For Safety or Profit?

How Science Serves the Strategic Interests of Private Actors

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Abstract

This paper traces how scientific information is used (and abused) by companies that have a vested interest in acquiring preferential regulatory outcomes. By studying the microfoundations of health and safety regulation, I am able to show that even when standards are overtly based on scientific information, they may not be scientific. Rather, through the strategic provision and withholding of information, innovative companies are able to leverage science-based rule making to eliminate cheaper products from the market, in favor of more profitable alternatives. The result is regulations that act as both domestic and international barriers to competition, raise consumer costs without improving consumer welfare, yet do not stem from public pressure or from political capture as it is traditionally conceived. In order to provide evidence for my claims, I take up the case of U.S. agrochemical regulation. I introduce cross-temporal data on thousands of individual standards, allowing me to test whether regulatory change reflects the public interest or the interest of private companies. I also leverage firm-level petition data and historical, qualitative evidence in order to directly test companies' preferences and the theorized mechanism. My findings have implications not only for how we think about the domestic regulatory process but also for how we evaluate the legitimacy of regulatory barriers to trade.

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Introduction

National regulations are now an international problem. As tariffs have moved towards zero around the world, policymakers and scholars have increasingly turned their attention towards addressing regulatory impediments to trade (e.g. Bagwell and Staiger 2001; Büthe and Mattli 2003; 2011; Kono 2006; Gulotty 2014). Among the regulatory areas that contribute to trade frictions, health and safety standards stand out as particularly problematic. Not only have such regulations led to hundreds of trade concerns under the World Trade Organization (WTO), but it is often impossible to determine whether a domestic safety rule is based on science – which is a legitimate justification for regulatory barriers – or on a more strategic desire to block competition. One of the central problems is that we generally know very little about how scientific information is introduced and incorporated into domestic decision making. Without a better understanding of the role that this information plays in the regulation of risk, how can we possibly determine whether regulatory rules reflect science or private interest?

This paper traces how scientific information is used (and abused) by companies that have a vested interest in acquiring preferential regulatory outcomes. By studying the microfoundations of health and safety regulation, I am able to show that even when standards are overtly based on scientific information, they may not be scientific. Rather, through the strategic provision and withholding of information, innovative companies are able to leverage science-based rule making to eliminate cheaper products from the market, in favor of more profitable alternatives. The result is regulations that act as both domestic and international barriers to competition, raise consumer costs without improving consumer welfare, yet do not stem from public pressure or from political capture as it is traditionally conceived.

In order to show this, the paper takes up the case of U.S. pesticide regulation. While most of us are primarily concerned with pesticides only to the extent that they end up on our plates, pesticide standards actually have enormous implications for agricultural trade, and as the largest importer and exporter of agricultural products, the U.S. is easily the most important player in this space. Moreover, because pesticide standards are so central to countries' ability to export agricultural goods, they have become the subject of numerous WTO trade concerns. Most notably, in 2007 Argentina accused a number of unnamed de-

veloped countries of imposing unfairly restrictive standards on the use of older pesticides for imported agriculture, thereby directly harming farmers in developing countries, who could not afford newer alternatives. My findings not only speak to why developed countries might have done this but, more generally, to why certain products may be systematically subjected to stricter standards than others for reasons that science alone cannot explain.

My theory breaks away from explanations that focus on domestic risk preferences (Vogel 2012; Meins 2003; Bernauer and Meins 2003; Bernauer and Caduff 2004), as well as those that focus on regulatory capture with the goal of erecting domestic (Stigler 1971; Posner 1974; Peltzman 1976) or international (Gulotty 2014) barriers to entry. I argue that because regulators frequently rely on those they regulate for scientific information about the area or products being regulated, private actors can effectively capture the regulatory process without needing to capture the regulator himself. In order to understand how companies leverage scientific information to win outcomes that go beyond what science alone would require, it is necessary to begin with a theory of what companies want. Counterintuitively, I suggest that what some companies want is regulation that undermines *their own* products. When applied strategically, such regulation allows innovative producers to push lower profit products off of the market, in favor of higher profit alternatives. Moreover, I show that regulatory institutions that have been championed by environmentalists and consumer groups contribute to the elimination of products for reasons unrelated to the protection of either the environment or human safety. Indeed, these institutions have been shaped not only by consumers but also by the very firms that stand to benefit from them. Finally, I offer evidence that although certain firms have been willing to join forces with public interest groups in order to advocate for these regulatory institutions, once those institutions are implemented, regulatory change is dictated not by capture but by firms' willingness or unwillingness to provide scientific data to regulatory authorities.

The next section provides a brief overview of the literature concerning the politics of regulation. After formalizing my theory of firm preferences, I suggest how companies' informational monopoly could allow them to leverage science-based rule making to acquire the outcomes they seek, even in the absence of a complicit regulator. The evidence I present in support of this theory is both quantitative and qualitative. First, I introduce an original

dataset that makes it possible to track changes to agrochemical regulations in the United States over a two decade period. Controlling for a variety of factors that we might expect would influence regulatory change in this sector, I demonstrate that a public interest story cannot adequately account for the regulatory patterns we see. Rather, the outcomes are consistent with what we would expect given the interests of innovative firms and the way in which they are able to use private information under the institutions in place. I then introduce firm-level petition data that allow me to show directly that, in accordance with the theory, innovative producers have actively sought stricter regulations on their own low-profit products. The petition data is supplemented with qualitative evidence that further bolsters the empirical findings and suggests that in addition to trying to eliminate low-profit products on a case-by-case basis, firms have actively sought regulatory institutions that, while seemingly both science-based and in the public interest, have the added benefit of allowing innovative firms to leverage informational advantages to systematically place stricter standards on low-profit products.

The Politics of Regulation

Political scientists and economists have long suspected that firms can and do use regulation to suppress competition and bolster profits. Early work by Bernstein (1955) and Huntington (1953) noted the influence of firms in setting regulatory policy, while Olson (1965) helped lay the theoretical groundwork for explaining why we might expect industry to outmaneuver the general public in the regulatory arena. Subsequently, in a piece that effectively catalyzed the regulatory capture literature, Stigler (1971) concluded that "as a rule, regulation is acquired by the industry and is designed and operated primarily for its benefit" (3). Stigler and those who immediately followed (e.g. Posner 1974; Peltzman 1976) suggested that regulation can act as a barrier to entry, keeping newcomers out and thereby benefitting established players. Subsequent work has greatly expanded upon this original insight, showing the many ways that regulations can benefit certain types of firms over others[1] and applying theories of capture beyond the domestic space to the world of non-tariff barriers (Gulotty 2014).

[1]This literature is substantial. For a good comprehensive summary, see Dal Bó 2006.

Many of the more traditional regulatory capture models, be they solely domestic or more international in scope, begin with the premise that regulators are complicit in setting suboptimal policy. Within this camp, some have suggested that special interests win influence through their ability to deliver votes or resources that can be translated into votes (e.g. Stigler 1971; Peltzman 1976; Becker 1983; Grossman and Helpman 1994), while others have focused on the so-called "revolving door" of private-public employment (e.g. Bernstein 1955; Gormley 1979; Cohen 1986). Yet these views of regulatory capture that assume bureaucratic complicity share a common shortcoming. Although regulators may experience a fair bit of leeway to set suboptimal regulation in esoteric areas, certain types of regulation are far more susceptible to public attention than others. In particular, when regulations touch on the health and safety of citizens, overtly corrupt rule setting could, quite plausibly, lead to public scandal, exposing regulators to the risk of penalty or public censure, not to mention the dreaded loss of their autonomy (Wilson 1980). In other words, despite the extensive literature on how private actors seek to benefit from regulation, an oft-ignored question in the regulatory capture literature is whether regulators will comply with private actors' preferences in high salience areas.

If we assume that health and safety regulation is one such high-salience area, then this suggests that voters should have strong preferences that policymakers get it right, potentially leading to effective political action (Lohmann 1993) and making it more difficult for firms to find legislators they can influence (Denzau and Munger 1986). Indeed, as many authors have compellingly shown, the public desire for protection from danger can have a notable impact on regulatory outcomes, potentially explaining why some countries impose stricter standards than others (e.g. Vogel 2012; Meins 2003; Bernauer and Meins 2003; Bernauer and Caduff 2004). Moreover, under WTO law, standards that diverge from international norms are required to be backed by science, giving countries an added incentive to incorporate scientific research into their decision-making. Should we then expect regulations in this sector to still reflect the interests of firms? I suggest the answer is yes. However, echoing Olson (1997) and Carpenter (2004) I caution that simply because outcomes benefit certain actors does not indicate that the regulators are "captured." Instead, we can think of regulators more as dependent. Specifically, they are dependent on those they regulate for information. This is

because the firms that are being regulated have far better access to data about their products and activities than the regulatory agents who oversee them, and this allows firms to provide that data strategically. Yet unlike lobbyists who may provide information as a subsidy to politicians (Potters and Van Winden 1992; Austen-Smith 1998; Hall and Deardorff 2006; Schnakenberg 2017), in this case, the withholding of information can be as powerful as its provision.

