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Regulatory Fog: The Informational Origins of Regulatory Persistence

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Abstract

Compared with other types of policy, regulation is very persistent, even when inefficient. We propose an explanation for regulatory persistence based on *regulatory fog*, the phenomenon by which regulation obscures information about the effects of deregulation. We construct a dynamic model of regulation in which the underlying need for regulation varies stochastically, and regulation undermines the regulator's ability to observe the state of the world. Compared to the full-information benchmark, regulation is highly persistent, often lasting indefinitely. The regulatory fog effect is robust to a broad range of partially informative policies and can be quite detrimental to social welfare.

JEL Classification: L51, D82, D83
Keywords: Regulation, Information, Experimentation

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Better the devil you know than the devil you don't. - R. Taverner, 1539

A bureaucratic organization is an organization that cannot correct its behavior by learning from its errors. - Crozier, 1964

1 Introduction

Regulation is a costly solution to market imperfections such as externalities and market power. Administration and enforcement require overhead. Lobbying and avoidance dissipate rents. Centralized control distorts investment and innovation.[1]

Another factor contributing to the cost of regulation is excessive persistence. Once applied, regulation tends to persist, often outliving its usefulness. Preferential trade policies for infant industries often persist well beyond the point in which dynamic learning might be present, and "temporary" assistance for disadvantaged groups often persists long after its intended time limits. Inefficient persistence can also be seen by the large productivity gains which occur after deregulation, as was the case in the deregulation of transportation, power, and communication networks.[2]

We propose an explanation for regulation's exceptional persistence based on its particular information consequences, what we call *regulatory fog*. Since regulation often has the feature of pooling various types or states together into the same (often second-best) result, regulation is much more likely to obscure information about the likely effects of its removal.[3] Our view is that regulatory persistence is a natural byproduct of optimal static regulation; regulation *itself* carries the seeds of its persistence by altering the information observed in the economy.

We construct a dynamic model of regulation in which the underlying need for regulation varies stochastically, and regulation undermines the regulator's ability to observe the state of the world. Even with a publicly interested regulator, regulation is more likely to persist indefinitely in this environment than in the full-information benchmark. For most reasonable parameter values, regulatory fog increases both the duration of an individual regulatory spell and the overall proportion of time spent under regulation. Regulatory fog also increases risk because the counterfactual is difficult to assess, thereby increasing the probability that socially beneficial regulation will be removed.[4] Thus, our baseline model illustrates that

[1] For a broad overview of costs and benefits of regulation, see Guasch and Hahn (1999).

[2] See, for example Moore (1988), Winston, Corsi, Grimm and Evans (1990), Peltzman and Winston (2000), and Joskow (2006).

[3] Note that other types of policy do not necessarily share this characteristic. A tax and transfer policy, for example, might create winners and losers but will have little effect on the information environment.

[4] Such deregulatory disasters are common. Take, for example, the California energy crisis and the more

regulatory fog may lead to important costs of regulation that are not often taken into account in the regulatory debate.

One response to regulatory fog is to consider other sources of information. In many cases, a regulator can implement a range of smaller scale policy experiments that are available or may gain information exogenously from experimentation by others. We examine such experiments, which are less risky than full deregulation but provide a weaker signal about the underlying state. We show that while such alternatives weakly reduce regulatory persistence, their value is non-linear in their effectiveness. This non-linearity reduces the value of weakly informative signals. Thus experimentation is only adopted when the experiment is informative and low cost. Using this framework we characterize the regulator's induced preferences over regulatory experiments, including the optimal trade-off between costliness and effectiveness.

The difficulty in finding direct empirical evidence of regulation sustained by regulatory fog is self-evident. However, the role that external information shocks have played in historical deregulation suggests that a lack of information is a major deterrent to deregulation. The persistence of entry, price, and route regulation under the Civil Aeronautics Board (CAB) provides a useful example of this phenomenon. Enacted in 1938, the CAB managed nearly every aspect of the airline industry, including fare levels, number of flights per route, entry into routes, entry into the industry, and safety procedures.[5] Leaving aside the efficiency of the enactment, the longevity of these regulations is mysterious. These were extremely inefficient regulations, as became apparent on their removal in 1978.[6] How did such inefficient regulation persist, and why did it end when it did?

