

Coping with Private Lobbies in Industrial and Product Safety Regulation: A Literature Survey

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Abstract

This literature review sheds light on the role of marketing authorisations and liabilities in controlling industry lobby behaviour aimed at enhancing the lobbyists' private interest to the detriment of the public interest. We present two political tools available to public authorities, marketing authorisation and liabilities (civil and criminal) to regulate firms that market products that could be harmful to society. We draw on the economic literature and contributions that study how these policy tools can be used to achieve three main objectives: providing incentives for risk mitigation, fostering innovation and the acquisition of information on unclear risks, and avoiding collusion between public bodies and the companies being regulated. We conclude with a brief discussion of the areas that require more in-depth research on this topic.

Keywords: industry risks, information acquisition, innovation, liability rules, lobby, scientific uncertainty.

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Introduction

A lobby is a group of people brought together to promote and defend interests by exerting pressure or influence on people, public institutions and agencies that hold power, or rather, public decision makers.¹ The purpose of a lobby's actions is to stop, delay and weaken all legislative measures, standards, and regulations and, more generally, any intervention or decision by a public authority which could harm their private interest. Contemporary lobbies vary widely. They can be representative organisations (American Medical Association, European farmers – COPA, K Street Project, Movement of the Enterprises of France – MEDEF...), private firms (Alphabet, Amazon, Facebook, Total, Sanofi...), associations (EuropaBio, which represents the interests of the biotechnology industry, including companies such as Bayer, Nestlé, Aventis, Syngenta Seeds, Unilever; CEFIC, the European Chemical Industry Council, with members like BP, Lubrizol and Versalis, among others; and BEUC, the European Consumer Organisation, which includes some 40 consumer associations from 30 different countries), charities (British Heart Foundation, Young Men's Christian Association [YMCA] and the Transparent Hands Foundation) or Non-Governmental Organisations (NGOs), such as the World Wildlife Fund (WWF) or Greenpeace. In this article, we focus on industry lobbies, that is, influential groups that defend the interests of industries (firms).

Lobbying is a legal activity. Lobbies behave as legitimising forces, sources of information and public opinion, and a means of putting pressure on politicians (Hurd, 1999). According to Zetter (2014), the lobby industry can be beneficial to public decision makers and democracy. It is important that both parties have access to representation to ensure their arguments are presented in a coherent and convincing manner. In addition, the lobby industry helps public decision makers to produce better legislation by responding to consultation documents that provide policy makers with detailed arguments and carefully drafted amendments.

However, not all lobbies behave ethically. In March 2021, Servier Laboratories was found guilty of aggravated deception and ordered to pay the state a fine of €2.7 million and to

¹ A public decision maker is defined as a person or a set of people forming a group, which has the power to determine policies and/or laws at the international, national, regional or local level. The Lisbon Treaty, signed on 13 December, 2007, which came into force on 1 December, 2009, endowed the European Union with seven institutions: the European Parliament, the European Council, the Council of the European Union, the European Commission, the Court of Justice of the European Union (CJEU), the European Central Bank (ECB) and the European Court of Auditors (ECA). It includes agencies with responsibility for health and the environment, such as the European Chemicals Agency (ECHA), the European Food Safety Authority (EFSA), the European Medicines Agency (EMA) and the European Environment Agency (EEA). The United States (US) institutions include the White House (the President), the United States Congress (the House of Representatives and the Senate) and the Supreme Court of the US (SCOTUS). US health and environmental agencies include the Food and Drug Administration (FDA), the Centers for Disease Control and Prevention (CDCP) and the Environmental Protection Agency (EPA).

compensate all victims of the deception to a total of €180 million in the case of Mediator.² At the same time, the National Agency for the Safety of Medicines and Health Products³ was fined €303,000 for negligence related to its delay in suspending sales of Mediator and its links with the Servier group. For 33 years, between 1976 and 2009, Mediator was authorised in France for the treatment of diabetes and people suffering from hypercholesterolemia. This compound of benfluorex, a hypoglycaemic molecule,⁴ was diverted from its initial use and prescribed to 5 million (non-diabetic) patients as an appetite suppressant to help with weight loss. In 2007, Irène Frachon, pulmonologist at the University Hospital of Brest, issued an alert on the dangers of Mediator, after a 10-year investigation into its cardiac effects. She reported cases of heart valve disease to the National Agency for the Safety of Medicines and Health Products, which, in 2009, withdrew Mediator and its generic equivalents from the French market.⁵ The Mediator case broke in June 2010 with the publication of Frachon's book *Mediator, 150 mg: how many deaths?*⁶ This book recounts her struggle to bring to light the fact that Servier laboratories had concealed knowledge about the risks involved in using Mediator, favouring their financial interests over the health of consumers of the medicine. In France, Mediator was estimated to have resulted in the deaths of between 1,000 and 2,100 people, plus many more who suffered the consequences of its side effects. This case exemplifies the strategies employed by industry lobbies to exploit flaws in the health and drug control system to satisfy commercial interests while harming society.

In another example, in March 2017, the American justice system declassified internal correspondence from Monsanto, which showed that, as early as 1999, Monsanto was concerned about the mutagenic potential of glyphosate. This declassification revealed Monsanto's manoeuvres against the International Agency for Research on Cancer (IARC), which had classified glyphosate as a "probable carcinogen." To defend its product, Roundup, a glyphosate-based herbicide, Monsanto practised "ghost-writing," a scientific fraud technique that consists of writing an article and having it endorsed, for a fee, by a renowned scientist who claims to be its author. In addition, Monsanto had succeeded in convincing Jess Rowland, an executive of the Environmental Protection Agency, to prevent any chemical regulatory agency from showing interest in glyphosate. Researchers had been threatened by Monsanto's lawyers, their work denigrated, their honesty questioned and the institution's donors approached to discontinue its funding. All these actions were deliberate and carried out by Monsanto to preserve its authorisation without any attention to health and environmental damage (Hobbs, 2019).

² The drug Mediator is an anorectic and hypolipidemic agent that is structurally related to Benfluorex.

³ In French : 'Agence nationale de sécurité du médicament et des produits de santé' (ANSM).

⁴ A hypoglycaemic molecule promotes synthesis of glycogen by the liver and therefore has the power to lower blood sugar levels.

⁵ Recall that, in 1999, Mediator had been withdrawn from the Italian market and was withdrawn from the Spanish market in 2003, due to its health risks.

⁶ In French: *Mediator 150 mg : combien de morts ?*

These two scandals pose questions about the role played by marketing authorisations and liabilities to prevent industry lobbies (private interests) from increasing risks and creating damage to health and the environment. Using the literature, we address these questions in this article. Section 1 describes the policy tools available to public authorities to regulate firms that market products with the potential to harm society. These tools include market authorisation (or approval), and liability (civil and/or criminal). We review the main contributions from the economics literature on how these policy tools can be used to achieve three main goals in different contexts: incentives for risk mitigation (Section 2), avoiding collusion between state agencies and the firms to be regulated (Section 3) and encouraging safe innovations and acquisition of information about imprecise risk (Section 4). Section 5 provides a discussion of future research directions related to this topic.

1 Policy tools: Authorisation and liability

In this section, we discuss the two main policy tools – authorisation and liability – used to manage production risks.

1.1 Authorisation

Authorisation is a tool that is enforced *ex-ante*, that is, before the risk is realised. It involves the public authority deciding whether or not to authorise a particular action by a firm, based on an examination of the costs (and advantages) for the whole society. In our context, an action and its performance can refer to selling a product that could be harmful to consumers or the environment. Authorisation introduces a barrier to market entry of such products and is employed by most industrial countries for sectors that perform activities and/or make products that could harm humans and/or the environment. Here, we distinguish between product approvals and authorisations to operate.

The sectors subject to product approvals mainly include pharmaceuticals, transportation, and chemicals. In the United States (US), the introduction of a new drug or pharmaceutical product requires authorisation from the Food and Drug Administration (FDA), which was created in 1906.⁷ In the case of the aviation sector, in 1958 the US Federal Aviation Administration (FAA) was created to ensure a minimum quality of aircraft devices.

In both the US and Europe, marketing authorisations are granted by agencies with responsibility delegated by the state. These authorisations are aimed at ensuring product safety

⁷ As a result of the 1938 Food Drug and Cosmetic Act, the US FDA has sole authority to approve prescription drugs for marketing.

for consumers in line with their allocated budgets. They are not managed directly by the state and have independence in relation to how they achieve their goals. They recruit experts to assess applications for market authorisation and periodically appoint external experts to conduct one-off assessments (Hiriart and Martimort, 2012; Martimort, 2011). The experts involved manage the discussion between the agency and the firm applying for authorisation and are independent of politics (state and/or parliamentary). Authorisations are also sought for day-to-day operations in relation to products, industrial plants or activities which are considered dangerous.

In the US, the Environmental Protection Agency (EPA), which was set up in 1970, assesses the impact on the environment and ensures the desirability of the most hazardous industries. One of the main pieces of legislation that imposes the need to apply for authorisation before operating is the Resource Conservation and Recovery Act (RCRA), which came into force in 1976. RCRA is “cradle-to-grave” legislation and applies to the generation, transportation, treatment, storage, and disposal of hazardous waste. It requires firms dealing with hazardous waste to meet certain standards to obtain authorisation to operate. Similar *ex-ante* policies exist in Europe. In France, Law 76-663, dated 19 July, 1976, obliges firms operating in the riskiest sectors to apply for authorisation, meet certain standards and provide the state with risk assessments related to their activities. As in the case of product approvals, authorisations to operate act as a barrier to entry and are managed by specific agencies (Environmental Protection Agency (EPA) in the US, Regional Directorate for Environment, Planning and Housing (DREAL) in France).

1.2 Liability

Unlike authorisation, liability applies only in the case of occurrence of a harm that damages a person or the environment. In that sense, it could be described as an *ex-post* policy, because it applies after the firm has received authorisation to operate and after its activity has caused harm. From a purely economic viewpoint, liability can be seen as a means for providing firms with incentives to undertake socially beneficial action (or deterring them from engaging in detrimental actions): the threat of having to pay for performance of a wrongful action provides decision makers with an incentive to regulate the firm’s behaviour.

In practice, for the cases of interest in this paper (i.e., harm to human health and/or the environment), two kinds of liability apply: civil liability and penal liability. Civil liability is the legal rule that compels any person (natural or moral) to repair any damage it causes to another person and/or the environment.⁸ In the US, Title 28 Chapter 171 of the US Code governs claims

⁸ Liability requires causality to be proved between the action of the injurer and the harm suffered by the injured. With the exception of Shavell (1987) and Rose-Ackerman (1991), discussed in Section 3.1, who highlight that proving causality can be a major problem in relation to enforcing liability (especially in the

procedures for torts and Title 15 of the US Code refers to liability for harm arising from use of a product (product liability). Liability for harm to the environment is governed by the 1980 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Civil liability regulates relations between persons: it organises compensation between a person, the injurer who caused the harm to another person, and the injured. It regulates the interaction between private parties. Civil liability can be contractual or extra-contractual. Contractual civil liability refers to relations between persons linked by a contractual relationship, including a market relationship. Hence, product liability is a specific area of law that regulates the harms that can occur from use of a product (producer–consumer relation). Extra-contractual civil liability regulates relations between persons not linked by a formal contract, who are “strangers,” that is, they are not known to one another. This includes the laws that regulate torts, that is, accidents involving individuals not linked by a contractual relationship (which includes most industrial harms, automobile accidents, etc.). For the present study, both contractual (product liability) and extra-contractual (tort law) liabilities are relevant: we are interested in the regulation of activities that could be harmful to others, which covers regulation of dangerous products and hazardous activities that could harm the (surrounding) environment. Penal liability results in blame or punishments issued to persons (individual and moral) for their (intentionally) deviant behaviour. In that case, it is the state, as the representative of people, that sues the individual and punishes the individual’s illegal action. Note that both civil and penal liabilities may apply if the harm is the result of a deviant behaviour: these two judicial tools are not mutually exclusive and, beyond penal liability, can add to the incentives provided by civil liability, which we discuss later in the paper.⁹

Liability can be implemented strictly or based on a negligence rule: strict liability triggers liability whenever a harm occurs, while a negligence rule liability depends on proof that the injurer was negligent about the (ex-ante) duty of care, established by the law. Product liability is strict: in the case of harm to a consumer using a product, the producer is liable whatever the level of care adopted when designing and making the product. Strict liability in the case of harm resulting from use of a product is justified by willingness to decrease the burden of information victims are required to provide to the court to establish liability, since there is an asymmetry in the degree of expertise for producer and consumers.¹⁰ In the case of an extra-contractual relationship (tort between strangers), the externality between the two parties in the case of harm from using a product can vary. Indeed, if the consumer of the product

case of latent hazards), most economic analyses of liability focus on the incentives for risk prevention provided by liability rules which assume that causality has been proven.