In order to show how companies can use strategic information provision and withholding to acquire preferential regulatory outcomes, even under institutions seemingly designed in the public interest, we first need to know what regulations these companies want. The formal model that follows demonstrates why sometimes a firm's preferred outcome is a ruling that its own product is unsafe. I then explore how companies' monopoly on data and scientific information, particularly under certain institutional structures can help them acquire the outcomes they seek.

Why Firms Want to Ban Their Own Products

Let us imagine a firm that produces two products that are differentiated by quality and price. While the model that follows can be generalized to any number of sectors in which certain firms produce two semi-substitutable products, one of which is more profitable than the other, the most obvious application is to a firm that has both an older, generic product and a newer, patented (imperfect) substitute. The patented product enjoys some improvement or alleged improvement over the original, and because it is patented, it can be sold at the monopoly price. The generic product, meanwhile, is sold competitively, not only by the firm that holds the patent on the substitute, but also by N other firms. The model that follows relies very closely on the vertical differentiation model found in Tirole (1988), which in turn, follows from Gabszewicz and Thisse (1979; 1980) and Shaked and Sutton (1982; 1983). There are two main adjustments. The first is the requirement that one firm produces both the high- and low- quality good. The second is the premise that the low-quality product is sold by multiple producers. By making these two modifications to the workhorse model, we can use it to illuminate preferences that, *a priori*, are quite surprising.

Replicating the setup from Tirole (1988, p. 296), I begin by assuming that there exists a

body of consumers (C), who receive $U_C = \theta s - p$ when they consume a given product. Here s is the universally agreed upon quality of the product, p is the product's price, and θ is the consumer's taste parameter, for which it is specified that θ is distributed uniformly across the population, with density equal to 1 and the location between $\underline{\theta}$ and $\overline{\theta}$, where $\underline{\theta} \geq 0$ and $\overline{\theta} = \underline{\theta} + 1$.

As indicated previously, there are two products on the market, which are imperfect substitutes: a high-quality good, with quality s_2 and a low-quality good, with quality s_1, where $s_2 > s_1$. In order to ensure that there is a market for the low-quality good, we make the following assumption:

Assumption: $\frac{s_2}{p_2} < \frac{s_1}{p_1}$

Breaking from the standard vertical differentiation model, I assume that one producer sells both goods, and while that producer holds a monopoly on the high quality product, he faces competition on the low quality product, an assumption meant to approximate the situation facing generic producers. One final specification is that the cost of producing both products is c, suggesting that producers receive a profit (Π_i) equal to $p_i - c$. Following standard economic assumptions about the price of a competitively produced product, all producers will set the price of the low-quality good such that $p_1 = c$, giving them zero profits.[2] At the same time, the high-quality monopolist will set the price of the high-quality good such that:

$$p_2 = \frac{\overline{\theta}(s_2 - s_1)}{2} + c \tag{0.1}$$

and

$$\Pi_2 = \frac{\overline{\theta}^2(s_2 - s_1)}{4} \tag{0.2}$$

Proof in Appendix

We can see that although the producer receives no profits from the low-quality good, the

[2]Although this assumption can be relaxed without undermining the central conclusion, it proves mathematically and intuitively useful.

existence of that good impacts the profits received from the high-quality good. So could the producer of the two goods be made better off if the low-quality good were not on the market? Or to put the matter more pertinently, if the high-quality producer could acquire regulation declaring that the low-quality product was unfit for sale, thereby eliminating both his and everyone else's low-quality good from the market, would this increase his profits? The easiest way to answer this is to ask whether the producer could sell the high-quality good at the same price in the absence of the low-quality good and thereby increase marketshare. If the answer to this question is yes, then it would suggest that the producer must be better off in the absence of the low-quality good.

Given the existence of two goods, a consumer buys the high-quality good if $\theta s_2 - p_2 > \theta s_1 - p_1$. In other words, he buys the high-quality good if his $\tilde{\theta} > \frac{p_2 - c}{s_2 - s_1}$. Otherwise, he buys the low quality good or nothing at all.

In the absence of a second good, the consumer buys if $0 < \theta s_0 - p_0$. This means he buys if his $\theta^* > \frac{p_0}{s_0}$. Now let's assume that the only good on the market is the high-quality good, meaning that $s_0 = s_2$. If the producer, in this situation, could set $p_0 = p_2$ and increase his share of consumers, then this means that the producer must be better off in this world. Mathematically, the question thus becomes:

$$\frac{p_2}{s_2} \stackrel{?}{<} \frac{p_2 - c}{s_2 - s_1} \tag{0.3}$$

As it turns out, this inequality will always hold. In order to show this, we begin by restating an assumption that was made earlier:

Previous Assumption: $\frac{s_1}{p_1} > \frac{s_2}{p_2}$

Given that $p_1 = c$, the following inequalities must also hold:

$$\frac{s_1}{c} > \frac{s_2}{p_2}$$

$$p_2 s_1 > s_2 c$$

$$-p_2 s_1 < -s_2 c$$

$$p_2 s_2 - p_2 s_1 < p_2 s_2 - s_2 c$$

$$\frac{p_2(s_2 - s_1)}{s_2(s_2 - s_1)} < \frac{s_2(p_2 - c)}{s_2(s_2 - s_1)}$$

$$\frac{p_2}{s_2} < \frac{p_2 - c}{s_2 - s_1}$$

We have now shown that in the absence of a second product, the producer could charge the same price and increase market share (and hence profits), meaning that the producer must do better in such a system. Of course, the producer will not charge the same price. Rather, the producer will charge a higher p such that:

$$p = \frac{s_2 \bar{\theta}}{2} + \frac{c}{2} \tag{0.4}$$

and

$$\Pi = \frac{s_2 \bar{\theta}^2}{4} - \frac{c\bar{\theta}}{2} + \frac{c^2}{4s_2} \tag{0.5}$$

Proof in Appendix

If we subtract the profits that the firm can make when there is both a high- and low-quality good on the market from the profits he can make when there is only the high-quality good on the market, we find that the producer can make the below amount in additional profits when there is no low-quality alternative:

$$0 < \frac{\bar{\theta}^2 s_1}{4} + \frac{c^2}{4s_2} - \frac{c\bar{\theta}}{2} \tag{0.6}$$

The equation above provides an answer to the puzzle of why producers would seek to acquire regulations declaring their own products unfit for sale. The answer is that such regulations can allow them to increase sales of more lucrative alternatives, thereby raising overall profits. Yet how might we expect firms to convince regulators to provide them with the stricter regulations they seek? Regulatory capture theories would suggest that innovative firms ought to to provide bribes, votes, or the suggestion of future employment. It is possible firms would engage in this, but the strategy's success seems questionable for several reasons.

First, the removal of a popular product for questionable reasons is unlikely to go unnoticed, in part due to the fact that individuals tend to be particularly sensitive to perceived losses (Kahneman and Tversky 1979). Second, if consumers' anger over their loss leads to any sort of backlash, it increases the possibility that any corruption would be uncovered, meaning regulators risk harming their reputations and possibly losing their jobs. Finally, unlike entry barriers which unite the establishment against the upstarts, the removal of a single product pits one firm against many. Though the model assumes the many are indifferent over the sale of their low-quality product, in practice, these firms may derive some value from continued production, leading them to oppose a regulatory ban.[3] While these firms may not be willing to pay high costs to out-bid the high-quality producer, they could step in to raise the alarm if the public failed to do so.

The Power of Information

Given the potential reluctance of regulators to give firms the regulations they seek, how might firms go about acquiring these regulations? The answer, I suggest, is information. Firms are uniquely positioned to learn about the risks of their products before anyone else. Not only can they observe adverse effects due to worker exposure, but they are the first to receive customer complaints, and they often continue to run proprietary studies of their products even after they are placed on the market. This means that firms have the opportunity to provide evidence of harm at strategic moments, when they believe the removal of the product in question would serve their interests. Regulators, meanwhile, need not be captured to respond to this information by requesting the withdrawal of a product that is, in fact, unsafe.

Of course there are two major factors constraining firms' behavior. First, if we retain our assumption that regulators have an interest in acting honestly when it comes to health and safety regulation, firms will only be able to acquire stricter regulations if the data actually supports the need for stricter standards, meaning the product must actually be dangerous. Second, to the extent that acquiring stricter regulation entails an admission of harm, firms

[3]This observation would not impact the model's conclusions about the high-quality firm's preferences, so long as the profits from the low-quality good remain below the potential additional profits from the low-quality product's removal.

may decide that the reputational cost of revealing a previously undisclosed risk outweighs any benefit.