Critical to airline deregulation was the growth in intra-state flights, especially in Texas and California, because they revealed information about the likely effects of deregulation. These intra-state flights, and the local carriers who worked them, were not subject to regulation under CAB, so they gave consumers a window into what might happen if regulation was dropped more generally. A series of influential studies starting from Levine (1965) and continued and expanded by William Jordan (1970) demonstrated that fares between San Francisco and Los Angeles were less than half the cost of those between Boston and Washington, D.C., despite the trips being comparable distances. Similar results were observed when looking at flights within Texas. There was also no discernable increase in riskiness,

recent Global Financial Crisis.

[5]For an extensive review of the CAB's powers and practices, see "Oversight of Civil Aeronautics Board practices and procedures : hearings before the Subcommittee on Administrative Practice and Procedure of the Committee on the Judiciary", United States Senate, Ninety-fourth Congress, First session (1975).

[6]For a clear overview and analysis of the economic effects of airline deregulation, see Morrison and Winston (1995).

delay, or evidence of so-called "excessive competition."

The dissemination of these large-state market results proved to be a major catalyst for deregulation.[7] The proximate driver of deregulation was a series of hearings held in 1975 by the Subcommittee on Administrative Practice and Procedure of the Senate Committee on the Judiciary (the so-called Kennedy Hearings). An entire day of testimony at these hearings was dedicated to exploring the comparison of intra-state and inter-state flights. William Jordan testified extensively, explaining and defending the results of the deregulatory studies.

The successful deregulation of airlines opened the door for deregulation in other related industries. The architect of the CAB deregulation, Alfred Kahn, cited the importance of the "demonstration effect," provided by airline deregulation, in understanding subsequent deregulation of trucking and railroads (Peltzman, Levine and Noll 1989). Likewise, the US experiment spurred airline deregulation overseas (Barrett 2008).

Consistent with our model of regulatory fog, a glimpse of the unregulated intra-state market provided regulators with new information about the underlying environment, which in turn spurred a successful deregulation of the airlines. The success of airline deregulation provided information which prompted deregulation in related industries.[8]

Finally, as our model would predict, deregulation often generates new information regarding the underlying primitives of an industry, as seen by the numerous academic studies which use the after effects of deregulation to understand the composition of the industry. In addition to the long literature of airlines cited above, significant empirical analysis has occurred after the deregulation of trucking (Rose 1985), railroads (Boyer 1987), and cable television (Rubinovitz 1993), to cite just a few examples.

1.1 Existing Explanations

The dominant theory of policy persistence is political, in which rent seeking by entrenched groups is the primary force. Coate and Morris (1999) develop a model in which actors make investments in order to benefit from a particular policy. Once these investments are made, the entrenched firms have an increased incentive to pressure the politician or regulator into maintaining the status quo. Similar dynamics can be found in Brainard and Verdier (1994), which studies political influence in an industry with declining infant industry protection.

[7]Derthick and Quirk (1985) lay out the politics and timing of the push for deregulation, and cite these academic studies as the primary "ammunition" for those in favor of deregulation, as have others who have investigated the issue. See, for example, Bailey (1980) and Panzar (1980).

[8]Given the Global Financial Crisis, some may argue that the deregulation wave went too far. Notice, however, that catastrophic deregulation failures are characteristic of regulatory fog. The inability to observe the counterfactual inevitably leads regulators to remove some regulation which is socially beneficial.

While they make important contributions to the literature on policy persistence, these models have no role for incomplete information, and so would have a hard time explaining the specific dynamics of regulation and deregulation. For us, one of the key features that distinguishes regulation from other policies is that it forces agents to take certain actions (or proscribes certain actions), and so generates similar signals in different states of nature. Contrast, for instance, the persistence of the CAB regulation to the huge variation in the US tax code over the same period (Piketty and Saez 2007). This effect is the essence of regulatory fog. As the political economy literature studies more generic policy, it ignores this important effect of regulation.

Asymmetric information has been combined with rent seeking models by Fernandez and Rodrik (1991). In their paper, uncertainty concerning the distribution of gains and losses of new legislation leads to lukewarm support by potential beneficiaries. Since uncertainty alters voting preferences in favor of the status quo, efficiency enhancing legislation rarely occurs. In their model it is the aggregation of uncertainty across consumers which leads to persistence. By contrast, we find persistence naturally arising even in situations where a single regulator maximizes social welfare.