⁹ In the case of harm to the environment, CERCLA introduces both civil liability and penal sanctions, for instance, for the unauthorised release of hazardous substances (US Code, Title 42, §9603). In Europe, directive 2004/35/CE introduces civil liability for harm to the environment. Directive 2008/99/CE introduces the concept of environmental offences and related criminal sanctions.

¹⁰ Whatever the rule (strict liability or negligence), the victim has to prove, in court, that the harm suffered was caused by the injurer (causality). In the case of negligence, victims have to prove that the injurer was negligent (as regards a duty of care). Enforcing strict liability exempts victims from this second burden of proof.

made by manufacturer A has the possibility of using a substitute product made by manufacturer B, and if he/she believes that the product manufactured by A is too dangerous, then market forces may act as incentives for manufacturer A to take more care when designing its product.¹¹ However, this market relationship, which can ensure (partial) internalisation of the expected harm, does not exist in the case of an extra-contractual relationship between strangers, which applies to most environmental harms. By default, extra-contractual liability is based on negligence. Liability for harm done to the environment was introduced in the US in 1980, with the CERCLA law. In Europe, it was established in 2004 by the 2004/35/CE directive. While negligence is the default rule governing torts, most hazardous activities are regulated by strict liability (Shavell, 2018). Again, the willingness to decrease the burden of proof for (non-expert) victims justified this turn to strict liability. However, the increased use of strict liability in the case of hazardous activities is also justified by the willingness to provide the operating firms with incentives to control their risks by any means, including those that can be defined by standards (of due care) and those that cannot.¹²

Following the findings in Weitzmann (1974), Magat (1978, 1979) and Coase (1960), the economic literature on the public regulation of negative externalities (pollutions, risks of harms to others) focused initially on policy tools based on market mechanisms. This applies to the case of Pigouvian taxation, tradeable permits (see Downing and White, 1986 and Milliman and Prince, 1989 for a comparative analysis of the incentives to abate pollution provided by these tools) and liability.¹³ Enforcing liability to regulate risky activities raises many issues, including comparison of the incentives provided by strict liability or negligence liability (Shavell, 1980) and the possibility to settle before the trial (Daughety and Reinganum, 2017), the interplay between liability and insurance (Shavell, 1982), etc.¹⁴ Among the most important issues is that of insolvency (first introduced by Summers, 1983 and Shavell, 1986).

Insolvency introduces a partial externalisation of the risk when firms benefit from limited liability. Limited liability states that the debt(s) that the firm must repay cannot exceed

¹¹ For comprehensive surveys of this topic, see Polinsky and Shavell (2010) and Daughety and Reinganum (2013).

¹² Negligence makes liability subject to the absence of compliance of the injurer with respect to a standard of due care. In other words, if negligence applies, the injurer is exempt from liability as soon as it complies with all the standards of due care. In the case of risk mitigation this requires actions that cannot be standardised (e.g., due to their non-observability) and then the negligence rule fails to provide incentives to exert these actions.

¹³ From a purely economic perspective (in terms of the incentives provided), liability can be seen as an application of Coase's theorem in the case where the victim has a "right to peace" (the injurer "buys" the right to operate its activity through payment of damages in the case of harm).

¹⁴ In this paper, we do not discuss how insurance can interact with liability (for an introduction to this topic, see Shavell, 1982). Not taking account of this interaction is not a limiting assumption for the analysis in the present paper. Consider the case of purchasing insurance that covers damage (civil liability). In the case that the insurer can observe the efforts made by the firm, the incentives for these efforts still hold, since they lead to a decrease in the insurance premium. In the case where the insurer cannot observe these efforts, an incomplete coverage will hold (to avoid moral hazard) and the retained risk will provide the incentives to perform the activities. Finally, in the case of penal liability, insurance is forbidden: a person cannot "delegate" the payment for penal liability.

its net financial value. If the firm causes a harm that exceeds this value, the part of the harm that exceeds the firm's value will not be compensated. In that case, the firm does not internalise the full extent of the risk it imposes on society, which leads to suboptimal decisions (Shavell, 1986 and Beard, 1990).¹⁵ Nevertheless, the reduced incentive for risk mitigation, due to potential insolvency, varies with the liability rule enforced. Shavell (1986) shows that the rule of negligence can provide a higher incentive for risk mitigation in the face of insolvency, due to the possibility for the firm to be exempted from liability if it complies with the standard of due care. However, this applies only if two conditions are met: (i) the firm, albeit potentially insolvent, has sufficient assets to lose in the case of a trial. and (ii) standards of care can be defined, which assumes that the risk mitigation measures are easily observable by the court. As a consequence, in addition to the fact that the rule of negligence allows the victims not to be compensated in the case of compliance by the firm, it fails to provide adequate incentives for all the measures for which a standard cannot be defined. In particular, this includes cases where the level of the risk depends on the level of activity, which cannot be constrained by a standard (see Shavell, 1980). To sum up, in relation to the incentives for risk mitigation under potential insolvency, a trade-off emerges between use of strict liability and use of negligence if the risk mitigation measures can be standardised. In that case, if the firm's solvency level is not too low, negligence can provide the firm with an incentive to comply with the (optimal) standard of due care, but leaves the victims uncompensated. Strict liability is more likely to dominate if risk mitigation measures cannot be standardised.¹⁶

The possibility of escaping liability through insolvency has been used strategically by some firms in mostly hazardous sectors. Ringleb and Wiggins (1990) show that, in the US, half of the small firm creation between 1967 and 1980, was due to a strengthened liability system, which allowed victims to be more easily identified (and compensated) in case of injury due to their activities. As a response to the increase in the (expected) burden of liability, those firms delegated the riskiest activities to undercapitalised subsidiaries (or subcontractors) to allow "rapid" declaration of bankruptcy in the case of harm, enabling them to escape large debts.¹⁷

To fight the adoption of these strategies, the US legislator, via CERCLA, introduced the possibility of extending civil liability to the firm's financial partners (mainly banks). This aimed at, on the one hand, extending the civil liability to banks to increase the financial basis available to pay victim compensation and ensure better ex-post justice. On the other hand, the threat of having to pay for the firm's harms provided the banks with incentives to control firms'

¹⁵ For instance: if a firm has a financial capacity of 10 and can cause a harm of 100, limited liability will restrict the damages paid to 10 (and the remaining 90 will not be compensated). Limited liability prevents extension of the liability to the personal wealth of the firm's stakeholders (to pay for the uncompensated harm). Assuming that a harm of 100 requires more care (to be properly mitigated) than a harm of 10, the firm only internalises 10 and will not have an incentive to properly mitigate this risk.

¹⁶ Moreover, strict liability ensures a strictly positive compensation for victims and decreases the burden of the related informational costs (no need to prove the injurer's negligence).

¹⁷ Several strategies involving construction of a "liability shield" are documented in Ringleb and Wiggins (1992).

risk management efforts. However, the informational asymmetry between the banks and the firms prevents the banks from making loans dependent on the firms' risk control actions, which leads to suboptimal situations, such as increased level of risk (Pitchford, 1995) or exclusion of certain firms from loan contracts (Katzmann, 1988; Anderson, 1998).¹⁸ Regarding this "liability crisis" (Anderson, 1998), in 1996, the US legislator had to (partially) retract with the introduction of the Asset Conservation, Lender Liability, and Deposit Insurance Protection Act, which allowed the banks to have some direct control over firms' day-to-day management.

While extending civil liability may be counterproductive, enforcement of penal liability, if applicable, may restore the incentives for firms to mitigate the negative externalities of their activities.¹⁹ Shavell (1985) shows that, when civil liability provides insufficient incentives to mitigate the risk of harm because of "dilution factors" (e.g., the difficulty of demonstrating causality, the difficulty of the victims accessing justice or any other event which allows the injurer to escape liability because of the absence of trial), penal liability may offset this effect by enforcing high fines, which increases the expected cost of causing harm. Indeed, the fines may be higher than the value of the harm done.²⁰ Moreover, enforcing penal liability on both the firm and its decision makers (e.g., the CEO) can work to complement the incentives provided by the firm's civil liability. However, this mechanism is also subject to insolvency constraints (both the firm and its decision makers have limited assets). Since civil and penal corporate liability may not have a sufficient deterrent effect, because of insolvency constraints, some scholars, such as Kahan (1998) and Friedman (2000) advocate for the application of individual criminal liability, with non-monetary sanctions (e.g., incarceration), to deter the most serious harms.

Beyond the combination of civil and penal liability, ex-ante and ex-post policies can be complementary. As previously mentioned, most firms involved in hazardous activities require authorisation to operate. The authorisation criteria include risk prevention and technological standards, although more and more country agencies responsible for risk regulation require the firm to have a minimum degree of solvency (Jacob, 2020).²¹ Firms are asked to provide minimum financial provisions. Both "third party mechanisms" (insurance) and "self-

¹⁸ Pitchford (1995) shows that, in the presence of information asymmetry between the bank and the firm (on the firm's risk management process), an increase in the bank's liability may push the bank to increase the price of the loan (risk premium), thus reducing the firm's incentives to mitigate the risk (because of a decrease in its payoff in the case of no accident, relative to the accident state).

¹⁹ Recall that penal liability is applicable to punish deviant action, serious negligence and/or intention to harm.

²⁰ In the US, punitive damages can play such a role (i.e., damages that are higher than the value of the harm caused). In Europe, punitive damages are not allowed, so the only way to increase the expected cost of causing harm is to impose high fines.

²¹ RCRA requires firms dealing with hazardous waste to have sufficient available funds to cover the costs of closure and 30 years of post-closure costs (long-term monitoring and maintenance, especially for units which leave waste in place upon closure). CERCLA, section 108(b), introduces the need to provide "evidence of financial responsibility", which is "consistent with the degree and duration of risk associated with the production, transportation, treatment, storage, or disposal of hazardous substances".

insurance” can be used to satisfy this requirement; in this case, self-insurance is use of bonds or deposits in trusts. Since the ability to issue bonds and/or to deposit in trusts increases with the firm’s level of equity, all these legal provisions indirectly require the firm to increase its level of equity. Thus, these requirements are aimed at reducing the capacity of the firm to choose its level of capital and to apply a strategy of “judgment-proofness” that makes it possible for the firm to (partially) escape from liability due to insolvency. These requirements introduce *de facto* a floor to the firms’ financial capacities, which limits the possibility for the firm to “choose” its solvency level. However, this policy has limits, imposed by the opportunity costs of tying up capital, and introduces barriers to entry, which can also be detrimental (Shavell, 1986). Overall, requiring minimum financial provisions ensures a minimum level of risk internalisation, but may be insufficient to induce optimal incentives for risk mitigation in the face of large risks of harm if the firm is declared insolvent. This suggests the need to improve risk regulation policy, especially through a mix of ex-ante technical requirements and ex-post liability.²² The possibility of combining policy tools has been studied in the economics literature.