However, there are certain regulatory institutions under which firms can receive stricter standards on low-profit products without sullying their reputations and without depending on the existence of actual risk or, alternatively, a regulators' complicity. These are what I will refer to for the remainder of the paper as "retroactive precautionary institutions." Over the past few decades, precautionary institutions more generally have become increasingly popular for regulating potentially dangerous products across Europe and Asia, though they can also be found in many other countries, including the United States. What makes a precautionary system precautionary is that it operates under the assumption that a lack of evidence of safety is equivalent to evidence of harm. Almost universally, it is the producers of the products in question who must provide the necessary proof of safety. Retroactive precaution is often framed as an attempt to ensure that regulations are more responsive to new scientific information, as it dictates that every time a product comes up for review, regulators will be provided with updated studies and data (EU Commission 2001). In the absence of such a system, regulations quickly obsolesce, as they are typically based on outdated studies from the time when a product was first brought to market.

Retroactive precaution has now been applied in a large variety of countries for sectors that include industrial chemicals, pesticides, and food additives. While the institutional system may stem from the best intentions, during a retroactive precautionary review, all innovative firms need to do if they prefer to see a product regulated out of existence is not provide the requested evidence of safety. In other words, they can simply withhold information. As for any other producers of the product in question, they may struggle to fill the gap. This is because the cost of developing the data necessary to retain favorable regulations may exceed the expected profits on the low-margin good (as evidenced by the formal model). In addition, producers of the low margin good may have difficulty creating a consortium willing to share the cost of data production, due to collective action problems. This also highlights that under retroactive precaution, more generally, profits will play a bigger role in regulatory outcomes. Because maintaining tolerances is now expensive, even in the absence of a patented substitute, firms may be unwilling to support less profitable products.

The strategic incentives of innovators to eliminate products for which they have a more profitable substitute, combined with the added cost of maintaining standards under retroactive precaution leads to the first testable hypothesis.

Hypothesis 1 – Profits Dictate Regulatory Levels:
In a retroactive precautionary system in which failure by firms to provide updated information leads automatically to stricter regulations, regulations will become stricter on less profitable products over time.

In addition, the model of firms' preferences and the institutional conditions under which they can best pursue them leads to two additional hypotheses.

Hypothesis 2 – Seeking Stricter Standards:
Producers will be incentivized to seek stricter regulations on their own products if it allows them to sell more of another product with a higher profit margin.

Hypothesis 3 – Support for Precaution:
Innovative firms with an interest in eliminating their less profitable products may also have an interest in supporting retroactive precautionary institutions; non-innovative firms will always oppose these institutions.

In order to test the hypotheses, I focus primarily on the case of agrochemical regulations in the United States. This case is ideal for testing the hypotheses for a number of reasons. First, due to the existence of agrochemical patents, firms' financial preferences, according to the theory, are clear: they will seek to eliminate generic products (including their own) when they compete with patented alternatives. Second, regulations are set on a pesticide-by-commodity basis, meaning there are thousands of regulations in the U.S. at any particular time. This provides significant empirical leverage to identify over-time trends. Third, thanks to the Freedom of Information Act, we can see what firms have actually requested from regulators, meaning we can study company behavior and not just the resulting outcomes. Fourth,

pesticide regulation in the United States represents the earliest global example of retroactive precautionary institutions. This means that enough time has passed to allow us to assess regulatory change under such institutions, while the transparency of the U.S. system allows us to evaluate the coalitions that favored or opposed the new rules. Finally, though perhaps not obvious at first glance, pesticide regulations are enormously important in their own right. Pesticides are used on the vast majority of commercial agriculture, meaning that we consume these products every single day. Regulations not only protect us from unsafe ingestion of dangerous chemicals, but they have enormous implications for how crops are planted, grown, and traded. In other words, these regulations are not simply esoteric requirements on paper; they effect all of us as consumers, and they have global economic implications.

The next section tests Hypothesis 1, asking whether regulations have become stricter on less profitable products under a system of retroactive precaution. After providing evidence that outcomes are consistent with the theory, I next offer direct evidence of firms' preferences, showing that innovative firms have systematically sought to use health and safety regulations to eliminate less profitable products. Not only have companies provided information strategically in order to request stricter standards on a case-by-case basis, but they have also thrown their support behind retroactive precautionary institutions that allow innovative companies to leverage their informational advantage to more systematically remove low-margin products.

Regulatory Change Under Retroactive Precaution

In order to evaluate whether regulations have become stricter on less profitable products under retroactive precaution, I focus on what are known as pesticide tolerance levels. Tolerance levels represent the maximum amount of pesticide residue that is permitted to remain on an agricultural commodity at the point at which that commodity enters the market. These are set on a commodity-by-pesticide basis in units of parts-per-million, meaning that each authorized pesticide could have more than one hundred individual numerical tolerance levels associated with it. These tolerances are one of the primary means through which the use of pesticides is regulated, and they have direct implications for the amount and ways in which farmers can apply pesticides. As a result, changes to tolerance levels can alter the

appeal to farmers of using one pesticide over another.

The United States officially put retroactive precautionary institutions in place in 1972. However, the system has been significantly updated several times. Most importantly for testing the first hypothesis, in 1996 Congress passed the Food Quality Protection Act, which mandated that tolerances be reevaluated on a repetitive, 15-year basis. During these reevaluations, companies are required to provide evidence that current or proposed tolerance levels are safe. In accordance with all precautionary systems, failure to provide evidence of safety leads, automatically, to the assumption of harm, meaning that if firms refuse to provide data, tolerance levels are revoked, and the United States moves to a zero tolerance for the pesticide-commodity combination.

In order to evaluate whether lower-profit products have disproportionately been subject to stricter standards under a system in which stricter standards are imposed automatically in the absence of information, I collected data on changes to U.S. tolerance levels between 1996 and 2015. 1996 was chosen as a starting point because it immediately follows the passage of the Food Quality Protection Act, while the twenty-year time period guaranteed that every pesticide in the dataset was placed under review during the time period studied, reducing concerns that older pesticides might have been subject to review, while newer pesticides were not. Indeed, each of the pesticides in the sample was reviewed exactly once during the time period in question. The sample contained all pesticides that were also regulated at the international level. This helped guarantee that the products studied were significant products, less likely to become obsolete due to lack of utility.

Squash, summer	10
Squash, winter	10
Strawberries	10
Sugar beets, tops	100
Sunflower seeds	1

Figure 1: 1996 Carbaryl Tolerance

Soybean, seed	0.5
Spinach	22
Strawberry	4.0
Sunflower, seed	0.5
Sweet potato, roots	0.2

Figure 2: 2015 Carbaryl Tolerance

American pesticide tolerance levels are published in the Code of Federal Regulations. Figures 1 and 2 provide an example of what the data collection strategy actually looked like. Figure 1 shows the 1996 U.S. tolerance level for carbaryl on strawberry in parts per

million (ppm), while Figure 2 shows the same tolerance level for 2015. For each pesticide tolerance, I evaluated how the tolerance changed between 1996 and 2015. In the example, the tolerance moved from 10 ppm to 4 ppm, meaning that the standard became stricter. These two tolerances, along with the pesticide name and commodity would be entered into the database, capturing the move towards a stricter standard. This strategy was then repeated for all commodities for which a carbaryl tolerance existed in 1996. Each pesticide in the sample was evaluated in the same fashion, resulting in a total of around 3,700 individual tolerance levels tracked across time.

Regulatory Outcome Results

Table 1: Changes to US Regulations 1996-2015

	Changes to Pesticide Standards (N = 3,683)
Revoked	28%
Stricter	10%
Same	49%
Less Strict	13%

Table 1 presents summary statistics showing overall patterns in tolerance changes. The most likely outcome for any tolerance that existed in 1996 was that it would remain the same in 2015. Nevertheless, there is considerable variation across all outcomes, and every category contains several hundred observations at least. The category that requires some discussion is the category "revoked," which is the second largest category after stasis. A revocation means that any discernible pesticide residue on an agricultural commodity is a legal violation. This effectively equates to a ban of the pesticide on the commodity in question. Revocations occur for one of two reasons. Either the data available suggest that a pesticide is not safe at any level on a particular crop, leading the Environmental Protection Agency (EPA) to revoke the tolerance. Alternatively, a revocation occurs because the registrant(s) fails to pay the necessary fees and provide the necessary data to retain the tolerance over time. This

suggests that if revocations reflect a strategic decision by firms to rescind support for a product, then revocations should be strongly determined by products' profitability. Indeed, this relationship should be even stronger than for the lowering of tolerances, since revocations are a much more effective way to reduce demand than simply making a standard stricter. Alternatively, if revocations reflect the public interest, there should not be a deterministic relationship between pesticide profitability and whether or not its tolerances are revoked (or lowered), once we have controlled for other factors.