A second extant explanation for policy persistence is that investment by firms leads to high or infinite transaction costs for changing policy. Pindyck (2000) calculates the optimal timing of environmental regulation in the presence of uncertain future outcomes and two sorts of irreversible action: sunk costs of environmental regulation and sunk benefits of avoided environmental degradation. Just as in our model, there are information benefits from being in a deregulated environment, and a social-welfare maximizing regulator takes these benefit into account when designing a regulatory regime. Zhao and Kling (2003) extends this model to allow for costly changes in regulatory policy. Transaction costs act to slow changes in regulation, thereby creating a friction-based policy inertia. In our model, policy inertia is generated endogenously by the information that policies produce about the underlying state of the world. We attribute inaction by policy-makers' to their desire to wait for the environment to improve, which reduces the cost of experimentation and drives up the value of information.

In the next section, we lay out the basic model, and solve for the optimal regulatory strategy under both the full-information benchmark and a simple incomplete information environment. In section 3, we compare the results of these two models to illustrate the effects of regulatory fog on persistence. In section 4, we extend the model to allow for small-scale deregulatory experiments, and show that while this extension can improve outcomes, it comes with its own set of problems that full deregulation avoids. Furthermore, the problem of regulatory persistence remains. Section 5 concludes.

2 Model

Consider an economy which is home to a single producer who, in each period, produces a single unit of output which is required by the community. Producers have the option of using one of two possible technologies which are *ex ante* unobservable to the community and the regulator: an efficient technology which delivers profit π_0, and an inefficient technology which delivers a profit of π_i.

There are two possible states of the world, good (G) and bad (B), which completely determine the firm's type. In state G, $\pi_i = \pi_G < \pi_0$, and the firm always produces using the efficient technology. In state B, $\pi_i = \pi_B > \pi_0$ and thus the firm has incentives to produce using the inefficient technology, barring intervention.[9]

Net of the social value of the producer's profits, the citizens suffer an externality cost of -1 when the producer in their community uses the inefficient technology. A welfare-maximizing regulator recognizes this cost and can enforce efficient production by regulating the production facilities, ($R \in \{0, 1\}$), where regulation costs the regulator $-d$ but induces type-B sellers to use the efficient technology.[10] We assume that $1 > d$ and thus the regulator will prefer to pay the inspection cost rather than simply accept the inefficient technology if she knows the producer is type-B. The regulator is risk and loss neutral, has a discount rate of δ, and will regulate if indifferent.[11]

Transitions between the two states follow a Markov process with transition matrices:

$$\mathcal{P} = \begin{pmatrix} \rho_{BB} & \rho_{BG} \\ \rho_{GB} & \rho_{GG} \end{pmatrix}, \tag{1}$$

[9] There are lots of ways to think about this inefficient technology. One possibility is that the production process involves a pollution externality that the producer doesn't internalize. A second possibility is that the firm is a natural monopolist who is making quantity or quality decisions which are constrained by the regulatory environment.

[10] This reduced form could easily arise from a simple auditing regime. The inspector will reveal the production method employed with probability $1 - p$ at cost $c(p)$, and confiscate the producer's profits if they are caught using the inefficient method. The type-B producers will produce using the inefficient technology unless the inspection level is high enough. Specifically, they will use efficient technology as long as:

$$\pi_0 \geq p\pi_B.$$

Let p^* represent the the probability which makes this hold with equality, and $d = c(p^*)$. Note also that $\pi_G < \pi_0$ is assumed for convenience. All we require is $\pi_G < \pi_B$ so that there are two possible regulation regimes which differ in cost and efficacy.

[11] We assume here that the regulator is strictly publicly-interested. Allowing for some degree of interest-group oriented regulation in the spirit of Stigler (1971) or Grossman and Helpman (1994), does not substantively change the underlying persistence we are exploring. While the particulars of the regulator's objective function will affect the relative value of different states and the interpretation of actions, the impact of regulatory fog on regulation and efficiency are quite similar.

where $\Sigma_j \rho_{ij} = 1$ and $\rho_{i,j}$ is the probability of changing from state i to j before the next period. Both the good and the bad states are persistent with $\rho_{BB} \in (.5, 1)$ and $\rho_{GG} \in (.5, 1)$ and where the transition probabilities are known to all parties.