2 A mix of ex-ante and ex-post policies to mitigate risk

Although the economics literature underlines the efficiency of market-based policy tools to mitigate negative externalities (Coase, 1960; Weitzmann, 1974) and their superiority over command-and-control policies (Magat, 1978, 1979; Downing and White, 1986; Milliman and Prince, 1989), the 1980s law and economics literatures raise the question of complementarity between command-and-control and market-based policies, that is, between ex-ante standards and ex-post liability. First, their complementarity has been studied in the context of the best (mix of) policy (or policies) to provide incentives for controlling risk. Some studies highlight the advantage of joint use of liability and regulation to prevent the risk of collusion between the firm and the regulator. Other studies include in the analysis of risk mitigation imperfectly known risks, for which additional information is available.

Shavell (1984) was one of the first studies to question the complementarity between ex-ante safety standards and ex-post (civil) liability for regulating an activity that might cause harm to others. He considers several parties (e.g., an industry), where each displays the risk of causing harm but can reduce the probability of causing harm by investing in care. x is the level

²² In cases where the magnitude of the harm depends on the firm’s level of activity, even if the firm has a strictly positive level of assets (from financial requirements, for instance), the firm’s (in)solvency becomes endogenous. So, it may be desirable to regulate the firm’s level of activity. While this cannot be achieved by enforcing standards, Jacob and Spaeter (2016) study the possibility of complementing liability with taxation on the level of activity. Finally, if the production is considered too dangerous, a ban on the activity can be imposed by law (as in the case of exploitation of shale oil in France).

of care (with $x \geq 0$), $p(x)$ the probability of causing harm (with $0 < p(x) < 1, p'(x) < 0, p''(x) > 0$), and h the magnitude of harm, which takes the value in $[a, b]$, with $0 < a < b$. The parties differ in the magnitude of harm they can cause, that is, each party is characterised by its own level of h . Values of h in $[a, b]$ are distributed according to density $f(h)$. The socially optimal care that a given party (h given) should choose responds to minimisation of:

$$x + p(x)h$$

so that the first-order condition that defines the optimal level of x , say $x^*(h)$, is

$$1 = -p'(x)h$$

Assume first that only liability holds and that the parties benefit from limited liability: their payment in liability cannot exceed the level of their assets. If all parties have the same level y of assets, with $0 \leq y < b$, then all parties that may cause a harm h with $h > y$ will be unable to compensate it entirely; thus, the risk is partially externalised. Shavell (1984) also assumes that all the parties may escape a suit, so that the probability q of a suit is lower than unity. As a result, no party fully internalises the externality. For a given h , the level of care that will be chosen if liability is the sole policy used to control risk responds to the minimisation of:

$$x + p(x)q \min\{h, y\}$$

and the resulting level of care that is adopted in equilibrium is denoted: $x_l(h)$. Given the externality that leads the private benefits from care to be lower than the social benefits, we have: $x_l(h) < x^*(h)$

Shavell (1984) also questions the efficiency of implementing a regulatory standard (alone). If the regulator is unable to observe h , but knows the distribution $f(h)$, it will set a unique standard, s , which each party has to satisfy in order to engage in the activity. Thus, the regulator's problem is to find a level of s that minimises:

$$s + p(s) \int_a^b hf(h)dh = s + p(s)E(h)$$

where $E(h)$ is the expected value of h over the industry. Note s^* is the level of s that solves this problem. The consequence of imposing such a unique standard, based on the expected harm, on all parties, is that parties presenting a level of harm that is below $E(h)$ will take more care than first-best, and parties presenting a level of harm that is higher than $E(h)$ will be under-deterred.

Shavell then compares the two policies by studying the difference in the expected social costs between the case where only liability applies, and the case where only an ex-ante safety standard is enforced. So, he studies the sign of:

$$\int_a^b \left[[x_l(h) + p(x_l(h))h] - [s^* + p(s^*)h] \right] f(h)dh$$

Shavell (1984) found that the use of ex-ante safety standards alone is superior to liability alone if the factors that dilute liability are sufficiently important, that is, if q or y are sufficiently low

or if the variability among parties is sufficiently small (i.e., values of h are sufficiently concentrated about $E(h)$).

Shavell (1984) also showed that simultaneous use of an ex-ante standard and ex-post-civil liability could improve the situation. In that case, the unique standard must minimise the following problem:

$$\int_a^b [\max\{s, x_l(h)\} + p(\max\{s, x_l(h)\})h]f(h)dh$$

Indeed, each party (or each “ h ”) must choose a level of care that complies at least with the standard. However, in the case of ex-post liability, the party has an interest in adopting a higher level of care (than the standard) and is free to do that. So, the level of care adopted is:

$$\max\{s, x_l(h)\}$$

Equivalently, the preceding problem to minimise can be rewritten:

$$\min\{A, B\} \text{ where:}$$

$$A = \min_{0 \leq s < x_l(b)} \int_a^{\hat{h}(s)} [s + p(s)h]f(h)dh + \int_{\hat{h}(s)}^b [x_l(h) + p(x_l(h))h]f(h)dh$$

$$B = \min_{s \geq x_l(b)} s + p(s) \int_a^b hf(h)dh$$

Recall that the only difference between the parties (firms) is the level of harm, h , they can cause. All other characteristics (including their level of assets y), are similar.

The expression A is split across two terms. The first term represents the firms that are associated with a low level of harm. For these firms, if only liability applied, they would choose a low level of care (the extreme being zero care a tends to zero). Hence, the standard is higher than the level of care that would prevail under liability alone, and the firms comply with the standard. Regarding the second term, for firms that are associated with a higher level of harm, the level of care “driven” by liability is higher than the level of the standard. The level of harm for which there is equality in the level of care between the level that is the best response to liability and the standard is $\hat{h}(s)$. Finally, the expression B represents the case where the standard is higher than the best-response level of care adopted by the firm, which is associated with a higher level of harm under liability, that is, $\min_{s \geq x_l(b)}$. In that case, all firms must comply with the standard.

Shavell highlights the conditions that ensure that joint use of tools is better than use of each tool on its own. On the one hand, joint use of standard and liability makes it possible to increase the level of care for firms that would choose a low level of care under liability alone (because of high dilution of liability). So, the standard provides minimum incentives for firms whose expected burden of liability is too low (because of imperfect enforcement of liability). On the other hand, liability can provide incentives for care in the case of harm of the highest magnitude (for which a unique standard would be too low). Finally, in the case of firms that could cause a low level of harm (and for which it is optimal to exert a low level of care), joint

use of liability and standard makes it possible to reduce the level of the unique standard in such a way that those firms will not waste resources by implementing a level of care that is too high.²³

Shavell's work led to research on the complementarity between regulation and liability. Schmitz (2000) extends Shavell's (1984) analysis to the case where the injurers are characterised by different levels of assets and shows that joint use of regulation and liability can also be better (than each tool used alone) in such a context. Hiriart *et al.* (2004), building on Shavell's (1984) assumptions (i.e., firms that differ in the level of harm, which is private information), highlight the virtues of coordination between the ex-ante regulator and the ex-post judge. This coordination would make it possible for the (both ex-ante and ex-post) regulator to offer a menu of incentives that stipulate both ex-ante standards and ex-post penalties and rewards. In this case, the social optimum can be achieved, but if the level of care is no longer verifiable, a moral hazard problem emerges and the first-best is no longer achievable.

Beyond these analyses, which highlight the incentives for care provided by public policies (ex-ante, ex-post, and in joint use) in a given context, other studies enable a map to be drawn showing the advantages and disadvantages of using ex-ante and/or ex-post policies (and the resulting trade-offs), depending on the characteristics of the situation being regulated.

Shavell (1987) was the first to attempt to highlight the possible trade-offs in the enforcement of different policies aimed at regulating risk. He developed a 2*2-category scheme to compare the advantages and costs of five policies (civil liability, safety regulations, fines, corrective taxes, and injunctions), depending on the timing of their enforcement (ex-ante or ex-post) and on the initiator (the state or a private person). If we restrict the analysis comparing civil liability and safety regulations, Shavell underlines that the virtues of civil liability include low administrative costs due to its ex-post implementation. In contrast, enforcing safety standards requires monitoring costs, which are incurred whether a harm occurs or not. However, providing incentives (only) through the threat of ex-post "penalties" may be inefficient if the liability is diluted and/or difficult to establish. Rose-Ackerman (1991) reminds us that liability can be diluted because the harm is diffuse and harms many individuals, but

²³ The unique standard that minimises the social cost of activity in the frame of joint use of standard and liability is lower than the unique standard to be enforced in the case of a standard used alone (firms that cause a high magnitude of harm and have a high level of assets will be deterred by liability, so the standard applies only to firms with low levels of assets that cause a low magnitude of harm, in which case a lower standard is optimal). This standard minimises $\int_a^b [\max\{s, x_l(h)\} + p(\max\{s, x_l(h)\})h]f(h)dh$, knowing that the firm adopts: $\max\{s, x_l(h)\}$.

only to a small extent, such that none of them has any incentive to sue. Dilution of liability may also apply to insolvency of the injurer, discussed in Subsection 1.2. In all these cases, ex-ante regulation (such as safety standards) may be better than ex-post liability. Moreover, under liability, the fact that private parties make all decisions may be inconvenient if these parties have imperfect information. Indeed, the injurer may be unable to take an optimal decision about the risk its activity imposes on others. Take the case of a small company that uses chemicals to exterminate pests: it may be difficult for its employees to gather information on these chemicals and to deduce adequate use of these substances. Here, safety standards published by a state agency (which gathers information on the level of danger of the substances and determines guidelines for their use) may be more relevant than letting the private party decide (under the sole threat of liability). Also, victims with the initiative to trigger liability may suffer from imperfect information. Rose-Ackerman (1991) describes the case of victims of latent hazards, such as cancers, who might find it very difficult to prove causality (necessary to assign liability). As a result, if the better-informed party is the state, ex-ante regulation may be more efficient, whereas if the better-informed party is a private party, liability will be more efficient. Finally, Rose-Ackerman (1991) complements Shavell's (1987) analysis by emphasising situations where both types of policies are complementary from a procedural point of view. She points especially to cases where ex-ante standards are the minima (e.g., because of high heterogeneity among firms that all operate a desirable activity – a case where stringent standards that work to exclude some firms may be costly). In that case, ex-ante regulation acts as a first filter, which ensures minimum risk mitigation, and must be completed by ex-post liability that provides “tuned” incentives for all.

The advantage derived from combining ex-ante and ex-post policies, by using ex-ante regulation as a first screen to improve the efficiency of ex-post liability, was analysed in depth by Schwartzstein and Shleifer (2013). They consider the implementation of only ex-ante regulation, only ex-post liability or a combination of the two, in an industry where several firms may each cause a harm h (the magnitude is the same for all firms). The first original contribution of their analysis is that it examines the firms' decisions to engage or not in the activity. The authors consider that firms' activities are a source of social externality, but that firms differ in their ability to capture this social benefit privately. As a result, a too heavy burden of liability could prevent engagement in (socially optimal) activities. Moreover, the firms differ in their probability of causing harm: “safe” firms are associated with a low probability, “unsafe” ones with a high probability. From a social perspective, the first type does not need to invest in care whereas the second type does. In the case of ex-ante regulation, the regulator seeks information on the firm's type, but this information may be incorrect. If the regulator considers the firm “unsafe,” it will ask for investment in care measures. “Safe” firms are exempt from such investment. The regulator might then control for whether the firm took precautions and impose a fine based on the firm's type and the occurrence of an accident. So, the regulator is free to investigate before or after the occurrence of an accident. Making the fine

dependent on the occurrence of an accident provides an additional degree of freedom to target unsafe firms (which are more likely to cause harm). Making the fine dependent on the firm's classification by the regulator allows for regulation that resembles performance-based standards. When ex-post civil liability is enforced, in the case of harm the court observes whether the firm took care or not (but the court cannot perfectly observe the firm's type). Damages are not capped and depend on both the (signal of the) firm's type and the firm's decision to invest in care or not. Given this framework, Schwartzstein and Shleifer (2013) highlight the benefits of the regulator's role as an ex-ante filter. To the extent that fines (and damages) may depend on the firm's type, ex-ante screening makes it possible to reduce the expected "penalty" cost for safe firms ("penalty" being fines and/or damages). This reduces the likelihood that those firms will not engage in risky activity and will be welfare improving. However, only the presence of a high social externality of the activity (i.e., a large gap between the social and private benefits deriving from the activity, the latter being smaller than the former) can justify exclusive use of ex-ante regulation to prevent activities that provide a high social benefit from being excluded due to a high burden of liability.