In order to test whether the regulatory outcomes suggest a public or private interest story, I used the year at which a pesticide was first registered as a proxy for that pesticide's profitability and the likely existence of a patented alternative, with the assumption that older pesticides are less profitable and are more likely to have a patented substitute.[4] Year of registration represents the first time that a chemical was legally allowed to be used or sold as a pesticide in the United States. As soon as a pesticide is first registered, a legal clock starts, during which the developer is granted exclusive use and data protection rights by the government. Companies have various ways of slowing the clock, sometimes extending it for many years, but they cannot stop it indefinitely. What this means is that the longer a pesticide is on the market, the more likely that the exclusive use period has expired, thereby significantly reducing the pesticide's profitability. In addition, the longer a product is on the market, the more likely that a patented substitute has been developed, further depressing a producer's financial interest in the product and, as detailed in the model, giving the producer an active incentive to eliminate the product entirely.[5]

An obvious problem with using pesticide age as the independent variable is that it could be correlated with other pesticide characteristics, such as toxicity, carcinogenicity, or effectiveness. Throughout the analysis, significant efforts have been made to control for these and

[4] An alternative proxy could have been the date of the initial patent filing for the active ingredient of the pesticide. However, this is arguably no better of a proxy than initial registration, and it presents far greater complications in terms of correctly identifying which patent date ought to be used. Moreover, because patent status does not account for the fact that market exclusivity can actually extend beyond patent expiration and may erode slowly over time, a simple, dichotomous variable capturing whether the product was in or out of patent is also undesirable.

[5] In the realm of pesticides, much like for pharmaceuticals, the developer of the original product is often the first to come up with an updated substitute. The reason is that substitutes are often variations on the original product, and since the developer has access to data on the original product before any other company, they can buy themselves as much as a two-decade head start.

other confounders. Although it is not feasible to rule out entirely the possibility that older pesticides are less desirable for reasons independent from their profit margins, the weight of the quantitative and qualitative evidence that follows suggests that this is not what drives the results.

A private interest story would suggest that tolerance levels for older pesticides should be more likely to become stricter or be revoked than tolerance levels for newer pesticides, controlling for relevant factors. A public interest story would suggest that pesticide age should not have an independent impact on outcomes. These competing explanations were tested using an ordered logit model. The pesticide's age as of 2015 is the independent variable of interest. The outcome categories were coded as 4 if the tolerance was revoked, 3 if the tolerance became stricter, 2 if it remained the same, and 1 if it became less strict.

A number of relevant controls were also included. The first control was *Toxicity*. Pesticide toxicity is one of the primary factors determining a pesticide's safety, and we should, therefore, expect it to enter heavily into any regulatory decisions. Toxicity is a measure of the acute risk a pesticide poses to health. Beginning in 1975, the World Health Organization (WHO) began releasing a document known as the WHO Recommended Classification of Pesticide by Hazard. This list, which has been revised every few years, ranks pesticide active ingredients on a five point scale from "extremely hazardous" (5) to "unlikely to present acute hazard in normal use" (1). In order to make its determination, the WHO utilizes independent scientists from a variety of countries and bases its decisions on scientific data about the pesticide itself, suggesting it should be a relatively objective measure. For every pesticide in the sample, I recorded its 1 to 5 ranking on the toxicity scale from 2009, which was the most recent publication of the WHO's guideline (WHO 2009). I also recorded the 1996-1997 classification (WHO 1997), as well as a dummy variable coded 1 if the classification had become more hazardous over time (*Toxicity Increased*). A change in classification to more hazardous might lead to a reevaluation of tolerance levels. I therefore attempted to account for that possibility.

The second set of controls was carcinogenicity. This reflects whether or not the pesticide is considered to be carcinogenic to humans. This measure differs from *Toxicity* in that it reflects dangers from long-term exposure, as opposed to short-term. The EPA, EU and the

WHO all publish a classification of carcinogenic potential. However, the WHO's list contains only a small portion of the pesticides in the sample, leading to issues of selection bias. As a result, I utilized the EPA's classification[6] in this case and supplemented it with the EU measure as a robustness check (Appendix II).[7] Unlike the WHO's Classification by Hazard, classification of carcinogenicity is not updated regularly by any of the documenting parties, thereby only providing a single data point for each pesticide from each source. The ranking for carcinogenicity (by both the EPA and the WHO) is on a five-point scale. The scale ranges from "Carcinogenic to Humans" (5) to "Not Likely to be Carcinogenic to Humans" (1). In the sample, no pesticide was ranked above a 4 on the carcinogenicity scale, where a 4 equals, "Likely to Be Carcinogenic to Humans." The EU, by contrast, has only a two point scale indicating whether or not the product is considered to be carcinogenic (1) or not (0).

A third set of controls captured the environmental effects of the pesticide. The primary environmental concern (outside of that already captured through *Toxicity* and *Carcinogenicity*) relates to the consequences of the pesticide seeping into the ground water, which could lead to its presence in streams, rivers, reservoirs, and oceans. The most recent and comprehensive recording of pesticides' aquatic impact comes from the European Union's Classification, Labelling and Packaging (CLP) standards.[8] In 2006, the E.U. passed legislation known as the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). This resulted in the classification of a wide variety of chemicals by hazard. Using these classifications, I was able to record both the acute aquatic risk from each pesticide, as well as the chronic aquatic risk. The first of these is a simple dichotomous measure for whether an acute (short-term) risk exists. The second ranges from 0 (no chronic aquatic risk recorded) to 4 (very toxic to aquatic life with long lasting effects) and measures the long-term aquatic risk of the product.

I also controlled for whether the tolerance applied to a fruit or vegetable, as opposed to a grain, an animal feed crop, or an animal by-product. The Food Quality Protection Act mandated that the EPA pay special attention to how pesticide exposure might impact

[6]Most recent version is available at: `http://npic.orst.edu/chemicals_evaluated.pdf`

[7]EU measure is available through C&L Inventory at: `https://echa.europa.eu/regulations/clp/cl-inventory`.

[8]Also available through the C&L Inventory

Table 2: Tolerance Changes in the US 1996-2015

	Tolerance Change 1996-2015:		
	1=Less Strict, 2=Same, 3=More Strict, 4=Revoked		
	(1)	(2)	(3)
Pesticide Age	0.049***	0.048***	0.043***
	(0.012)	(0.014)	(0.015)
Toxicity		0.647***	0.666***
		(0.194)	(0.193)
Toxicity Increased		0.243	0.254
		(0.369)	(0.373)
US Carcinogenicity		0.082	0.091
		(0.141)	(0.144)
Aquatic Chronic		0.082	0.090
		(0.143)	(0.140)
Aquatic Acute		0.495	0.490
		(0.510)	(0.505)
Fruit/Veggie			0.367*
			(0.194)
Primary Acreage			−1.373*
			(0.772)
Pesticide Age*Primary Acreage			0.026*
			(0.016)
Observations	3,683	3,459	3,459
Note:			*p<0.1; **p<0.05; ***p<0.01

children. As a result, residues on fruits and vegetables have been held to a higher standard, due to their prevalence in child diets (EPA 2017).

Finally, the model controls for whether the tolerance related to one of the three largest acreage crop groups in the United States (*Primary Acreage*). Producers have far more to gain from selling pesticides that can be used across a large number of acres. Therefore, we might expect that companies would invest more in retaining tolerances on pesticides that can be used on high-acreage crops. It is also possible that companies lobby harder to raise tolerances for their newer pesticides on large acreage crops, due to the fact that the potential financial gains from increased spraying of a high margin pesticide on a large acreage crop are enormous. For this reason, an interaction term for high acreage crops and year registered was also included.

The primary results are presented in Table 2. All standard errors are clustered at the pesticide level. Most significantly, we find that even after controlling for a variety of factors that we might expect could influence regulatory change, *Pesticide Age* continues to have an independent and statistically significant effect, with older pesticides far more likely have their tolerances become stricter or be revoked. In addition, the control variables have the expected directional effects, though many do not reach the level of significance, given the larger standard errors that result from clustering.

As for the magnitude of the *Pesticide Age* effect, if we hold each of the variables at their modes, the model predicts that a pesticide registered relatively recently, in 1995, had only a 6% chance that its tolerance would become stricter and an 8% chance that it would be revoked. By contrast, a pesticide registered 20 years prior had a 10% chance that its tolerance would become stricter, while the odds of a revocation more than doubled to 17%.

Of course, an alternative reason why the government might impose stricter standards on older products is that older pesticides are simply more dangerous and/or their dangers are more likely to be uncovered the longer they are on the market. Assuming this were the case, it could also be true that the included measures of toxicity and carcinogenicity failed to capture either evolving knowledge or the actual level of risk. In order to control for this possibility more thoroughly, I recorded all pesticides for which environmental or safety reasons were noted in the Federal Register as factoring into tolerance revocations. I then

Table 3: Tolerance Changes Dropping Most Dangerous Pesticides

	Tolerance Change 1996-2015:		
	1=Less Strict, 2=Same, 3=More Strict, 4=Revoked		
	(1)	(2)	(3)
Pesticide Age	0.047***	0.048***	0.042***
	(0.013)	(0.015)	(0.016)
Toxicity		0.541**	0.557**
		(0.235)	(0.233)
Toxicity Increased		0.150	0.158
		(0.360)	(0.363)
US Carcinogenicity		0.164	0.170
		(0.152)	(0.155)
Aquatic Chronic		0.102	0.107
		(0.141)	(0.138)
Aquatic Acute		0.255	0.257
		(0.507)	(0.503)
Fruit/Veggie			0.353*
			(0.211)
Primary Acreage			−1.183
			(0.807)
Pesticide Age*Primary Acreage			0.024
			(0.016)
Observations	3,237	3,019	3,019
Note:			*p<0.1; **p<0.05; ***p<0.01

dropped all such pesticides from the sample, even if not all of their tolerances were revoked. The results are displayed in Table 3. Notably, this had little impact on the coefficient of interest.