The timing of the model is as follows: at the beginning of every period, the regulator chooses the policy environment R. Next, nature chooses the state according to the transition matrix above.[12] The firm observes the policy environment and the state before choosing their production technology. At the end of the period, the production technology is observed.

As the adoption of inefficient technology perfectly reveals the underlying state, type-B firms never have an incentive to signal jam by mimicking good firms and delaying their inefficiency. The per-period value to the regulator for inspecting and not inspecting in each state is given by:

$$\begin{array}{lcc} & \textit{Good State} & \textit{Bad State} \\ \textit{Regulation} & -d & -d \\ \textit{No Regulation} & 0 & -1 \end{array} \quad . \tag{2}$$

While the regulator would prefer to regulate in the good state and to not regulate in the bad state, the current period's regulation decision alters the information available to the regulator for future decisions. Under regulation the regulator gains no new information about the underlying state, and simply updates according to the transition probabilities and her prior belief. When she deregulates she will learn the state for certain, since if the state is bad firms will use the inefficient technology. This difference in information generated by different policy implementations is the information cost we explore throughout the paper. Less extreme informational differences generate substantively similar results. We consider the case where some information about the state is revealed under regulation in section 4.

2.1 Full Information Benchmark

Before developing the optimal policy for the regulator, it is useful to determine the optimal policy when the chosen policy does not influence future information. Consider briefly a small change to the model above, in which the regulator observes the state every period regardless of the regulatory decision.

[12] Note the difference between this model and the K-arm bandits originally developed by Robbins (1952). A distinguishing feature of bandit problems is that the distribution of returns from one arm only changes when that arm is chosen. This feature implies that the distribution of returns does not depend explicitly on calendar time and there is no new information being generated about other actions. By contrast, a fundamental decision in our model is the potential improvement of alternative actions through waiting. See Bergemann and Valimaki (2006) for a discussion of bandits.

As the regulator knows the previous period's state with certainty, the information environment is greatly simplified. If, in the previous period, the regulator was in the good state, the probability that the state is bad is given by ρ_{GB}. Likewise, if the state was bad the probability that the state remains bad is ρ_{BB}. The regulator is not clairvoyant, as she does not observe the state before she makes her regulatory decision for the period, but she does learn what the state was at the end of the period, even if she chooses to regulate. The following proposition characterizes the policy function of an optimal regulator:

Proposition 1 *Assume that the state is revealed at the end of each period. Then the regulator's optimal strategy falls into one of the following cases:*

1. *If* $\mathrm{d} \leq \rho_{GB}$*, the regulator regulates every period.*

2. *If* $\rho_{GB} < \mathrm{d} \leq \rho_{BB}$*, the regulator regulates after the bad state and does not regulate after the good state. Conditional on enactment, the length of a regulatory spell follows a geometric distribution with expected length* $1/\rho_{BG}$*. The proportion of time spent under regulation is given by the steady state probability of the Markov Process* $(\frac{\rho_{GB}}{\rho_{GB}+\rho_{BG}})$*.*

3. *If* $\mathrm{d} > \rho_{BB}$*, the regulator never regulates.*

Proof. All proofs in the appendix. ■

Proposition 1 identifies the key comparisons that drive the regulator's decision, absent differences in information generated by policy. Recall that d is the cost of regulation which scales between zero and the cost incurred to society in the unregulated bad state, which we normalized to 1. When d is small relative to the probability of transition to the bad state, the regulator will regulate in every period regardless of last period's state. This permanent regulation reflects the rather innocuous costs of regulation relative to the potential catastrophe of being wrong.

Likewise, if the cost of regulation is very high relative to the cost of the inefficient technology, the regulator prefers to take her chances and hope that the underlying state improves in the next period. The regulatory cure is, on average, worse than the disease and leads to a *laissez-faire* policy.