In addition to these initial studies on joint use of ex-ante and ex-post policies as desirable for controlling risks, other work that builds on Stigler (1971) and Viscusi (1992) focus on another advantage of this mix of policies, that is, preventing capture of the ex-ante regulator by the firm.

3 Mixing ex-ante and ex-post policies to avoid collusion between industry lobbies and decision makers

Industry lobbies and policy makers are important actors in all political processes. Both are related and final political outcomes are the result of their mutual interactions. Stigler (1971) was the first economist to document the possibility of state agency capture by large firms. Lobbyists create privileged and lasting relationships with policy makers. Most policy makers lack expertise, time, and personnel (Jones and Baumgartner, 2004). Lobbyists can potentially "subsidise" them by selling their time and expertise to make the decision (Austen-Smith and Wright, 1994). Bennedsen and Feldmann (2006) show that the actions of lobbies provide a positive "information externality" to the decision maker. As a theoretical basis for understanding political decision making, Keim and Baysinger (1988) proposed the principal-agent model. They suggest that the firm should develop political strategies to create and maintain effective agency relationships with regulators. Private firms will adopt a policy of pressure on decision makers and seek to dictate public policy agendas. All their efforts are focused on influencing the government's position to their advantage. They may try to

consolidate their position as arbitrators or regulators in their area of specialisation. This both saves time for the decision maker and at the same time facilitates the access of industry lobbies to the decision makers (Baumgartner *et al.*, 2009; Betzold, 2014; Mahoney and Baumgartner, 2008).

Personal relationships between lobbyists and policy makers can be built on shared work experience and so-called revolving doors (Blanes and Vidal *et al.*, 2012), or repeated work on specific issues or campaign financing (Bertrand *et al.*, 2014). Lobbyists use debate, forums, think tanks and clubs²⁴ to solicit policy makers. During these meetings, proposals for changes to the law, such as amendments, may be circulated. Lack of resources for drafting and lack of time among policy makers can lead to presentation of amendments drafted by lobbyists (Hall and Wayman, 1990). All of this complies with the code of ethics and is legal. The tobacco industry adopted this type of behaviour to influence policy makers. They offered gifts, charitable donations, and group entertainment, such as travel and sporting events, to connect with policy makers and to build mutual political trust and support (Givel and Glantz, 2001).

Lobbying can be a strategy used to dominate competitors and/or to build barriers to entry for new firms. Carpenter (2004) defines capture or collusion as: “*larger and older firms [that] use regulation as a political substitute for economic competition, constructing entry barriers against their smaller and newer competitors (existing or potential) or using regulation to impose disproportionate costs upon smaller and newer firms*” (Carpenter, 2004, p. 613). Hiriart *et al.* (2010, p. 1013) focus on the case where a firm might bribe its monitors so that they hide information on misconduct. Bribes might take the form of promises for future job opportunities in the private sector for current regulators, direct monetary bribes or campaign contributions targeted towards lawmakers and key elected officials who have influence at the various stages of the firm’s monitoring. In this case too, the firm obtains advantages from the ex-ante regulator in terms of its new products being more likely to be approved, relative to those from a competitor that did not engage in this collusion process.

Thus, from an economic point of view, lobbying introduces two main risks: distorting the competition and reducing the efficacy of risk regulation. In the latter case, Hiriart *et al.* (2010) show the extent to which a mix of policies, involving adding the possibility of an ex-post judgment, can avoid the risk of collusion on the ex-ante side of the policy. They try to define the optimal scope of monitoring between the ex-ante regulator and the ex-post judge, in cases where the ex-ante regulator is either benevolent or corrupt. The ex-post judge is assumed to be incorruptible. The authors analyse the impact of the possibility of corruption of the ex-ante regulator on the optimal regulation scheme. They propose the case of a firm that wants to operate a risky activity and is asked to invest in safety measures. An ex-ante regulator may

²⁴ The French ‘Club Hippocrate’ is funded by various pharmaceutical companies, including several deputies and senators on the Servier mediation commissions.

invest in monitoring the firm and, in the case of non-compliance with safety standards, it may impose a fine on the firm. Ex-post monitoring, by a judge, occurs after an accident or at any moment that the ex-ante regulator grants authorisation to the firm. In the case of the ex-ante regulator (who must monitor the firm's safety level before it enters the market), it is important to note that the authors do not consider it an "institutional body." Instead, they consider the personal relationship between the firm to be regulated and the employee of the agency who must monitor it. This employee suffers a disutility from the investigation and receives a wage that depends on whether he/she reports evidence of the firm's safety efforts. The firm can bribe the employee if he/she promises to remain silent in the case of discovery of evidence about negligence relative to safety. In this context, where the ex-ante monitor, but not the ex-post judge, can be corrupted, the authors show that keeping ex-ante and ex-post monitoring in the hands of two different entities allows for better prevention of ex-ante corruption. The judge's ex-post investigation makes it possible to highlight the "inefficiencies" of ex-ante monitoring (i.e., lack of safety measures by the firm that ex-ante monitoring did not detect) and thus makes it costlier for the agency employee to be lenient. In the case of the ex-post judge, the authors assume that he/she may fine the firm in the case of misbehaviour (after an accident investigation). This could be a negligence rule, the standard being not to collude with the regulator. The fine is a monetary fine that is subject to the firm's solvency constraint. Therefore, penal non-monetary sanctions (such as incarceration) are excluded from this analysis, but the monetary fine considered by the authors could, in reality, be a payment of a fine (criminal liability) and/or payment of damages to victims (civil liability). Therefore, the presence of an ex-post judge and a system of wages based on the performance of the regulator's employees makes it possible to prevent collusion and increase social welfare.

Boyer and Porrini (2004) also consider the possibility of capture for the ex-ante regulator, in an analysis that compares the separate use of ex-ante regulation and ex-post civil (only) liability, which can be extended to financial partners (if damages exceed the firm's net value, as enabled by the CERCLA, for instance). They consider a firm that needs an external loan to invest in a project whose return is random (possible returns and probabilities are known). In addition to the return risk, the project may cause harm, but the firm can invest in safety measures to decrease this probability. However, this safety investment is not observable, so neither an ex-ante regulator nor a financial partner can write a contract that depends on the firm's safety investments. As in Hiriart *et al.* (2004), the ex-ante regulator offers the firm an incentive contract. This specifies both the conditions for being financed or not, and the payments (conditional on the realised profit).²⁵ This also applies to the case of an external financial partner that is subject to extended civil liability. However, the objectives of these two actors are different: the financial partner wants to maximise its own profit (including the

²⁵ Since external financing is required for the operation, granting the loan or not is similar to granting authorisation to operate or not.

possibility for extended liability), while the ex-ante regulator aims to maximise a welfare function including the firm's profit, the level of harm and the cost of using public funds. The ex-ante regulator can be "captured," in the sense that, compared to a benevolent regulator, it can benefit from bribes paid by the firm. The bribes are financed by the informational rents conveyed to the firm. Because of this particular channel of capture, the captured regulator tends to make environmental protection stricter because higher safety measures are conducive to higher informational rents.²⁶ The authors find that in the case of ex-post liability, both financing and high levels of safety measures are less likely to be induced by the financial partner (relative to the first-best), since it would bear the full cost of the informational rents while not perceiving the full social benefit deriving from the activity. In contrast, the ex-ante regulator has a higher incentive to impose a high level of safety, especially if he/she is captured (because of the prospect of bribes based on the informational rents). As a result, the authors found that, in the case of the large costs of using public funds, extended liability has an advantage over ex-ante regulation, while low values of the cost of reducing the probability of accident favour ex-ante regulation (even in the case of capture). We would point out that the liability schemes of Hiriart *et al.* (2004, 2010) and Boyer and Porrini (2004) differ. The first assume that ex-post discipline is ensured by a judge, who, if collusion holds, triggers liability following an accident. This is ultimately the "standard" on the collusion that provides the ex-post discipline. Boyer and Porrini (2004) instead assume strict liability (liability always holds whenever an accident occurs), but the ex-post discipline is provided by the financial contract, which is designed by the financial partner, who by extension bears the liability. Thus, discipline is delegated to a private actor.

In a political economy essay, Hiriart and Martimort (2012) propose a comprehensive description of the decision making involved in the public regulation of risk, the political issues involved and their consequences for the process, highlighting in particular "governance failures". The authors begin by justifying public intervention to govern emerging risks. This relies mainly on the fact that only the state is able to consider externalities and is sometimes the only agent able to make a (significant) financial investment in searching for information about risks, especially in contexts of radical uncertainty.²⁷ However, in the case of high uncertainty (inherent in new technologies), safety norms need to be defined before the emergence of new scientific knowledge that would make it possible to reduce (or eliminate) these uncertainties.²⁸

²⁶ The "traditional" channel of capture is through an increase in the firm's profit, in form of bribes. This channel tends to result in the captured regulator leaving the environment unprotected. Authors writing about efforts not to tilt the balance either one way or another (ex-ante or ex-post policy) draw on this understanding. See Boyer and Porrini (2004, p. 29).

²⁷ The authors cite the example of the risk of a leak from a nuclear power plant, for which few insurers would be able to assess the possible consequences (or the probabilities of its occurrence).

²⁸ If a time lag is expected before uncertainty about the degree of dangerousness of the new product/technology can be reduced, the opportunity cost of not using it could be excessive. Therefore,

The authors then discuss the political process of regulation-building and highlight the difficulties related to implementing cost-benefit analyses of new (and not well-known) products. The first problem is information, and especially information on the potential benefits of the product: this is held by the firm, which has an interest in its overvaluation. The public regulator may react by overweighting the costs associated with authorisation of the product and may provide the firm with an informational rent to obtain information.

The second problem is the regulation process, which is delegated to independent agencies. These agencies, which focus on implementing evaluations and granting authorisations, can develop expertise, which allows their employees to hold discussions with the regulated firms and to assess the quality of the information they provide. At the same time, there is asymmetric information between the state (or its representatives, politicians) and the agency's employees. To the extent that the agency's employees and the politicians' objectives differ, this asymmetric relation may lead to a biased public decision-making process. The authors cite the example of agency employees with career ambitions, which might affect their recommendations: established experts who risk loss of reputation in the case of a "bad" decision, may be pushed to recommend the status quo, thus blocking new (and risky) projects. By contrast, new experts who need to build their reputation may be more likely to authorise new and risky projects since, if the worst happens, they have little to lose, while if the project is successful, it will improve their career prospects and add to their reputation (Prendergast and Stole, 1996).

The authors observe that agencies may have wide scope for discretion (Van Houtven and Cropper, 1996), which can favour capture or bias in decisions (made by careerist employees). Discretion leaves room for a misalignment between political will and agency decisions. However, delegation to an agency is decided by politicians, who question the reasons for such delegation. The political science literature (see Bendor and Meirowitz, 2004, and Huber and Shipan, 2002, 2006) shows that for politicians, there is a trade-off between the imposition of strict rules on agencies and discretion. Imposing strict rules guarantees alignment of objectives between the (uninformed) politicians and the agency; discretion allows the agency to decide, based on its expertise (with less government control). The social utility of agency expertise enables the decision to be made between these two alternatives. To avoid the risks associated with a large degree of agency discretion and the risk of systematic conservative decisions (if the agency is subject to political rules), Hiriart and Martimort (2004, 2011) call for the inclusion of an ex-post judge,²⁹ and the possibility of an ex-post investigation that could provide information on the relevance of the decision made by the ex-ante regulator, making it more difficult for the ex-ante regulator to be captured or make biased decisions.

temporary norms may need to be defined to make it possible for the new product to be used; these norms can be revised as new knowledge emerges.