Another possibility is that as pesticides become older, they lose some of their utility, meaning that the imposition of stricter standards should not be viewed as catering to the preferences of firms but rather as the natural regulatory evolution. Pests do develop resistance to pesticides, and eventually products do become less effective. However, there are two primary problems with this explanation. First, if pesticides become less effective over time, farmers would need to use more of them, not less. This would suggest that if we drop the revoked category, tolerances should actually be increasing over time, not decreasing. Yet as shown in Table 4, when the revoked category is dropped and we only focus on tolerances that became stricter, less strict, or remained the same, the sign on *Pesticide Age* retains the same direction, despite losing significance in two of the models.

An additional problem with the effectiveness explanation, which will be discussed in the next section is that it fails to explain the lobbying behavior that we see on the part of farmers and firms. More generally, the stability of the coefficient on pesticide age, even after controlling for toxicity, carcinogenicity, and environmental effects and also after incorporating multiple robustness checks suggest that the public interest is unlikely to adequately explain why U.S. regulators have imposed increasingly strict standards on older products. At the same time, on its own, the regulatory outcome results might leave us wondering whether the mechanism can truly be attributed to firms' preferences and their provision (or lack thereof) of information. The remainder of the paper addresses the question of mechanism directly, first using a combination of data and qualitative evidence to show that firms, unlike farmers, the other relevant actor in this space, actively request stricter standards on older products. In addition, I introduce historical evidence that innovative firms helped put retroactive precautionary institutions in place, whereas generic producers vehemently opposed such a system.

Table 4: Tolerance Changes Dropping Revoked

	Tolerance Change 1996-2015		
	1=Less Strict, 2=Same, 3=More Strict		
	(1)	(2)	(3)
Pesticide Age	0.027**	0.019	0.009
	(0.011)	(0.014)	(0.015)
Toxicity		0.054	0.082
		(0.164)	(0.160)
Toxicity Increased		0.122	0.152
		(0.371)	(0.359)
US Carinogenicity		0.258**	0.272**
		(0.122)	(0.121)
Aquatic Chronic		−0.104	−0.097
		(0.133)	(0.128)
Aquatic Acute		0.559	0.563
		(0.394)	(0.382)
Fruit/Veggie			0.646***
			(0.214)
Primary Acreage			−2.009**
			(0.922)
Pesticide Age*Primary Acreage			0.044**
			(0.021)
Observations	2,636	2,465	2,465
Note:			*p<0.1; **p<0.05; ***p<0.01

Out With the Old

In order to show that innovative firms systematically seek stricter standards on their own low-margin products, I looked at the petition behavior of pesticide companies. In the United States, interested parties may petition for changes to tolerance levels at any point. These petitions are then made public in the Federal Register and, more recently, through the website, `regulations.gov`, providing the opportunity to see which standards producers actually request and to then compare producer preferences with the preferences of other relevant parties.

Petition Data

I collected all petitions submitted to the Environmental Protection Agency between 1999 and 2015 requesting changes to existing pesticide tolerance levels. Because there is a significant fee that must be paid in order to submit a petition, and because data must be provided in support of the request, nearly all pesticide tolerance petitions come from one of two types of petitioners: registrant(s) (i.e. chemical companies that produce the pesticide in question) or the Interregional Research Project No. 4 (IR-4), which is a non-profit group that lobbies on behalf of American specialty crop farmers.[9]

In total, the sample contained over 200 individual petitions. These petitions, in turn, contained nearly 900 specific tolerance amendment requests. An example of one of these petitions is included in Figure 3. For each petition the Federal Register lists the identity of the petitioner and the new tolerance the petitioner is requesting.[10]

After collecting all tolerance amendment requests during the relevant time period, the sample was divided into two categories. The first category included all petitions submitted by innovative chemical companies,[11] a total of 622 specific tolerance requests. The second

[9]Specialty or "minor use" crops are those for which the overall U.S. acreage is less than 300,000 acres or for which the government "determines that ...the use does not provide sufficient economic incentive" for agrochemical companies to support the pesticide financially (7 USC §§136(ll)). Notably, IR-4 is the sole party that is exempt from having to pay a petition fee, an accommodation that is meant to facilitate the ability of specialty farmers to have their interests represented.

[10]In some cases the Federal Register lists the old tolerance, whereas in other cases it does not. When the old tolerance was omitted, I was able to cross-reference the Code of Federal Regulations (where all U.S. regulatory rules are recorded annually) in order to determine what the tolerance had been at the time that the petition was submitted.

[11]Of the 629 tolerance change requests by companies, there were only seven cases in which the petitioner was not or could not be confirmed to be a developer of innovative products. In other words, the vast majority of company petitions came from large companies with their own product lines.

2. *PP 9F7622*. (EPA-HQ-OPP-2010-0287). Valent U.S.A. Company, 1600 Riviera Ave., Suite 200, Walnut Creek, CA 94596-8025, proposes to amend the tolerance in 40 CFR 180.617 by decreasing the established tolerance for residues of the fungicide metconazole, 5-[(4-chlorophenyl)methyl]-2,2-dimethyl-1-(1H-1,2,4-triazol-1-ylmethyl)cyclopentanol, measured as the sum of *cis*- and *trans*-isomers, in or on nut, tree (crop group 14) from 0.04 ppm to 0.02 ppm. Independently validated analytical methods have been submitted for analyzing parent metconazole residues with appropriate sensitivity for all canola crop and processed commodities for which a tolerance is being requested. Contact: Tracy Keigwin, (703) 305-6605, e-mail address: *keigwin.tracy@epa.gov*.

Figure 3: Pesticide Tolerance Petition

category contained all petitions submitted by the specialty crop group, IR-4, a total of 253 specific tolerance requests. Unlike chemical companies, specialty farmers should have no direct incentive to petition against older, cheaper pesticides. If they did, and if this mirrored the behavior of agrochemical producers, we might question whether a different mechanism than the one proposed was driving the result. Therefore, the farmer petitions act as a comparison group.

As for the petitions submitted by the pesticide companies, in an ideal world we would want to know both whether the petitioner had substantial competition from generic producers (which would affect the possible profit margin) and whether the petitioner produced a patented substitute for the product in question. Unfortunately, determining the existence of a substitute is nearly impossible without extensive knowledge of farmer preferences and the chemical properties of each pesticide. In addition the actual existence of generic competition may not be the best proxy for profit margins. On the one hand, a lack of competition could indicate an unpopular (and unprofitable) product. On the other, it could indicate a particularly lucrative product, given that firms with a blockbuster chemical can engage in numerous strategies to to delay or minimize the market entry of competitors. Therefore, rather than use actual competition, the pesticide's age, in this case the number of years that a pesticide had been registered in the U.S. at the time of the petition, again serves as a proxy for a producer's financial interest in the product.

Petition Results

Table 5 presents summary statistics of the petition behavior of pesticide producers and

Table 5: Summary Statistics for Petitions

	Companies N = 622	Farmers N = 253
Requests for Less Strict Standards	85%	86%
Requests for Stricter Standards	15%	14%

specialty farmers. Both farmers and producers are far more likely to request more lenient standards, yet both groups also ask for stricter standards approximately 15% of the time, a percentage that may seem surprisingly high.

While farmers and producers look quite similar when it comes to the rate at which they request stricter or less strict standards, a very different picture emerges when we evaluate these requests based on the year that the pesticide was registered. Table 6 shows the results of a logit model, for which the outcome was designated as a 1 if a request was for a stricter standard and 0 if it was for a less strict standard. Model 1 uses a continuous measure for pesticide age, while Model 2 uses a dichotomous measure, intended to capture whether the product was in or out of patent at the time that the petition was submitted. All models use standard errors clustered at the pesticide level. We see that in both specifications, pesticide age is statistically significant for the companies, while it does not reach significance, and even has the opposite sign for the farmers.

To put the pesticide producers' petition results in perspective, using the continuous variable for pesticide age, whereas if a company submitted a petition for a pesticide registered five years ago, there was an 8% probability that the petition would be for a stricter tolerance, in the case of a pesticide registered 20 years ago, that number jumps to 17%, and after 50 years it increases to 51%. In interpreting these results, one should keep in mind that requests for lower tolerances only made up 15% of the sample. Therefore, a 51% probability that a request would be for a stricter tolerance is remarkably high.

The results presented thus far provide suggestive evidence that companies actively lobby against *their own* products as profits diminish. This suggests that producers are attempting

Table 6: Company and Farmer Petitions For Stricter Standards

	Petition Request: 0=Less Strict, 1=Stricter			
	Company Petitions		**Farmer Petitions**	
	(1)	(2)	(1)	(2)
Pesticide Age	0.046***	1.959***	−0.006	−0.052
	(0.014)	(0.723)	(0.032)	(0.668)
Observations	622	622	253	253
Note:				*p<0.1; **p<0.05; ***p<0.01

to use regulations as a means of shortening the product cycle on existing products in order to boost sales of more profitable alternatives.