The interesting case for our model is the range of intermediate costs for which the regulator finds it in her interest to adapt her policy to the information generated in the previous period. In the full information case, the regulator applies the policy which is optimal relative to the state observed in the previous period. Except for the periods in which the state actually transitions, the policy adopted by the regulator will be *ex post* efficient. Even in this full-information environment, there is some regulatory persistence. If the regulator regulates this period she is more likely to regulate next period, since the underlying state is persistent.

2.2 Optimal Regulation with Regulatory Fog

Return now to the base model, where the state is revealed only in the absence of regulation. Regardless of the state, regulation will deliver a certain payoff of $-d$, since it will lead both types of producer to use the efficient technology. Deregulating may have a negative single period expected value, but may reveal the state of nature and lead to less wasteful regulation in the future.

A sufficient statistic for the regulator is the probability of being in the bad state. Call that belief ϵ, and define a function $P \to [0, 1]$, such that

$$P(\epsilon) = \epsilon\rho_{BB} + (1 - \epsilon)\rho_{GB}. \tag{3}$$

This function represents the Bayesian updated belief that the state is bad given the prior belief ϵ and no new information. Let $P^k()$ represent k applications of this function. Then for any starting $\epsilon \in [0, 1]$,

$$\lim_{k\to\infty} P^k(\epsilon) \equiv \tilde{\epsilon} = \frac{\rho_{GB}}{\rho_{GB} + \rho_{BG}}.$$

Further note that $P(\epsilon)$ is continuous and increasing in ϵ, $P(\epsilon) \leq \epsilon$ for $\epsilon \geq \tilde{\epsilon}$, and $P(\epsilon) \geq \epsilon$ for $\epsilon \leq \tilde{\epsilon}$.

Let $R(\epsilon) \in \{0, 1\}$ represent the regulator's decision when she believes the state is bad with probability ϵ, where $R = 1$ indicates regulation and $R = 0$ indicates deregulation. Let $V(R|\epsilon)$ be the regulator's value function playing inspection strategy R with beliefs ϵ. Define $V^*(\epsilon)$ as the value function of a regulator who chooses the maximizing inspection regime, and let $R^*(\epsilon)$ be that maximizing strategy.

Given maximization in all subsequent periods for any belief ϵ,

$$V(R = 1|\epsilon) = -d + \delta V^*(P(\epsilon)), \tag{4}$$

$$V(R = 0|\epsilon) = \epsilon[-1 + \delta V^*(P(1))] + (1 - \epsilon)[\delta V^*(P(0))]. \tag{5}$$

For notational simplicity, let $V_B \equiv V^*(P(1))$ and $V_G \equiv V^*(P(0))$. V_B represents the value function after observing a bad state while V_G represents the value function after observing a good state.

$V(R = 1|\epsilon)$, $V(R = 0|\epsilon)$, and $V^*(\epsilon)$ are all continuous and weakly decreasing in ϵ. Also

$R^*(0) = 0$ and $R^*(1) = 1$ since $1 > d$. The Intermediate Value Theorem thus guarantees the existence of a belief that makes the regulator indifferent between regulating and not. In fact, this belief is unique. The following Proposition formalizes this result.

Proposition 2 *There exists a unique cutoff belief $\epsilon^* \in [0, 1]$ such that the optimal policy for the regulator is to regulate when $\epsilon > \epsilon^*$ and to not regulate when $\epsilon < \epsilon^*$.*

While the proof for Proposition 2 is included in the appendix, it is useful to develop its intuition here. Define

$$G(\epsilon) = V(R = 1|\epsilon) - V(R = 0|\epsilon) \tag{6}$$

as the difference in value between regulation and deregulation given beliefs ϵ. Substituting from (4) and (5) in equation (6) yields:

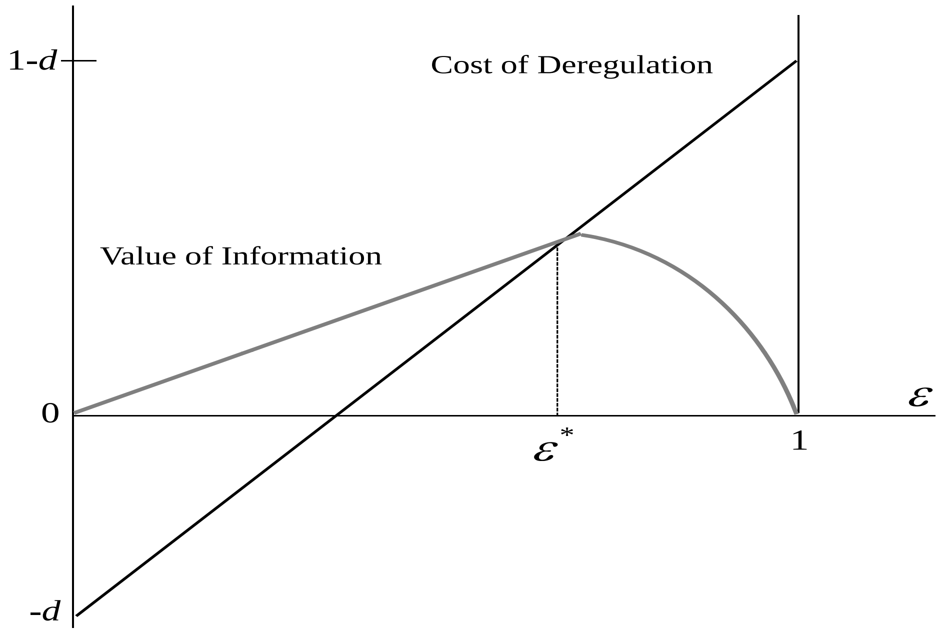
$$G(\epsilon) = \underbrace{\epsilon - d}_{\substack{\text{Expected} \\ \text{Cost of} \\ \text{Search}}} - \underbrace{\delta[\epsilon V_B + (1 - \epsilon)V_G - V^*(P(\epsilon))]}_{\text{Expected Value of Information}}.$$

The first term represents the expected current period cost of deregulating, since the regulator will suffer the bad state with probability ϵ , but saves the cost of enforcement (d). The second term represents the value of information associated with learning the true state: instead of having to work with a best guess of $P(\epsilon)$, the regulator will know with certainty that she is in the good or bad state and can act accordingly.

Figure 1 shows the current period cost of deregulation and the value of information over the domain of ϵ. The expected cost of deregulation is linear; negative when $\epsilon = 0$, and positive at $\epsilon = 1$. By contrast, the value of information is concave and equal to zero at both endpoints. It follows directly that there exists a unique point where $G(\epsilon) = 0$.

In this dynamic setting, the value of information relates strongly to the static models of Hirshleifer and Riley (1979) and Radner and Stiglitz (1984) in that information is most informative when the regulator is least certain about the underlying state. At $\epsilon = 0$ and $\epsilon = 1$ the regulator knows the underlying state and thus learns no new information by deregulating. In these cases, the value of information is zero. In the interior, the value of information is strictly positive. For low ϵ, a regulator who does not deregulate this period will, optimally, deregulate in the next period. Both the potential value of information, and the cost of future search, increases linearly in this region. The only valuable information is that which changes this strategy, i.e., information that reveals you are in the bad state, and that information will arrive with probability ϵ. For $\epsilon > P^{-1}(\epsilon^*)$ the regulator has an

Figure 1: The cost and value of deregulation: Uniqueness of ϵ^*



incentive to maintain regulation for at least one period. The longer the delay in search, the lower the expected cost of search. Thus, the value of information decreases non-linearly in this domain due to the recursive nature of the updating operator $P^k()$.

Proposition 2 provides structure to the solution of the regulator's problem, which we now use to characterize the regulator's equilibrium play. Although strategies are defined for any belief ϵ, only countably many (and often finite) beliefs will arrive in equilibrium. Let ϵ^* be the regulator's optimal cutoff as defined in Proposition 2, and define k^* as the unique $k \in \mathbb{N}^*$ such that $P^{k+1}(1) \leq \epsilon^* \leq P^k(1)$. If there does not exist a k which satisfies this condition, then $k^* = \infty$. This will be the case if and only if $\epsilon^* \leq \tilde{\epsilon}$.