²⁹ Similar to Hiriart *et al.*'s (2010) analysis, payments ordered by the judge can be damages (in the case of civil liability following an accident) and/or fines (penal liability for misconduct). Here, the analysis focuses on the incentives provided by this scheme of payments, whatever the rule triggering the payment.

Finally, building on the studies cited above, which follow Stigler (1971), Carpenter (2004) highlights the possibility of capture of the ex-ante regulator. He shows that even in the absence of collusion, the system of authorisation may advantage large and/or old firms. Carpenter recognises that collusion may exist, but that its effect is additional to another effect. He argues that, by construction, the organisation of the authorisation process favours old and large firms more than small and young firms. Carpenter's (2004) model considers an ex-ante regulator that must decide on the approbation of products, in an industry composed of firms that differ in age and size. He also includes consumers, who might benefit from authorisation of the product (the new product responds to consumer needs). Knowing that the ex-ante agency may value its reputation, it considers the individual welfare of both firms and consumers. The agency may benefit from early authorisation of the product. Once the product is authorised, Carpenter does not consider the possibility of removal of the product from the market (approval is irreversible). Carpenter (2004) also considers that, prior to authorisation, firms engage ex-ante in experimentation and accumulate information on the dangerousness of the product, following a Wiener process. Firms can apply for authorisation of different products (that meet different consumer needs). These different applications may allow the regulator to learn about the "seriousness" of the firm, which adds to its reputation: thus, the relationship between the agency and the firm is a repeated game. In this context, Carpenter (2004) shows that a "value of familiarity" exists, especially when it comes to firms seeking approval of their version of a product which has already received approval in the case of a different firm.³⁰ In this specific situation, conditional on a decision of approbation by the regulator, the author shows that the expected review time is decreasing with the number of applications made by the firm in the past. The intuition relies on the fact that any application made by a firm with a history of applications will provide valuable information to the regulator, and this holds even if the firm has a history of unsuccessful applications. To the extent that the product has already been approved for another firm, the product is expected to be socially desirable. In any new application, a firm that shows poor application performance, and is known because of this, provides the regulator with relatively precise information about the upper bound of the potential risk. If this upper bound is not too high, approval will be granted without delay. However, if a firm with no application history seeks approval of its product, the uncertainty about its ability to mitigate risk will be higher. The regulator will ask for more information (to accumulate knowledge and belief about the firm's abilities), and the review time will be longer.

Except for Carpenter (2004), all the studies cited so far deal with perfectly known risks. However, in many cases, and especially in the case of innovations and newly discovered products, the risk to society may not be precisely known at the time of marketing (even though, from a purely operational point of view, the products work and respond to consumers' needs). This requires public policies designed to meet two additional objectives. First, they must

³⁰ For more details, see Carpenter (2004), Proposition 5 p. 620.

provide incentives for searching for more information and knowledge about this imperfect new risk, in order to reduce the remaining uncertainty about the dangers of the new product. Second, they must reduce, as far as possible, the risk of introducing new and undesirable (dangerous) products onto the market.

4 Mixing ex-ante and ex-post policies: a means of fostering safer innovations and dealing with imperfectly known risks

Other virtues related to the complementarity between authorisation and liability can be found in the regulation of imperfectly known risk, which may provide incentives to encourage safer innovations and production of knowledge about remaining uncertainties.

4.1 Encouraging safer innovations

The regulation of innovations that encompass new and imperfectly known risks, developed following work on environmental economics, aimed at identifying the most appropriate policies to promote innovation and reduce (negative) externalities (Downing and White, 1986; Fischer *et al.*, 2003; Magat, 1978, 1979; Milliman and Prince, 1989). This body of work refers to “traditional” environmental policy tools – taxes and permits (see Endres *et al.*, 2006, 2008, 2011 and Jacob, 2015 for the case of liability rules).

The analysis in Immordino *et al.* (2011) investigates the regulation of a firm which seems to market a product whose dangerousness is imperfectly known. The authors focus on attempts to prevent the introduction of a new product that, ultimately, is more dangerous than previous products. They suggest that innovation is not always socially desirable, which is in line with Tuncak (2013), who refers to “regrettable substitutions”: new products or substances developed to replace old (and dangerous) products that are found to be as or more dangerous in comparison to the older versions. How public policies can help to prevent such regrettable substitutions is the focus of Immordino *et al.*’s (2011) study.

The authors consider a risk-neutral firm that is already engaged in a (risky) activity.³¹ This firm has the possibility of making an effort $I \in [0,1]$ in a bid to discover a new product. They assume that the level of this effort coincides with the probability of success in discovering the new product, but that this investment is costly (increasing and convex): $c(I) = c \frac{I^2}{2}$, $c > 0$. In the case of discovery, two states of nature may apply. In a good state, the new product is socially beneficial. The welfare from producing it is: $W^g = w^g y$, with y the firm’s level of activity ($y \in [0, \bar{y}]$). The new product is even a source of positive externality, since the private

³¹ Both profit and social welfare associated with this status quo situation are normalised to 0.

profit $\Pi = \pi y$ from producing y of the new product is lower than the social welfare (i.e., $w^g > \pi > 0$). In a bad state, the new product is socially detrimental while private profit is positive: the welfare is $W^b = -w^b y$, with $w^b > 0$, and the private profit is still $\Pi = \pi y$. In that case, social and private interests come into conflict and the firm might have an incentive to market a socially undesirable product, which would lead to a regrettable substitution. The probability of being in the good state is $1 - \beta$ and the probability of being in the bad state is β , where $0 < \beta < 1$ exogenously given. The schedule is as follows: the firm makes its effort I , to discover whether the new product works or not; it observes whether it is socially beneficial or detrimental (state good or bad) and then decides on its level of activity y . The public regulator cannot observe the state of nature, but can investigate to find evidence about which state applies: with probability p (with $0 < p < 1$), the regulator finds evidence about the social effects of the new product. In such a context, the social welfare that a benevolent dictator would have to maximise is:

$$W = I[(1 - \beta)(W^g y^g) + \beta(-W^b y^b)] + (1 - I)0 - c \frac{I^2}{2}.$$

This welfare has to be maximised by deciding on I, y^g and y^b . It is obvious that, conditional on the bad state, the social level of activity must be equal to 0 (i.e., $y^b = 0$), and conditional on the good state, the social level of activity has to be maximum (i.e., $y^g = \bar{y}$). So, the optimal level of the only remaining decision variable I , say I^* , will be defined by:

$$\frac{\delta W}{\delta I} = 0 \Rightarrow I^* = \frac{(1-\beta)(W^g \bar{y})}{c}.$$

The authors then analyse the incentives related to the firm's (private) decisions about I, y^g and y^b under three decentralised policies: two regimes of ex-ante approval ("lenient authorisation" or LA and "strict authorisation" or SA), and a regime of ex-post penalties.

Both regimes of ex-ante approvals exist for the firm, before entering the market and applying for authorisation from the regulator. However, the regulator finds evidence of the true state of nature with a probability p . If the regulator finds evidence of a good state g of nature, the product is authorised. If it finds evidence of a true bad state b , the product will be prohibited and cannot be sold on the market. This applies to the cases of both LA and SA. However, these two approval regimes are distinguished by what happens in case of failure to find evidence: under LA, the product is approved; under SA it is not approved.

In the case of an ex-post penalty regime, the firm is free to market (or not) its new product. But the firm may be fined if the regulator finds evidence that the product is harmful to society. So, this regime of ex-post penalty, considered by Immordino *et al.* (2011), differs somewhat from a civil liability system, in that it does not assume compensation for the harm done: the penalty can be higher or lower than the harm done. For a given level of activity y , if the regulator finds evidence that the bad state s is the true state, it can impose a fine $f(y) = [0, F]$, $F > 0$. The authors include the possibility of defining a menu of fines, depending on the level of y .

In the case of a firm with limited assets (which imposes an upper bound on fine values) where the regulator's investigation may not succeed (i.e., $p < 1$), the authors show that the preferred policy depends on the likelihood that the new product is harmful (i.e., the value of the probability β to be in the bad state). For low values of β , no policy (or a laissez-faire policy) should be applied, since the expected social benefit from the new product is sufficiently high to not hamper innovation by the imposition of regulation. As the value of β increases, the optimal policy must be stricter: penalties or lenient authorisations are preferred for intermediate values of β , and strict authorisation is preferred for the highest values of β . Finally, Immordino *et al.* (2011) show that the stringency of the public policy needs to increase if the net social benefit of a good new product relative to a bad product (i.e., the value of $W^g - W^b$) is low in terms of the private benefit derived from marketing the new product (i.e., the value of π). The authors highlight that increasing the severity of the policy is socially desirable since innovations can be expected to be more dangerous.

Another issue related to the debate on liability in the case of new products is the possible trade-off between safety and innovation. Deffains and Demougin (2008) suggest that if knowledge about the dangerousness of a product is likely to evolve over time, holding the firm liable for a (latent) hazard, which, given the scientific knowledge at the time, could not have been anticipated when the product was introduced, this could reduce the incentive to design other new (but potentially dangerous) products.³² Beyond the need to provide incentives to design innovations or new products that will be safe, while keeping the innovation process profitable, there is no agreement over which type of liability would hold in the case of a harm that occurred during use of those products (see Boyd and Ingberman, 1997). While product liability is strict, it could be argued that, in the face of uncertainty about the dangerousness of the product, a defence could be introduced for firms that had conducted due diligence in relation to the product design: if the state-of-the-art, that is, frontier scientific knowledge, did not allow a possible risk to be detected, is it reasonable to hold the firm liable for failing to prevent this risk? Also, if a possible defence based on state-of-the-art knowledge is introduced, which criteria should apply?

The analysis by Deffains and Demougin (2008) sheds light on these questions. In the case that scientific knowledge is still evolving, no standard of due care can be defined objectively (and definitively). Therefore, on what should due diligence, in the context of defending liability, be based? In practice, there are two competing defences: defence based on a *customary practice test* and defence based on a *technological advancement test*. While “traditional” defences of negligence are associated with tests based on the absolute level of

³² Porter (1990) was one of the first scholars to highlight this possible trade-off, by stating: “product liability in the United States is so extreme and uncertain as to retard innovation, it places firms in constant jeopardy of costly and lengthy product liability suits”.

care adopted by the defendant (see Shavell, 1980), in this new case, the two possible defences are associated with tests of the relative effort made by the defendant compared to the effort made by colleagues/competitors. In case of a *customary practice test*, defence is based on whether the injurer has exerted similar efforts to its competitors; in the case of the *technological advancement test* a more exceptional safety level is required (higher than competitors, at the forefront of technological capacities). Deffains and Demougin (2008) note that enforcement of these kinds of defences can be distinguished from enforcement of a negligence rule; for example, in the former, the level of the standard is not given and is not evaluated in absolute terms.³³ Here, the standard, to some extent, is endogenous to the industry (the group of competitors that market the same kind of product). Thus, the “standard” on which the defence will be stated can vary with the number and “quality” of the competitors in the pool of reference.