Admittedly the analysis does not control for other reasons that actors might seek stricter tolerances, such as the risks of the pesticide in question. Because so many of the petitions relate to newer pesticides, for which publicly available safety classification data is lacking, controlling for pesticide attributes in the petition analysis would lead to a selection problem. Nevertheless, considering that farmers also have reasons (in fact, arguably stronger ones) to seek stricter standards on more dangerous or less effective products, it is unlikely that pesticide safety or efficacy attributes would impact company behavior but not that of farmers. Moreover, it is also possible to identify numerous specific cases, both inside and outside the realm of pesticides, in which producers have engaged in far more overt attempts to use regulation to undermine less lucrative products in favor of more expensive substitutes.

Setting Subtlety Aside

While requesting lower tolerances is a relatively indirect way of encouraging farmers to switch to alternatives, chemical producers have not always been so subtle. In 1979, Ciba-Geigy, which was subsequently bought by the agribusiness giant, Syngenta, patented metolachlor. In 1999, six years after that patent had expired, Syngenta came out with an updated variation, *S*-metolachlor. At the same time, they pulled metolachlor from the market. However, Syngenta's withdrawal of metolachlor did not stop generic production. In order to

block generic producers, Syngenta (unsuccessfully) filed suit, requesting that the EPA ban the very product that it itself had produced up until it manufactured an alternative. In the process, Syngenta claimed that failure to ban metolachlor "would be a clear statement to the public and to the agrochemical industry that EPA no longer values the environmental benefits associated with reduced risk products" (Watkins 2002).

Similarly, in 1998 Novartis patented a new pesticide known as mefenoxam and at the same time cancelled its older out-of-patent pesticide, metalaxyl, which had chemically similar properties. According to the pesticide supplier, Nation's Ag, which subsequently sued both Novartis and the EPA, Novartis' decision to cancel metalaxyl was intended to "prevent registration of a competing [generic] metalaxyl technical product" (Tawasha 1998). When asked directly whether companies have an incentive to seek stricter standards on older pesticides, a senior manager at BASF informed me, "Yes. It's all about the profits. Companies are constantly trying to phase out old products in favor of newer ones" (in-person interview).

It should be noted that neither these incentives nor this behavior seem to be restricted to agrochemical producers. For example in 2005 GlaxoSmithKline successfully lobbied to ban chlorofluorocarbon (CFC)-omitting inhalers that it itself, produced after coming up with a CFC-free alternative. Likewise, in 2013, Purdue Pharma, the inventor of OxyContin, convinced regulators to withdraw its license for the painkiller *the same day* it came off patent (thereby preventing all future sales), because Purdue had come up with a harder-to-abuse substitute.[12] Finally, in 2015, Total SA and Royal Dutch Shell urged regulators to introduce an effective carbon pricing system that would make coal less attractive at the same time that these two companies were contemplating moving out of the coal business.

Hypothesis 2 stated that producers would seek stricter standards on their own products if it allowed them to sell more of another product with a higher profit margin. This section has empirically demonstrated that pesticide producers do indeed request stricter standards on older products, seemingly in reaction to the fact that their exclusive use period has expired. If we assumed that these petition requests reflected public safety concerns, then we would

[12]Shortly after Purdue received a favorable decision from U.S. regulators, Endo Pharmaceuticals similarly petitioned the Food and Drug Administration to end all sales of its painkiller, OPANA ER. This followed Endo's development of a new, and supposedly harder to abuse version of the drug. In this case, however, the petition was denied ("Determination on OPANA ER" 2013).

expect the petition behavior of farmers to look the same. Yet this has not been the case, pushing against such an interpretation. Rather, the findings support the hypothesis that agrochemical firms lobby against their own products primarily in order to increase profits.

While introducing new information to support a petition for stricter tolerance levels or even the ban of a pesticide altogether can be an effective strategy for shifting the market to alternatives, it is both inefficient and unpredictable. It is inefficient, because it requires paying a fee for each new petition, not to mention spending resources on acquiring the necessary data, providing that data to regulators, and then convincing them that a stricter standard is, indeed, warranted. More importantly, the strategy is unpredictable. As evidenced by the metolachlor case, unless companies present compelling evidence that their product is unsafe (which carries its own reputational risks), they cannot be guaranteed a favorable ruling. However, the situation becomes far more favorable for firms hoping to eliminate generic products under a retroactive precautionary regulatory system, because under such a system, once a product comes up for review, firms don't need to provide new scientific evidence of risk, they just need to avoid offering updated information on safety. Such a system allows innovative firms to effectively shorten the product cycle by eliminating products from the market before consumer demand has actually waned. Firms can then substitute in patented alternatives that command a much higher premium.

Changing the Institutions

I now turn to the final hypothesis, which is that innovative companies stand to benefit from and have, therefore, been willing to support retroactive precautionary institutions, whereas these institutions are directly harmful to and opposed by generic producers. In order to evaluate the hypothesis, this section briefly sketches the legislative history of agrochemical regulations in the United States. The historical evidence suggests that producers anticipated that retroactive precaution would lead to the elimination of less profitable products, leading innovators to support the changes, in opposition to their less innovative counterparts.

Early regulation of pesticides in the United States aimed to achieve two distinct goals: protect farmers from ineffective or dangerous products and protect consumers from ingesting harmful levels of pesticide residues in their food. Prior to the establishment of the Envi-

ronmental Protection Agency, these two tasks were divided between the Food and Drug Administration and the Department of Agriculture. However, in 1970 the tasks were reassigned to the newly created EPA.

Up until 1972, producers of agricultural chemicals were only required to demonstrate safety upon initial registration. However, if subsequent evidence emerged that a pesticide posed a hazard to humans or the environment, "the burden of proof was paradoxically shifted to the federal government. Each use, in essence, was considered innocent until proven guilty, and manufacturers could produce and sell the product until all appeals were exhausted, which could take years" (Bosso 1987, p. 156).

By the early 1970s, following the publication of *Silent Spring* in 1962 and extensive public debates about the dangers of agrochemicals, there began to be a rising awareness that the system in place was unable to respond to scientific developments. During a 1971 Congressional hearing contemplating revisions to existing laws, Dr. Albert Kolbye, Deputy Director of the Bureau of Foods in the FDA testified:

> It has become apparent... that some of the decisions made on pesticides in the past deserve our attention. Pesticide residues formerly undertaken because of technological limitations have become evident in some cases as our analytical tools have improved. More important, in recent years, we have begun to ask some questions about certain biological effects of pesticides when humans are exposed...In brief, we need to arm ourselves with better scientific understanding of the biological effects of pesticides (*Federal Pesticide Control Act of 1971*, p. 94).

The proposed solution was something known as "re-registration," which came about in 1972 under the Federal Environmental Pest Control Act. Through this process, producers of existing products would be required to submit updated data on their pesticides, proving that they were safe by modern standards. In theory, this meant that pesticide companies took on the burden of providing adequate information to prove that old chemicals were safe. In practice, the lack of funds allocated to the effort meant that little had changed in terms of actual burden shifting. Testimony by Senator Richard Lugar during a 1987 Senate hearing

revealed that, "Despite two mandates by Congress in 1972 and again in 1978 to review and re-register some 600 active ingredients, the EPA has re-registered less than one percent of these products" (*FIFRA Hearings*, p. 5). The result was a "'double standard' among old and new products: older products, registered by the USDA under the 1947 law, remained on the market pending re-registration (which lay dead in the water), while newer products encountered more formidable regulatory barriers" (Bosso 1987, p. 200).

In 1988, following years of impasse and numerous Congressional hearings, the U.S. government passed an amendment to regulatory law requiring that pesticide companies not only provide the data for re-evaluations but that they also help pay the costs of regulatory review. The hope was that this could speed up the re-registration process, making the theoretical requirement of re-evaluation a reality.

On its face, the 1988 legislation appears to be a clear victory for the conscientious consumer, a triumph of safety and environmentalism over the private interests of firms. However, a closer look at the testimonies and coalitions that emerged in the law's lead up suggest that not all firms were losers.

The Baptist-Bootlegger Coalition

During the debates preceding the 1988 legislation requiring pesticide producers to help finance the re-registration process so as to ensure that it took place in a timely fashion, environmentalists, consumer groups, and government officials discovered an unlikely ally: the large agrochemical companies. In the summer of 1985, with legislation interminably stalled, the large, innovative chemical companies sat down with the environmentalists and drafted a proposal. Notably absent from those meetings were the smaller, typically generic companies (Bosso 1987), a representative of which noted during 1986 Congressional hearings, "I think it would be fair to say that we were not included [in the negotiations]... we were not invited" (*Reauthorization of FIFRA*, p. 52).

