evidence of one type of policy instrument being overall superior to others in terms of promoting green technological change and innovation. Specific policy designs, various implementation strategies and institutional contexts (e.g. trust), which have often evolved over several decades, matter just as much (see also Kemp and Pontoglio 2011).

Moreover, the results also suggest a few specific implications for the design and implementation of future licensing processes. Our results suggest that: (a) licensing authorities could together with industry representatives develop generic guidelines for how the existing legal rules should be interpreted in different situations, this in order to strengthen the predictability of the licensing procedure; (b) the licensing authorities' knowledge of various industrial projects, including their environmental impacts, available technical solutions and costs, could be strengthened; (c) there could be increased transparency concerning how various tradeoffs have been dealt with and assessed during the licensing processes;[14] and (d) the environmental licensing procedure should, to a greater extent, be designed as a continuous process rather than as a 'one-shot game', such as through a more systematic use of longer probation periods. Furthermore, it is important to recognize the difficult tradeoffs involved in most licensing procedures. For instance, it has been suggested that 'green' industrial projects should get special treatment, a 'priority lane', in the licensing assessments (e.g. Ministry of Environment and Energy 2018). However, such 'simple' solutions may add to the uncertainty facing investors; it is far from straightforward what should be considered 'green' in a specific context and the risk of appeals may increase.

7. Conclusion and avenues for future research

This paper contributed to the existing literature by identifying the prerequisites for achieving a regulatory-driven transition toward deep reductions in industrial pollution level. We developed an analytical framework that outlines how environmental licensing procedures can be designed and implemented in order to help promote a radical greening of industry without jeopardizing its competitiveness. This framework was illustrated by investigating six licensing processes in the Swedish mining and metals industry over an extended time period. In brief, the conceptual framework and the empirical findings suggested that well-designed regulatory approaches must address the predictability, transparency and timeliness of the decision-making process, as well as the flexibility in terms of the required pollution abatement measures, and, not least, the time allowed for complying with the standards. The above, in turn, builds on regulatory competence concerning the technological opportunities and their costs, and the facilitation of continuous sharing of knowledge between the industry and the regulator. The empirical findings illustrated how this has enabled consensus-based and yet tough negotiations, which have been essential for realizing the flexibility and predictability prerequisites as well for resolving any tradeoffs between these two characteristics.

It should be clear, though, that there is plenty of scope for additional conceptual and empirical research on the role of environmental regulation, including climate policy, in various industrial sectors. As noted in the introduction, there is a need for research on how to choose, design, and implement environmental regulations that can facilitate the introduction of new sustainable value chains and technological fields, such as the supply of critical metals (e.g. lithium) for the zero-carbon transition in the transport sector. While this article has pinpointed a number of lessons from previous green transitions, it is essential to consider in more detail how future – and to some extent already ongoing – restructurings could be affected by the environmental regulations and other policies. The more radical greening of industrial process, such as phasing out carbon dioxide emissions in the iron and steel industry, will typically be characterized by long development periods during which new, technology-specific innovation systems, i.e. actor networks and institutions, have to be established. Well-designed as well as legitimate regulatory approaches should be able to support such green restructuring processes, while regulations that remain poorly designed, short-term and which lack a recognition of the institutional context, could instead (somewhat paradoxically) pose threats to the future greening of industry.

Notes

1. Several types of regulations affect the mining industry. Still, in this paper, the attention is devoted to the pollution control requirements stipulated in the (environmental) licensing conditions for new investment or, in the case of amendments (e.g., production expansions), for existing operations. This means that the analysis does not address the role of other necessary permits such as exploitation concession permits involving the regulation of land use issues. See Williams (2012) for a review of mining regulation in several important mining countries.
2. See Söderholm, Bergquist, and Söderholm (2019) for a recent review of the literature on the impacts of environmental regulation in the pulp and paper industry, and the challenges involved in making such regulations more effective.
3. See Söderholm, Bergquist, and Söderholm (2017) on the transition to chlorine-free pulp in the Nordic pulp and paper industries, Weiss, Stephan, and Anisimova (2019) on environmental regulations in the Swedish pulp and paper industry, and Söderholm (2013) on the global phase-out of mercury use in products.
4. The information advantage of the polluting firms will not necessarily relate to the characteristics of the abatement technologies as such; it could instead often concern the ways in which these technologies affect production costs (and product quality) once implemented in a specific production process.
5. This section partly departs from, but also develops, the discussion in Söderholm *et al.* (2015). While this previous research provides an empirical investigation of the design of environmental regulations in three mining countries, the present paper instead offers: (a) a much more in-depth conceptual framework concerning the circumstances under which plant-specific performance standards can facilitate radical reductions in industrial pollution; and (b) an empirical, case-based, investigation of how such standards have been designed and implemented in one single country over a long time period.

6. One can distinguish between compliance and probation periods. The former implies that the regulator decides on a new standard (e.g., emissions in kg per ton produced), but provides the plant with time (e.g., two years) to comply with this. Probation periods refer instead to the period during which companies can test different technology solutions *prior* to a final decision (Söderholm, Bergquist, and Söderholm 2017). Both approaches, though, provide when-flexibility.
7. In most countries, regulatory authorities often take into consideration the performance standards typically used for specific sectors in other countries, not least in the case of air emissions (e.g., Ministry of Environment (Canada), 2007). In this way, the stringency of the performance standards may converge across countries, but with remaining differences due to various context-specific factors.
8. This conclusion is also supported by research on the environmental regulation of the Swedish pulp and paper industry. Söderholm *et al.* (2019) investigate the regulation of chemical oxygen demand (COD) load emanating from 21 pulp and paper mills over the period 1981-2013. During this period, a total of 16 probation (or compliance) periods of at least three years were identified, and out of these, 11 were introduced before the Environmental Code was enacted. In addition, under the current system, reassessments of existing license conditions initiated by the regulatory authorities are rare (in spite of existing EU requirements) due to a lack of adequate regulatory resources.
9. Government investigations have also evaluated the various ways of streamlining the licensing process, such as the possible introduction of a 'fast track' for green industrial projects (e.g., Ministry of Environment and Energy 2018).
10. One expert at one of the Land and Environmental Courts in Sweden confirmed this in a recent interview, and noted that the overall lack of engineering competence makes it difficult to challenge companies concerning issues related to BAT (cited in Pettersson and Söderholm 2019, 72).
11. For instance, in the LKAB-Gruvberget case, the verdict from the Land and Environmental Court of Appeal did not contain any new – or more stringent – regulatory requirements compared to those emanating from the lower court. In other words, in this case, the demand for an integrated environmental assessment did not influence the design and stringency of the required performance standards.
12. Our results underscore, and provides and explanation for, the conclusion reported in Kriström and Wibe (1992), namely that industrial pollution control in Sweden during the 1970s and 1980s led to substantial environmental improvements at a relatively low total cost.
13. There are other examples of the flexibility-predictability trade-off. In some instances, companies may prefer technology over performance standards, even if the former provides less flexibility. Two reasons for this are that technology standards risk leading to fewer surprises during the environmental monitoring process, and could be easier to comply with on a daily basis, thus increasing predictability (Pettersson and Söderholm 2019).
14. If this is not achieved, there will be limited lessons for the licensing of future industrial projects, thus reducing the predictability of the outcomes of the licensing process.

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