Deffains and Demougin (2008) try to test the incentives for the design of new, safe products, in a context where the impossibility of defining an objective (and definitive) standard justifies enforcement of a defence of state-of-the-art knowledge. They compare the incentives to spend on safety, provided by a defence based on the customary practice test, with a defence based on the technological advancement test. More precisely, they consider N firms that sell a product that could cause harm. They derive the level of the firms’ expenditure on developing a safe product under each of the two defence rules.³⁴ In the case of harm, the court is only able to observe a noisy signal, but not the level of expenditure made by the injurer firm (this applies to all the firms the court wants to observe). First, the court decides about the size of the sample (say n) used to compare the injurer’s expenditure and the mean expenditure (of the sample). Second, the court has to decide which defence rule to apply: the *customary practice test* compares the (noisy signal of) the injurer’s expenditure with the mean expenditure in the sample (of n firms); the *technological advancement test* requires a *larger* expenditure than the mean, and its extent requires another decision by the court (let δ be the excess expenditure over the mean).³⁵ Given the liability framework (n , δ) announced by the court, each firm must decide its level of expenditure, based on a trade-off between this cost of care and expected damages payments, in the knowledge that the level of expenditure of all the firms, in case of harm, implicitly defines the likelihood of being exempted from liability thanks to a state-of-the-art defence (a Nash game between the firms applies).

Focusing on the ability of the liability framework to implement a given level of expenditure by the firms, Deffains and Demougin (2008) show that different liability

³³ In the case of defence against liability, the burden of proof is on the injurer (while negligence has to be proven by the plaintiff).

³⁴ To simplify their analysis (focusing on the firms’ behaviour under each defence rule and knowing that the firms’ expenditures have an impact of the “level of standard” on which the defence can be stated), the authors consider already active and profitable firms. New entries and the possible trade-off between safety and innovation/activity are ignored.

³⁵ If δ is strictly positive, a technological advancement test applies. If δ is equal to 0, a customary practice test applies.

frameworks (n , δ) can achieve this goal. It is possible to reduce the size of the sample n while maintaining the incentives to spend on safety, by increasing the level of δ (i.e., applying a more stringent test). They also show that the incentives for expenditure are ensured by requiring a large sample (large n) and reducing the stringency of the test *below* the mean (i.e., negative δ). In other words, there is a trade-off between the stringency of the standard (δ) and the sample size n of the firms to which the defendant is compared. The technological advancement test necessitates a smaller sample size than the customary practice test. As a result, depending on which cost is the most important one to avoid, between the cost of collecting information on firms' expenditure (the size of n) or the cost of spending expenditures in safety for firms, the respective preferred test will be a technological advancement test or a customary practice test. Hence, the authors show that the incentives for designing safe products can be maintained with the introduction of a defence for liability, despite the possibility for the firms to (indirectly) define the standard for defence.

The two studies discussed above deal with the issue of setting a regulatory framework that both pushes the firm to make efforts to design safer products (and processes) and avoids the marketing of dangerous products. The last stream of work we consider focuses on another important issue – the case where the risk of causing harm is imperfectly known and may evolve over time. This is related to the possibility of searching for more information about the (imperfectly known) risk.

4.2 Fostering knowledge on (new and) imperfectly known risks

Shavell (1992) was the first study to analyse civil liability as a means of regulating an imprecise risk where the knowledge evolves over time. Specifically, Shavell analysed the incentives provided by civil liability to invest both in safety measures and in efforts to acquire knowledge about the risk (which, initially, is imperfectly known).

In Shavell (1992), the firm's risk management strategy involves two decisions related to safety efforts and investment in acquisition of (more) information about the risk. Consequently, both decisions are optimal and the public policy (here, civil liability) is therefore required to provide the private agent with optimal incentives regarding these two decisions.

Shavell points out that, apart from ultra-hazardous activities for which strict liability is increasingly applied, the negligence rule remains the default liability rule. However, in contrast to strict liability (where liability is "automatic" once causality is proven), negligence requires the gathering of more information to be enforced. It requires to search for ex-ante information to determine the level of the due care standard and requires collection of information ex-post to determine whether the injurer complied or not with the standard (and if not, liability is

enforced).³⁶ In the case where acquisition of information is part of a risk management strategy, additional requirements may apply to allow the negligence rule to regulate this “new and additional” decision. These requirements may imply additional costs, which must be kept in mind when assessing the social desirability of rules.³⁷

Shavell (1992) analysed the incentives provided by four kinds of negligence rules. The first two kinds of negligence do not lead to the court incurring any additional costs (compared to a negligence rule which is designed “only” to regulate a safety effort). The first rule assumes that *the information about risk is obtained* by the firm; the second assumes that it is based on *information that the agent already possesses*. In both cases, the court needs to make no assessment about the optimal information policy: in the first case, it is assumed that the firm has information (whether as the result of a search or not and whether it is optimal or not to conduct this search) and in a second case, the due level of care depends on the information possessed by the firm, regardless of its policy towards information acquisition. These two kinds of negligence can be applied in practice.

The other types of negligence considered by Shavell are costlier to apply, in terms of the information required. In the case of a rule that is based *on the optimal level of care, given optimal acquisition of information*, the court must determine the socially optimal information policy (in our context, this is a binary case: investing a fixed amount, or not, in information acquisition), to know which standard of care applies. This may be socially costly. A similar cost must be borne by the court in relation to the fourth rule studied, namely *complete negligence*, for which the firm is liable if it fails to make the optimal investment in information acquisition. Shavell studies this last rule from a purely normative perspective since it has never been enforced in practice.

Shavell’s proposed framework considers a risk-neutral agent (e.g., a firm) that is engaged in an activity that could cause harm to others. By making a costly effort $c \geq 0$, the firm can determine the existence or not of the risk of causing harm. If the risk exists, the probability that the harm will occur is p and the agent has the possibility to reduce the magnitude of the harm by making a safety investment x , where $x \geq 0$. The level of potential harm is $h(x)$, and the risk of the harm (if it exists) is $ph(x)$, where $h'(x) < 0$, $h''(x) > 0$. If no information on the existence of the risk of causing harm is acquired, a benevolent dictator must choose the level of safety that will maximise:

$$x + ph(x).$$

In this case, the optimal level of safety is defined as: $1 = -ph'(x)$. Note x_0^* the level of safety that is conditional on not searching for more information about the existence of the risk. In the case of acquisition of more information, if there is found to be no risk, the level of safety is 0. In the case of existence of risk, the optimal level of safety must maximise:

³⁶ In other words, under negligence, liability is established only if it can be shown (by the victim) that the injurer was negligent about the due standard of diligence.

³⁷ Shavell’s (1992) concluding remarks call for discussion on the informational costs of each rule, but her core analysis does not consider these costs.

$$x + h(x).$$

Thus, x^* is defined as $1 = -h'(x)$. It can easily be checked that: $x^* > x_0^*$. If the existence of the risk is proven, then optimal safety is higher than in the case where its existence is not proven (since there is a chance for safety investment to be a waste). The value of information, v , can be deduced:

$$v = [x_0^* + ph(x_0^*)] - p[x^* + h(x^*)].$$

That is, relative to the case of no investment in information acquisition (for which the expected cost is $x_0^* + ph(x_0^*)$), investment leads to a situation where the agent incurs a cost $[x^* + h(x^*)]$ in the case of risk (which exists with the probability p), and incurs no cost in the case of no risk (probability $(1 - p)$). This can be rewritten as:

$$v = p\{[x_0^* + h(x_0^*)] - [x^* + h(x^*)]\} + (1 - p)x_0^*.$$

That is, in the case of risk (probability p), information makes it possible to identify a more efficient level of safety $x^* > x_0^*$, and in the case of no risk (probability $(1 - p)$) information makes it possible to save on safety investment costs x_0^* . It is socially optimal to invest in information acquisition as soon as: $v > c$.

Shavell (1992) compares the decisions of the private decision maker, subject to a rule of civil liability. Under strict liability, whenever there is no problem of risk internalisation (e.g., because of limited assets or the probability that the victim may not succeed in suing, etc.), optimal incentives are provided, and the first-best is reached.

Under negligence, Shavell (1992) first considers the case of *complete* negligence. This involves the perpetrator being recognised as negligent (and thus fully liable) if it either failed to exercise optimal care (given optimal acquisition of information) or failed to obtain information when it should have done so (even if it exercised optimal care).³⁸ As already mentioned, this rule does not exist in practice, but Shavell studies it from a purely normative perspective (although its implementation would be costly since, as already mentioned, it would require gathering a vast amount of information). In that case, it can easily be deduced that liability holds only in the case of (socially) undesirable decisions, so that the first-best is reached. Shavell next introduces negligence based *on the level of care that is optimal, given optimal acquisition of information*. In contrast to the previous case, the agent will not be held liable if it does not invest in information acquisition when it is socially optimal to do so. However, in the case of harm, if it was not optimal to acquire information the agent will be held liable if $x < x_0^*$, and if it was optimal to acquire information the agent will be held liable if $x < x^*$. The agent can choose not to invest in information acquisition and to protect against liability by adopting $x = x^*$. However, Shavell shows that, where it is optimal to acquire information, the prospect of saving x^* in the case of absence of risk is enough to incentivise

³⁸ Put differently, if it is not optimal to acquire information, the party is liable if and only if $x < x_0^*$. In the case where it is optimal to acquire information, the party is liable if it has not acquired information or if it has and the information reveals that the risk of harm exists, it will adopt $x < x^*$.

the agent to invest in information acquisition. Where it is not optimal to acquire information, the agent has no incentive to acquire information. As a result, the incentives to invest in information acquisition are optimal and, conditional on the information, internalisation of the full risk will push the agent to adopt the optimal level of care (the agent is assumed to be highly solvent). Overall, again, the first-best is enforced (even if, again, the court requires a large amount of information to apply this type of rule).

Finally, Shavell (1992) studies two other types of negligence, both of which are applied in practice and are less costly to implement than the previous two since their application requires less information. First, Shavell considers the case of a negligence rule based on the *optimal level of care given the information that the agent actually possesses*. Therefore, if the agent has not invested in information acquisition, it will be held liable only if $x < x_0^*$, and if it acquired information it will be held liable if $x < x^*$. In that case, it is possible that the agent will choose not to acquire information when it is optimal to do so. To understand this, it is important to assess the private value of information and to compare it to its social value. From a private perspective, if the agent (based on information acquired) learns that there is a risk, it will choose x^* , while in the absence of the information, it would have chosen x_0^* . Therefore, the agent is worse off.³⁹ If the agent learns that there is no risk, it will not invest in care and will save x_0^* and be better off. In this latter case, both the agent and society are better off. However, in the former case, private and social interests' conflict: the private agent is worse off from adopting x^* instead of x_0^* , but this choice is better for society. As a result, the private value of information is lower than the social value and it is possible that the agent will not acquire information when it is optimal to do so.

The last rule of negligence studied by Shavell (1992) is based on the optimal level of care, *presuming that information about risk is obtained*. However, this rule is also suboptimal, in the sense that it provides too strong an incentive to acquire information. The agent might decide to acquire information when it is not optimal to do so. This might be because learning about the existence of risk allows the agent to escape liability by complying with x^* , while risk of harm is not eliminated for society (it is only reduced). Therefore, the private value of information is higher than the social value and information may be acquired when it is not optimal to do so. Also, if the agent does not acquire information, this maintains doubt about the existence of risk. To guarantee exemption from liability in the case of harm occurring, the agent may exert x^* while social optimality requires x_0^* (if it is not optimal to acquire information).

In the case of negligence in regulating such imprecise risk, there is a trade-off between efficacy in providing optimal incentives (for information acquisition and safety) and the cost of implementation of the rule. Indeed, the first two rules we discussed are considered optimal

³⁹ Recall that under negligence, when the agent complies with the standard, it is exempted from liability. Therefore, the agent no longer incurs the risk $ph(x)$ (x is given).

(in this model framework), but, in practice, they require the court to gather a lot of information (especially on the optimality of searching for more information on an imprecise risk). Implementation of the other two rules is less “information intensive,” but provides suboptimal incentives to the agent (incentives that are too weak or too strong to search for more information). Thus, to guide the policy maker, additional information on the cost of scientific expertise (for the court), and on the (opportunity) cost of searching for more information must be considered.