What the large, innovative companies and the environmentalists came up with was a way of speeding up the re-registration process by leveling a fee of $150,000 on companies for each requested re-registration. Carl J. Kensil, chairman of the board of directors for the National Agricultural Chemicals Association, a trade organization for the largest pesticide producers,

and an employee of CIBA-GEIGY Corp, one of the largest pesticide companies at the time, had this to say about the proposal:

> We have heard and been sensitive to repeated criticism about the integrity of data supporting a few old commodity chemicals whose entry into the marketplace predated modern detection technology by several decades. And we have debated among ourselves how we might respond to publicly expressed concerns about... EPA's missed re-registration deadlines... We have come to recognize that we are more than simply manufacturers and formulators of products that enable our farmer customers to control ever-present insects, weeds, and diseases. We have come to accept that in one way or another, every American is exposed to the products of our industry. That recognition puts an even greater burden on us. What we are here to say to you, Mr. Chairman and members of the subcommittee, is that we accept our responsibilities to our customers and to the public at large. Their concerns are really identical (*Reauthorization of FIFRA*, p. 9).

During the same Hearing, Jack Early, the president of the National Agricultural Chemicals Association said the following:

> The situation we are really trying to address... is a situation that I think is unacceptable to our industry, to the public, and to the American farmer, and that is, EPA is projecting that the re-registration process will take up to 20 years. Now, that is too long, we believe, to leave products in the marketplace (*Reauthorization of FIFRA*, p. 13).

The concern expressed by the larger companies for the public well-being seems to have not been entirely shared by their smaller counterparts or some of the farmers who relied on pesticide products. Ralph Engel, the president of Chemical Specialties Manufacturers Association, which represented smaller companies, most of which did not develop their own products but instead produced generic versions of existing chemicals stated, "Any system of re-registration fees would in effect result in taxing a few to finance a regulatory system that benefits many. When Government services benefit society generally, the expense of these

services should be borne by the taxpayer at large and not by individuals" (*Reauthorization of FIFRA*, p. 43). Meanwhile, a representative from the National Cotton Council observed, "Our biggest immediate concern is the threatened loss of many of our older pesticide products. Patents on many of them have expired, and many of the registrants are small businesses which are understandably reluctant to spend large amounts of money to save those products without having any market protection" (*Reauthorization of FIFRA*, p. 60).

All of this raises the following questions: why would companies that had seemingly benefitted from the ability to sell old products indefinitely volunteer to pay a substantial fee to help the EPA speed up the process of potentially removing those products from the market? And why was there a divergence between the large companies on the one hand and the farmers and smaller, less innovative companies on the other? What makes the sudden generosity of the bigger producers particularly puzzling is the attempt to avoid fees for initial registration, while being willing to pay for the subsequent re-evaluation of older products. As Early, the president of the National Agricultural Chemicals Association, notes, "Now I differentiate between registration and re-registration. I think re-registration money is an appropriate thing to do to get the old products registered in an appropriate and up to new science and technology [way]. We do not believe that this should translate to a registration fee, which we believe is still in the public's interest, the consumer's interest, and the farmer's interest" (*Reauthorization of FIFRA*, p. 11).

The willingness of the large innovative companies to volunteer a $150,000 re-registration fee that could help remove old products from the market, and the concomitant unwillingness to pay for initial registration, struck at least some participants at the Hearings as odd. Representative Leon E. Panetta, Democrat of California, had this to say, "You are beginning to talk like us in Congress. I have a feeling, if I know most business managers, 150 grand is still 150 grand." (*Reauthorization of FIFRA*, p. 17).

What Panetta perhaps failed to see was that a $150,000 fee for re-registration was actually a cheap price to pay for what the larger companies expected to get. This was true for two reasons. First, it seems likely that the larger companies knew that a fee that might be negligible for them could be enough to push smaller companies off of the market. In that sense, the companies' eagerness to succumb to more onerous regulations follows the

classic Stigler (1971) model, since the regulations would act as a barrier to entry. However, Early's differentiation between registration and re-registration, combined with the concern of the cotton producers, suggests a second motivation: by accelerating and also increasing the cost of re-registration, the large innovative companies could push generic products off the market, thereby making room for their own patented alternatives. This accords with the final hypothesis, which suggested that innovative firms, unlike their generic counterparts, ought to be more willing to support a system of retroactive precaution.

What's Information Got to Do With It?

If we accept that regulatory change under retroactive precaution has served the interests of innovative firms at the expense of the generic competition, the question of the mechanism through which firms acquire these preferential outcomes still remains. I proposed at the beginning of this paper that firms' ability to acquire preferential outcomes under retroactive precaution rests on their informational advantages and not on regulatory capture, as it is traditionally understood. The question now becomes whether the evidence supports such an interpretation.

On the one hand, we know that innovative firms actively lobby for stricter standards on older products, and it is the case that they receive the stricter standards they seek approximately 53% of the time.[13] Although petitions, themselves, are a form of information provision, we cannot learn through observation of outcomes alone whether firms' success is due to information or capture. Much as Carpenter (2004) notes, the two are observationally equivalent.

However, when it comes to actual outcomes under retroactive precaution, there is strong evidence that the ability of firms to use information strategically has played a central role in the regulatory patterns identified. Prior to the implementation of re-registration, U.S. tolerance levels changed at a substantially slower rate. For example, between 1955 and 1970 only 7.7% of all standards experienced any sort of change, and within that, only 6.5% of those standards became more strict (21 CFR 120 1955; 21 CFR 120 1970).[14] Since the total

[13]This percentage was calculated from the selection of company petitions collected for the time period 1999-2015.

[14]This percentage was calculated by entering all tolerance levels listed in the U.S. Code of Federal Regu-

number of tolerances in 1955 was just over 500, this means that on average, only about 2.5 individual standards actually changed per year, or about one half of a percent of existing tolerances. Moreover, all but one of those changes related to the pesticide DDT, which was famously the subject of Rachel Carson's, *Silent Spring*, and which was only finally restricted after approximately a decade of significant environmental group and public pressure. In other words, almost all the change that occurred was for a pesticide that by any objective standard ought to have been subject to stricter regulation and for which there was enormous public (not just private) pressure to impose those stricter regulations.

By contrast, following the implementation of an effective re-registration system, tolerance levels became stricter at a rate of approximately 2% of tolerance levels per year, well over a four-fold increase from before. This occurred despite the absence of a public push for stricter standards commensurate with what was seen in the wake of *Silent Spring*. The significantly greater amount of change that occurred following the implementation of a system that allowed firms to withhold information in order to receive stricter standards suggests that there has been much more opportunity for stricter standards to reflect profits under such a system.

Moreover, the fact that firms supported the more precautionary system is, itself, evidence that the ability to use information was part of the calculus. After all, if firms anticipated that they could simply capture regulators and ensure favorable outcomes without retroactive precaution, they would have had low incentive to favor institutions that raised their own costs, while offering the same outcomes they could have already enjoyed through capture.

Also notable, the primary critique of the U.S. system prior to 1988 and of similar systems that have existed to regulate industrial chemicals in both the U.S. and Europe is that a lack of re-evaluations of existing products leads to under-regulation over time and regulatory stasis more generally (Commission of the EU, p. 4). The reason is that under such a system, damaging information about products is often hard to come by. Although firms may occasionally have incentives to reveal damaging information about their products in order to make room for newer alternatives, the general stasis that seems to characterize these systems suggests that firms do so only on rare occasion.

However, when firms are faced with the decision of providing information in order to

lations (CFR) in 1955 and comparing them to tolerances listed in the 1970 CFR.

retain steady standards or withholding it in order to receive stricter regulations, their choice is no longer about actively revealing their products' dangers but instead about passively allowing regulations to push those products off the market. These are clearly very different calculations. Not only is there now no lobbying or other monetary cost associated with acquiring stricter standards, but there is also no reputational cost. As for the non-innovative producers who may have an interest in maintaining generic products, a combination of collective action problems, low profit margins on the products in question (by definition), and the fact that generic companies have less infrastructure for producing research all combine to make it difficult for them to fill the data gap.

Not surprisingly, there is a substantial amount of qualitative evidence that firms' decisions to provide information given a system in which re-evaluations occur is largely dependent on profit considerations. This is partially revealed by the National Cotton Council's concern that manufacturers would pull support for out-of-patent products once the re-registration system was put in place (*Reauthorization of FIFRA*, p. 60). It was also directly confirmed by a representative of Bayer, one of the largest chemical producers in the world, who informed me during an in-person interview that once a pesticide goes out of patent "it's really not profitable to continue to pay for the research" to retain lenient tolerance levels (Interview June 1, 2016). Moreover, given that the system put in place in 1988 means that failure to pay for research leads automatically to stricter standards, firms' strategic decisions about when to pay for requested re-registration research clearly plays a central role in determining outcomes.

Taken together, the results are consistent with the hypothesis that given a system in which producers must defend the continued existence of lenient standards with updated data, standards will become stricter on less profitable products. These are products for which producers have a low incentive to continue paying for the research necessary to maintain stable standards. They also may be products for which certain firms produce a patented substitute, giving them an active reason to want stricter standards. While producers may seek and receive stricter regulations on some products in a system in which acquiring favorable regulations depends entirely on finding a sympathetic regulator or producing new evidence that stricter regulations are warranted, a system that allows firms to acquire the

regulations they seek by simply doing nothing undoubtedly makes the strategy of using regulations to push the market towards more profitable alternatives both easier and more attractive.