Acquiring information about an imprecise risk is at the core of the analysis in Chemarin and Orset (2011). They consider an agent (e.g., an innovating firm) that might invest in a project that could cause harm to third parties in the future, but where the probability of the harm is not perfectly known: this involves two scenarios associated with a high or a low probability of causing harm, respectively. However, before the occurrence of harm, the agent can make a costly (pecuniary) effort to obtain a signal (about which scenario is the most plausible, i.e., the one most likely to be true). The reliability of the signal increases with the intensity of the information-seeking effort. Receiving an information signal allows the agent to update its prior beliefs about which of the two scenarios is more plausible; the revision is made based on Bayes’ rule.⁴⁰ In the case of a “bad” signal, the agent can halt the project before completion, which will allow it to recover a part of its investment (partial irreversibility), but not benefit from the full profit that the completed investment might have generated. However, stopping before completion reduces the magnitude of the harm in the case of harm occurring in the future. The timing is as follows: in period 0, the agent decides how much to invest in information acquisition; in period 1, a signal is received and the agent decides whether it wants to continue with or stop the project before completion; in period 2, the harm may occur.

In the case of harm, civil liability applies. The authors distinguish among strict and unlimited liability, strict and limited liability, and the rule of negligence.⁴¹ They distinguish, also, between two types of agents, that differ in how they discount the future. First, they consider an agent that discounts the future according to an exponential discounting factor. Second, they consider an agent that discounts the future according to a hyperbolic factor. The first case is the “traditional” case, assumed by expected utility theory. The case of hyperbolic discounting was proposed by Phelps and Pollack (1968) and allows for consideration of the possibility of inconsistent preferences over time. In each period, the agent may over-depreciate

⁴⁰ Chemarin and Orset (2011) assume that the innovator is an expected utility maximiser. Gollier and Treich (2014) point out that expected utility can be used for decision making under imperfectly known risk, but implies that the decision maker is perfectly able to assess (and understand) the probabilities.

⁴¹ As discussed in Section 2, limited liability caps any financial “penalty” on the firm’s net value. If the magnitude of the harm exceeds this value, the excess harm remains uncompensated. By contrast, unlimited liability allows the judge to extend liability to the firm’s shareholders’ personal assets, which increases the level of compensation (in this case, we consider compensation to be complete).

the following periods and over-appreciate the present period. As a result, the agent may make decisions that conflict with past decisions.⁴²

Their main results are as follows. First, they show that an agent that chooses hyperbolic discounting will prefer not to invest in information acquisition, to remain uninformed, thus, reducing the probability of abandoning the project in the case of bad news. An agent that over-appreciates the present period can anticipate, at period 0 (the moment of deciding whether to invest or not in information acquisition), that in period 1, it will discontinue the project in the case of bad news, in order, in period 1, to secure the amount it would recover from cancelling the project (even though this amount will be lower than the initial investment, due to partial irreversibility). To avoid having to make such a decision in period 1, in period 0, the agent may decide not to invest to constrain his future self's decision, if period 2 (and the perspective to get the full income of the project) is not too depreciated relative to period 1. The authors show, also, that a time-consistent agent (with exponential discounting) will not buy information if it expects that information will have no impact on its decision (e.g., if bad news leads the agent not to cancel the project, the information is useless). They also show that limited liability reduces the incentives to invest in information acquisition, because the cap on maximum liability reduces the gap (in the firm's payments) between high and low levels of harm.⁴³ However, the authors show that implementation of a negligence rule, which is based on a minimum investment in information acquisition, may restore the incentive to invest as soon as this amount makes it possible for the firm to obtain an information signal that is useful, that is, a signal that increases the firm's interest in cancelling the project in the case of bad news.

Shavell (1992) and Chemarin and Orset (2011) show that the legal context, that is, the system of liability, affects the incentives to search for more information on an imperfectly known risk. They consider the process of information acquisition to be a research process or a technical test, whose reliability may depend on the resources allocated to this process. However, there is another means of acquiring information – that is, learning-by-doing/using, a process that is based on experimentation, and on its known failures during use or accidents caused by the product.

⁴² Different behaviours may lead to time-inconsistent decisions, which are captured by hyperbolic discounting. Frederick *et al.* (2002) refer to anxiety, lack of confidence in the future and impatience. Bénabou and Tirole (2002) refer to lack of willpower. In all these cases, the agent distinguishes between “self-in-the-present” and “self-in-the-future”. Preferences for “self-in-the-present” may be discordant with preference for “self-in-the-future,” which can imply strategic interactions between different “selves” across different periods.

⁴³ Since damages are capped at the firm's net value, small harms can be fully compensated (e.g., if the project is cancelled at period 1), while part of the highest harms (if the project is continued) could be externalised if they exceed the firm's net value. If the highest harms are capped and the lowest are not capped, the gap in the damages that need to be paid between these two types of harms is reduced. This lowers the incentive for information acquisition, since the cost of continuing a potentially dangerous project is reduced (as is the benefit from receiving “bad news”).

Baumann and Friehe (2016) analyse the case of an imprecise risk of the product to cause harm where information can be gathered via learning-by-using, that is, post-market experimentation. Observing the product’s accident history adds to the knowledge and makes it possible to update beliefs about the “true” nature of the risk. To analyse the impact of civil liability rules on decision making in this context, Baumann and Friehe (2016) build a two-period model of a firm that manufactures a product that could cause harm with an unknown probability of $l(x)$ or $h(x)$, where $0 < l(x) < h(x) < 1$. As often assumed in the literature, the firm can invest in care x to reduce the probability of causing harm, whether $l(x)$ or $h(x)$ is the true probability function, and where $l'(x) < 0 < l''(x)$ and $h'(x) < 0 < h''(x)$. However, the authors make no assumptions about the relative levels of $l'(x)$ and $h'(x)$.⁴⁴ In the first period, the firm decides about care. An accident may happen or not. Based on this occurrence or not, the firm updates its prior belief (Bayesian updating) and then decides on the level of care in the second period. Again, an accident may or may not happen in this period.

Because the first-period level of care affects the probability of suffering an accident, which would allow the firm to deduce the likelihood of facing $l(x)$ or $h(x)$, first-period care plays a role not only with respect to the minimisation of social costs in that period but also regarding the direction of search for information about accident technology. Since no assumptions are made about the value of $l'(x)$ relative to $h'(x)$, a “wrong belief” about which probability function is the correct one can induce a too high or a too low level of care (relative to what would be desirable were the true probability function known). This can result in two types of error. First, the absence of an accident in period 1 may lead the firm to mistakenly believe that the true function is $l(x)$. Second, the occurrence of an accident in period 1 may lead the firm to mistakenly believe that the true function is $h(x)$.

After determining the socially optimal levels of care, the authors compare strict liability and negligence.⁴⁵ They show that both rules may fail to provide the optimal incentives for care, especially the negligence rule, because the period 2 standard of due care is endogenous to the firm’s period 1 decision. Indeed, the period 2 standard of due care is set conditionally to the (updated) belief about whether $l(x)$ or $h(x)$ is the true technology, and this updated belief depends on the occurrence of (no) accident in period 1, which is dependent on the period 1 level of care. Thus, the standard of due care in period 2 depends on the firm’s decision in period 1. This can provide the firm with an incentive to deviate from the standard of care in period 1 to strategically manipulate the standard of care in period 2, which is a suboptimal decision. The authors highlight that if the standard of due care varies with the firm’s accident history, the firm may strategically (and suboptimally) manipulate ex-post regulation by manipulating the search for knowledge.

⁴⁴ The authors test the two cases of the probability function $l(x)$ providing a higher or a lower marginal benefit from care than $h(x)$.

⁴⁵ In period 1, the first-best level of care considers that the outcomes “accident” and “no accident” provide the firm with signals about the “true” accident technology (i.e., $l(x)$ or $h(x)$).

Along similar lines, Goeschl and Pfrommer (2015) analyse how liability rules can affect post-market learning dynamics. As in the case of Baumann and Friehe (2016), they assume no ex-ante regulation (i.e., the firm is free to decide, on its own, whether to market the product), and ex-post observation provides information on the risk of harm. However, in Goeschl and Pfrommer (2015), the risk is binary in nature, as in Shavell (1992): there is a risk or there is no risk. The authors propose a two-period model and consider an industry composed of several firms that can market a homogeneous product (which may display a risk of causing harm). Each of the firms can invest in care, which, in the event that risk exists, will reduce the level of expected harm. Since the firms gather information on the risk after marketing the product (from users' experiences), the higher the number of firms that market the product, the higher the likelihood of discovering whether a risk exists or not.

In period 1, all the firms share the same prior knowledge on the likelihood that the risk exists. Depending on the liability scheme, the firms decide whether to market the product; if they decide to market it they must also decide about the level of care. The firms differ in their private benefits from marketing the product. Therefore, requiring the firms to implement a higher level of care reduces the level of expected harm (in the case that the risk exists), but could prevent some firms from selling the product due to the higher costs involved in preventing expected harm, which, in turn, reduces the likelihood of learning about the existence of the risk.

The authors show that, in this context, negligence might be preferred to strict liability, since the prospect of being exempt from liability pushes more firms to market the product, which, in turn, allows a higher level of experimentation (information on the risk). Compared with the analysis in Baumann and Friehe (2016), the virtues of negligence are higher due to the binary nature of the risk: there is either a risk (with only one probability function) or there is no risk. As a result, the firm's period 1 decision cannot strategically alter the standard of due care.

Finally, there are a few more recent studies that highlight the possible interplay between ex-ante policies (approval) and ex-post policies (liability), in a context of imprecise risk, and call for more research on this area.

Friehe and Schulte (2017) consider the case of a new product developed by a unique firm. As in Shavell (1992), the product could be the source of a risk of causing harm, with the true harm probability either 0 or 1. There is a prior belief about which of these two is the true state. The firm could conduct an experiment, but this might be inconclusive.⁴⁶ Also, the probability that the experiment will be conclusive is state-dependent. The act of conducting the experiment and the results of the experiment are both publicly observable. Both ex-ante and

⁴⁶ This last point (inconclusive experiment) differs from the case in Shavell (1992) where investing in information acquisition reveals with certainty which of the states (existence or absence of risk) is the true state.

ex-post policies are enforced simultaneously. An ex-ante regulator is responsible for approving (or not) the new product, with the aim of maximising the firm's revenue and the consumer surplus, net of the expected harm caused to society.⁴⁷ In the case of an approved product that causes harm, the firm is strictly liable for a portion of the harm (between 0 and 1). Only strict liability is considered (no negligence rule).

Friehe and Schulte (2017) also consider the possibility that marketing the product may not be profitable for the firm; thus, the firm might decide not to apply for approval of the product and not to market the product. This might occur if the firm considers its expected burden of liability to be too great. The authors then introduce the possibility of partial liability. As a result, both the regulator and the firm have threshold beliefs about the existence of the risk; below this threshold, the firm will agree to it being marketed.

Given this framework, the authors show that if the firm is not fully liable for the harm that could be caused by its product, it will have insufficient incentive to search for more information on the risk, but in case of full liability, the incentive to acquire information will be excessive. This applies particularly if the product is a source of high consumer surplus.⁴⁸ This could lead the regulator to want the product to be marketed (without searching for more information, since "bad news" could lead the firm to not market the product), while the expected liability, with regard to the firm's revenue, will push the firm to additional experimentation (to prevent the introduction of a dangerous product that might result in its having to pay damages). The authors show how the (partial) liability could be tailored to the particular circumstances and the relative degrees of externalities resulting from the product.

One of the findings in Shavell (1992) is extended by Friehe and Schulte (2017) to include the possibility of excessive incentives, provided by liability, to search for more information on the risk. However, Friehe and Schulte (2017) and Shavell (1992) use different mechanisms. In Shavell (1992), the "too strong" incentives are observed only in a specific case of negligence and arise from the nature of the standard of care required to escape liability. A standard of care that assumes that information on the risk has been obtained will provide the firm with an incentive to obtain information, even if it is not socially optimal to do so, in the hope of escaping liability in the case of harm. However, in Shavell (1992), the incentives under strict and full liability are always optimal, especially because the firm internalises all the social benefits and costs derived from the product. In Friehe and Schulte (2017), there could be a misalignment between private and social objectives, since the product is the source of two types of externalities (negative and positive).

⁴⁷ The consumer surplus is not captured by the firm (the firm earns a revenue, which is different from the consumer surplus derived from using the product). So, the product may also be a source of positive externality.

⁴⁸ If the consumer surplus and the firm's revenue exceed the level of the potential harm, then the regulator will be keen for the product to be marketed, without searching for more information.

Finally, the study by Henry *et al.* (2021) also examines the interaction among ex-ante approval, ex-post policies and acquisition of information. The authors consider the two ways of acquiring information – ex-ante experimentations (before approval) and ex-post learning (after marketing) – which are considered separately in the previous studies. What distinguishes the two sources of information is the cost of the information and the information flow. Ex-ante information acquisition (based on laboratory experiments) is costly and the flow of information is controlled by the firm.⁴⁹ Ex-post information acquisition (based on occurrence of accidents and feedback from users) is costless, but the flow of information is exogenous to the firm. Henry *et al.* consider three policies, implemented separately or in combination. An ex-ante policy of approval authorises the firm to sell its product in the market if the product is acknowledged to be (relatively) safe. There are also two ex-post policies. The first consists of withdrawal or banning the product if enough “bad news” about its dangerousness is collected via ex-post learning/using. A withdrawal is definitive: the firm cannot search for more information in the hope of later reintroducing its product to the market. The second ex-post policy considered is an ex-post penalty, which the firm is required to pay at each period of marketing a product acknowledged to be dangerous.

Before presenting the main results, we need to describe the authors’ proposed model and the model characteristics. They consider that the social desirability of the product is distinguished by two states of nature. In a good state, the social value of the product is positive and high. In a bad state, the social value of the product is negative. Whatever the state of nature and regardless of the additional costs that might result from the introduction of public policies, the firm earns a strictly positive payoff if it is able to market the product, but this payoff is lower than the social payoff from a good state of nature. As a result, the product is a source of a positive externality on the good state and a source of negative externality on the bad state. The authors consider a model with infinite time. At each period, a decision is required: in the case of an ex-ante authorisation policy, before approval the firm must decide whether to invest in an additional information signal and the regulator must decide whether to approve the product. The case of ex-post withdrawal depends, at each period, on the regulator, deciding on the basis of ex-post learning, whether to allow the product to continue in the market or to withdraw it. In the case of ex-post liability, if the product has been deemed dangerous and needing to be withdrawn, the regulator must impose a fine on the firm for each period it continues to sell its product.⁵⁰

The authors found that, in the case of activities that are the source of high positive externalities, only ex-ante approval should apply, since this would result in rapid introduction

⁴⁹ The authors assume that the flow of ex-ante information follows a Wiener process, which is path-dependent (the probability of receiving a given signal depends on the past history of received signals).

⁵⁰ In equilibrium, the firm itself will withdraw the product if the likelihood of the state in which the product has been deemed dangerous and needing to be withdrawn is high. Although the authors seem to refer to liability and penalty as the same thing, here, there is no connection between the amount the firm is required to pay and the level of harm done. Thus, this system is closer to a penalty than a liability system that is aimed at compensating for a harm caused.

into the market. This supports the idea of pre-emption, which states that regulatory approval should shield firms from future liability claims. This can be seen as contrasting with the recommendations in Hiriart *et al.*'s analysis, which advocate for a mix of ex-ante and ex-post policies. However, Hiriart *et al.*'s recommendations refer to a context of imperfect information between firm and regulator, which leaves room for capture of the regulator by the firm (the ex-post judge is used as a "disciplining device"). However, Henry *et al.* (2021) find that liability still works to discourage excessive ex-ante experimentation in the case of activities and products that generate small positive externalities. In those cases, the threat of liability is aimed at reducing waste of resources employed in (prolonged) ex-ante experiments, related to products with low positive externalities.

The contributions discussed in this section highlight the range of topics covered in the literature on risk regulation. They include the incentives for care provided by different individual policies or a mix of these policies and issues such as regulator capture and the need to search for more information before the introduction of products that carry imperfectly known risks. Nevertheless, there are many avenues for future research in this field.

5 Conclusion

The regulation of dangerous industries and products involves many problems. In the conclusion to our paper, we offer some recommendations that might resolve some of these issues.

Many hazards, especially those caused by chemicals, are latent in the sense that it may take a long period of time of exposure to the particular product for harm to emerge. A good example is the case of asbestos, documented by Ringleb and Wiggins (1990, 1992), where it took between 20 and 40 years for the first cases of lung cancer to emerge among workers who had been exposed to asbestos. In the face of such types of risk, it would seem desirable to implement policies that encourage long-term research, testing, documenting and information monitoring, to allow re-evaluation of approvals based on new information. Baumann and Friehe (2016), Goeschl and Pfrommer (2015) and Henry *et al.* (2021) consider the case of the emergence of ex-post information (while the product is being marketed) and how it affects the design of optimal regulatory policies. However, all these authors assume that the ex-post learning is built on the history of accidents that occurred during use of the product. To our knowledge, the idea of additional ex-post research, aimed at learning about the possibility of latent hazards before an accident occurs, has not been considered. Therefore, the benefits of a policy design that might prevent hazards over the long term remain to be investigated.

Several contributions, such as Hiriart *et al.* (2010, 2012), deal with collusion between the firm and the (ex-ante) regulator. The regulator (or, more precisely, its employees) are subject to different biases, which make them vulnerable to capture by the firm. These contributions assume information asymmetry between the firm and the agency, which promotes collusion (Boyer and Porini [2004] suggest that bribes for the regulator can be financed by the firm's informational rents). However, this information asymmetry can also lead to other wrongful behaviours by the firm and at the expense of the regulator. The Mediator and so-called Dieselgate cases show that firms can strategically use asymmetric information to conceal information about the hazardousness of their products, as in the Mediator case, or to introduce fraudulent evidence or devices to increase the likelihood that a new product will be approved, as in the Dieselgate case. This points to the need to provide the regulator with an incentive to remain benevolent (and avoid capture by the firm), and the need to provide the firm with an incentive to search for information about the risks related to its new product and, more especially, to disclose all its findings to the regulator. This would reinforce the use of penal liability (imposition of fines or criminal sanctions – including imprisonment), in addition to other policy tools, since the application of civil liability could be limited by both the need to prove that the action was harmful to society or the environment, and the financial capacity of the firm.

Future work should focus more on studies likely to deepen the impact of civil and criminal liability on the behaviour of manufacturers of doubt from industry lobbies. So-called persuasion models consider that interest groups generate or communicate favourable information to the decision maker (Orset and Monnier, 2020). These models are based on persuasion theory which claims that the transmission of information from interest groups to policy makers is a mechanism that improves, rather than modifies, policy makers' preferences (Austen-Smith, 1993, 1994). The information asymmetry between policy makers and lobbies is considered an important aspect. Policy makers can adjust their beliefs based on information provided by lobbies. Stone (2011) examines the effects on policy making of strategic funding for research and reporting interest groups, in a context of uncertainty. Policy makers may not rely on interest groups to obtain new information while lobbies may fund publicly observable research that is indistinguishable from independent research. For example, Western Fuels⁵¹ and Cyprus Minerals⁵² paid substantial sums to researchers to conduct research on global warming. Many of the results of this research entered the public domain and could have been observed as and confused with independent research funded by policy makers. If the interest group's information is solely based on public research, the interest group may decide to supplement it by producing its own research internally. This strategic investment might lead the policy maker to take note of the research findings that favour the interests of the lobby, regardless of the true

⁵¹ Western Fuels is a US coal industry trading group.

⁵² Cyprus Mineral represents German and UK coal groups and the Kuwaiti government.

state of the world. The signal that the policy maker receives is scrambled, which biases its political choice. Tobacco companies, for example, are well known for funding research on the effects on health of tobacco products.

The Bayesian persuasion model proposed by Kamenica and Gentzkow (2011) would seem to challenge the claim that industry-funded studies often produce more industry-friendly results than do independent studies. Their model suggests that ordering biased studies when policy makers are rational may not be optimal from an industry perspective. On the other hand, Nguyen and Tan (2021) analyse the case of a pharmaceutical company that wants to persuade the public decision maker, the FDA, to approve a new drug by announcing its supply, following tests by the firm to obtain more information on its safety. The drug company's problem is modelled as a Bayesian persuasion problem. The drug company is supposed to commit to honest disclosure to the FDA of the results of its tests or (equivalently) allowing the FDA to observe the results directly. However, the model shows that the pharmaceutical company's commitment to honestly revealing persuasive Bayesian information, which can be seen as a communication cost, could weaken.

In the cases of damage caused by tobacco and climate change, industry lobbies have deliberately fabricated doubts to avoid, weaken or postpone regulation (Oreskes and Conway, 2010; Ding *et al.*, 2011; Proctor, 2011). According to Brezis (2008), the chemicals, tobacco and food industries created doubts about health issues, recruited researchers and infiltrated universities, councils, media, and legislative agencies. For example, the pharmaceutical industries long tried to downplay and deny the side effects of the drug Vioxx. For years, they invested millions of dollars in advertising Vioxx and hired researchers to publish favourable results in scientific journals. They infiltrated an FDA advisory panel that recommended the continued sale of Vioxx, despite its obvious cardiovascular toxicity. In their model, Bramoullé and Orset (2018) explain the sudden reversals in the official positions of interest groups, and episodes of sudden awareness of the dangers posed by certain industrial activities. They found that the optimal communication policy of industry lobbies depended on what public opinion and the scientists believed. If the scientists consider that pollution is unlikely to be harmful, the benefits of miscommunication are too small and the industry does not try to change the beliefs of citizens. If the scientists are less certain about the adverse effects of the pollution, the industry engages in miscommunication and targets a specific level of citizen belief. If the scientists' beliefs reach a critical danger threshold, the costs of miscommunication become too high and industry will abruptly discontinue its efforts. Thus, optimal limited communication is non-monotonic and discontinuous with scientists' beliefs. Bramoullé and Orset also show that this behaviour of industry lobbies can harm social well-being. Thus, there needs to be more analysis of regulation: civil and penal liabilities would seem necessary to limit the damaging effects of lobbying behaviour on society as a whole, to preserve the private interests of the lobby.

Finally, research could analyse criminal law as a means of controlling the behaviour of industry lobbies (Bowles *et al.*, 2008; Harel *et al.*, 2013; and Hylton, 2005). Industry lobbies can influence policy makers by corrupting them. Campos and Giovannoni (2007) and Bennedsen *et al.* (2011) show that lobbying and corruption are substitutes. However, Bennedsen *et al.* (2011) highlight four differences between lobbying and bribery. First, corruption is illegal, while lobbying is not. Second, corruption is an attempt to avoid a given set of rules on a case-by-case basis (bribes), while lobbying is an attempt to change the rules. Third, lobbying offers more lasting advantage and can therefore be costlier than corruption, which seeks a one-off deviation from a rule. Fourth, the benefit derived from corruption is individual (to the firm or an individual), while lobbying changes the rules for the collective (a group of firms or industries). Campos and Giovannoni (2007) suggest lobbying is the preferred means for exerting influence in rich countries, while corruption is the method of choice in poor countries. However, they find that lobbying is a more effective instrument of influence than corruption, even in the poorest and least developed countries. Empirical research on this area is lacking.

Existing work and data on lobbying and corruption do not provide sufficient information on the various types of corruption and lobbying activities and their interrelationships. Recanatini *et al.* (2005) is the only study that discusses the supply of corruption and focuses on the disaggregated characteristics that make specific public institutions inherently more vulnerable to corruption, and the reasons why. This line of research should be extended to assess the impact of criminal law on deterring both industry lobbies from corrupting and decision makers from allowing themselves to be corrupted.

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