Conclusion

This paper has shown how companies leverage their monopoly on scientific information to impose health and safety standards that are less reflective of science than of firms' financial interests. Most notably, companies have been able to do this in part because of institutional rules that are intended to ensure the regular incorporation of new scientific information. While companies' strategies (and the empirical evidence) play out at the domestic level, the consequences are international. In the specific case under consideration, the phasing out of tolerances for older pesticides has led to agricultural trade barriers that tend to hit farmers in developing countries the hardest. To take just one example, according to Roger Ruiz Zapata, an official in Costa Rica's Ministry of Agriculture and Livestock, 30% of Costa Rican pineapple production is by "small farmers who don't have the necessary capital to use more expensive pesticides" (email communication). When countries like the United States revoke tolerances for the pesticides these farmers can afford, small growers in developing countries may be faced with the decision of finding new buyers or risking having their produce rejected at the border.

Yet the implications extend well beyond the realm of pesticides. Many of us think of science-based regulation as the gold standard of regulatory decision-making. If regulations are founded on scientific studies, with steadfast rules dictating that no product can be sold without safety data to support it, one would assume that this should eliminate or at least seriously reduce the ability of private actors to manipulate outcomes. Instead, I find that science-based institutions actually *contribute* to regulatory manipulation. Moreover, there is nothing in the theory to suggest that these findings ought to be restricted to the United States. Unlike traditional, regulatory capture, informational capture does not depend on votes, corruption, or specific political structures.

The findings also have important implications for how we think about when a regulatory barrier to trade is or is not legitimate. The WTO has framed this question largely around

whether rules are based on science, a standard that, at least on its face, seems reasonably objective. The problem is that any judgement about whether a regulation is scientific can only be as valid as the availability of scientific information allows. When private actors are the proprietors and distributors of scientific information, they are in a position to determine what is and is not scientific. In other words, we have left the fox to guard then henhouse.

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Appendix I

Proofs for Equations 0.1 and 0.2

If a producer sells two products, one of high and one of low quality (s_2 and s_1 respectively), with prices p_2 and p_1 (where $p_1 = c$), respectively, then the consumer will be indifferent between the two products iff $\theta s_1 - p_1 = \theta s_2 - p_2$, and he will prefer the high quality product whenever $\theta s_1 - p_1 < \theta s_2 - p_2$. This means the consumer will prefer the high quality product whenever $\theta > \frac{p_2 - p_1}{s_2 - s_1}$. Where $F(\theta)$ is the CDF, this gives us the demand function for the high quality good:

$$\begin{aligned} D_2(p_1, p_2) &= 1 - F(\frac{p_2 - p_1}{s_2 - s_1}) \\ D_2(p_1, p_2) &= 1 - \frac{p_2 - p_1}{s_2 - s_1} + \underline{\theta} \\ D_2(p_1, p_2) &= \bar{\theta} - \frac{p_2 - p_1}{s_2 - s_1} \\ &= \bar{\theta} - \frac{p_2 - c}{s_2 - s_1} \end{aligned} \tag{0.7}$$

The producer will then maximize the following, with respect to p_2:

$$\begin{aligned} \max \Pi(p_2) &= (p_2 - c)(\bar{\theta} - \frac{p_2 - c}{s_2 - s_1}) \\ 0 &= \frac{\partial \Pi}{\partial p_2}(p_2 - c)(\bar{\theta} - \frac{p_2 - c}{s_2 - s_1}) \\ 0 &= \bar{\theta} - \frac{2p_2}{s_2 - s_1} + \frac{2c}{s_2 - s_1} \\ p_2 &= \frac{\bar{\theta}(s_2 - s_1)}{2} + c \end{aligned} \tag{0.8}$$

This now gives the producer profits:

$$\begin{aligned} \Pi &= (\frac{\bar{\theta}(s_2 - s_1)}{2} + c - c)(\bar{\theta} - \frac{\frac{\bar{\theta}(s_2 - s_1)}{2} + c - c}{s_2 - s_1}) \\ &= (\frac{\bar{\theta}(s_2 - s_1)}{2})(\bar{\theta} - \frac{\bar{\theta}}{2}) \\ &= (\frac{\bar{\theta}(s_2 - s_1)}{2})(\frac{\bar{\theta}}{2}) \\ &= \frac{\bar{\theta^2}(s_2 - s_1)}{4} \end{aligned} \tag{0.9}$$

0.1 Proofs for Equations 0.4 and 0.5

If only one product exists, with quality s_2 and the same preference distribution among consumers as in the case of two products, then the demand for the product will be:

$$\begin{aligned} D(p) &= 1 - F(\frac{p}{s_2}) \\ D(p) &= 1 - (\frac{p}{s_2} - \underline{\theta}) \\ D(p) &= \bar{\theta} - \frac{p}{s_2} \end{aligned} \tag{0.10}$$

This means that the producer will maximize with respect to p as follows:

$$\begin{aligned} \max\Pi &= (p-c)(\bar{\theta} - \frac{p}{s_2}) \\ 0 &= \frac{\partial \Pi}{\partial p}(p-c)(\bar{\theta} - \frac{p}{s_2}) \\ 0 &= \bar{\theta} - \frac{2p}{s_2} + \frac{c}{s_2} \\ \frac{2p}{s_2} &= \bar{\theta} + \frac{c}{s_2} \\ p &= \frac{s_2\bar{\theta}}{2} + \frac{c}{2} \end{aligned} \tag{0.11}$$

Given this price, the firm's profits will be

$$\begin{aligned} \Pi &= \left(\frac{s_2\bar{\theta}}{2} + \frac{c}{2} - c\right)\left(\bar{\theta} - \frac{\frac{s_2\bar{\theta}}{2} + \frac{c}{2}}{s_2}\right) \\ &= \frac{s_2\bar{\theta}^2}{4} - \frac{c\bar{\theta}}{2} + \frac{c^2}{4s_2} \end{aligned} \tag{0.12}$$

Proof of Proposition 3
If $i = 0$, then $E(U_{F_I})$ outside of precaution is:

$$\begin{aligned} E(U_{F_I}) &= \Pi(1-d)^2 + \Pi^+ d(1-d) + d(1-d)(\Pi - \phi c) + d^2(\Pi^+ - \phi c) \\ &= \Pi - d\Pi + d\Pi^+ - d\phi c \end{aligned} \tag{0.13}$$

Meanwhile $E(U_{F_I})$ under precaution is simply $(1-d)(\Pi^+ - e)$. This means F_I prefers precaution whenever:

$$\begin{aligned} \Pi - d\Pi + d\Pi^+ - d\phi c &> (1-d)(\Pi^+ - e) \\ \Pi^+(1-2d) - \Pi(1-d) &> e(1-d) - d\phi c \end{aligned} \tag{0.14}$$

And F_I will pay up to:

$$\begin{aligned} &\Pi - d\Pi + d\Pi^+ - d\phi c - (1-d)(\Pi^+ - e) \\ =&\Pi^+(1-2d) - \Pi(1-d) - e(1-d) + d\phi c \end{aligned} \tag{0.15}$$

Of course, F_I may not have to pay this much. Rather, F_I only needs to pay enough that $b + v > -v$

Company Petitions With Dichotomous Age

The cutoff for model 1 is less than or equal to 20 years since registration ensures all pesticides in the old group are out of patent, while accounting for the fact that pesticides are typically registered within 1 to 4 years after initial patenting. Model 2 uses a cut point of 19 years, while Model 3 uses 18 years, to ensure robustness

Table 7: Company Petitions With Dichotomous Age

	Petition Request:		
	0=Less Strict, 1=Stricter		
	(1)	(2)	(3)
Pesticide Age	1.959***	1.912***	1.810**
	(0.723)	(0.733)	(0.729)
Observations	622	622	622
Note:	*p<0.1; **p<0.05; ***p<0.01		

Appendix II

Table 8: Tolerance Changes in the US 1996-2015

	Tolerance Change 1996-2015:		
	1=Less Strict, 2=Same, 3=More Strict, 4=Revoked		
	(1)	(2)	(3)
Pesticide Age	0.049***	0.050***	0.044***
	(0.012)	(0.014)	(0.015)
Toxicity		0.658***	0.671***
		(0.191)	(0.189)
Toxicity Increased		0.281	0.289
		(0.384)	(0.389)
EU Carcinogenicity		0.396	0.381
		(0.403)	(0.400)
Aquatic Chronic		0.113	0.115
		(0.134)	(0.131)
Aquatic Acute		0.448	0.457
		(0.478)	(0.474)
Fruit/Veggie			0.358*
			(0.192)
Primary Acreage			−1.264
			(0.770)
Pesticide Age*Primary Acreage			0.024
			(0.016)
Observations	3,683	3,459	3,459
Note:			*p<0.1; **p<0.05; ***p<0.01