We analyze two cases to characterize the regulator's optimal policy. First, assume that $\epsilon^* \leq \rho_{GB}$. Here, even after observing the good state, the regulator will want to regulate. Since the regulator takes the same action in the good and the bad states, $V_G = V_B = V^*(P(\epsilon))$ and thus the value of information is zero. Thus $G(\epsilon^*) = 0$ when $\epsilon^* = d$, so this case will occur only if $d \leq \rho_{GB}$, just like in the Full-Information benchmark.

Looking at the more interesting case, assume that $\epsilon^* > \rho_{GB}$, so regulation will not be imposed in the period immediately after the good state is observed. In this case equilibrium regulation has the following simple structure. After observing the bad state, the regulator will regulate for k^* periods (perhaps infinite) and deregulate in the $(k^* + 1)$ period to see if the state has changed. If, upon sampling, she observes the bad state, she updates her posterior to $P(1)$ at the start of the next period and begins the regulation phase again. If, on the other hand, she finds herself in the good state, she does not regulate again until she experiences the bad state.

For $\epsilon^* > P(1) = \rho_{BB}$ this strategy means the regulator actually never imposes regulation. As the value of information in this case is zero, the no regulation criterion is the same as the full information model, with no regulation imposed when $d > \rho_{BB}$.

For $\epsilon^* \in (\rho_{GB}, \rho_{BB}]$, a regulator who arrives in the bad state will impose regulation and lift it every $k^* + 1$ periods to see if the state has changed. This region is characterized by potentially long (or infinite) periods of regulation, punctuated by deregulation at fixed intervals. If $\epsilon^* \leq \tilde{\epsilon}$, the regulator's beliefs will converge to the stationary state which is above the cutoff necessary for deregulation. The regulator's future value from deregulating is not high enough to justify the potential risk of being in the bad state.

To differentiate between the permanently persistent regulation case and the regulatory cycles case, it suffices to find the parameter values for which ϵ^* converges to $\tilde{\epsilon}$ from above. In the region of mixed regulation V_G is related to V_B by the potential transition from the good to the bad state. Let κ denote the expected cost of the first bad state discounted one period into the future:

$$\kappa = \sum_{t=0}^{\infty} \delta^t (1 - \rho_{GB})^t \delta \rho_{GB} = \frac{\delta \rho_{GB}}{1 - \delta + \delta \rho_{GB}}. \tag{7}$$

The expected value of the period following the good state is given by

$$V_G = V^*(P(0)) = \rho_{GB}[-1 + \delta V_B] + \rho_{GG} \delta V_G = \kappa[-1/\delta + V_B], \tag{8}$$

where the first term is the cost of being caught in the bad state without inspection and the second term is the future valuation of being in the bad state with certainty.

As ϵ^* converges to $\tilde{\epsilon}$ from above, $k^* \to \infty$ and thus

$$\lim_{k^* \to \infty} V_B = \frac{-d}{1 - \delta}. \tag{9}$$

Finally, recall that ϵ^* is defined as the point where $G(\epsilon^*) = 0$ or equivalently where $V(R = 1|\epsilon^*) = V(R = 0|\epsilon^*)$. Since $\epsilon^* \geq \tilde{\epsilon}$, $P(\epsilon^*) \leq \epsilon^*$ and thus $R^*(P(\epsilon^*)) = 0$. Replacing $V^*(P(\epsilon^*))$ in $G(\epsilon^*)$ yields the following indifference condition:

$$d = (1 - \delta)\big[\epsilon^*(\delta V_G - \delta V_B + 1) - \delta V_G\big] + \delta(\delta V_G - \delta V_B + 1)[\epsilon^* - P(\epsilon^*)]. \tag{10}$$

Since $\epsilon^* - P(\epsilon^*)$ converges to zero as $\epsilon^* \to \tilde{\epsilon}$, regulation is fully persistent if:

$$\frac{d}{1-\delta} \leq [\tilde{\epsilon} + (1-\tilde{\epsilon})\kappa]\left[1 + \delta\frac{d}{1-\delta}\right] \tag{11}$$

The left hand side of this equation represents the cost of permanent regulation. The right hand side represents the expected cost of deregulating in the steady state and then permanently regulating once the bad state occurs. Solving for d and bringing this result together with the foregoing discussion leads to the following proposition, which summarizes the regulator's optimal strategy:

Proposition 3 *There exists a unique pure strategy perfect Bayesian equilibrium for the regulation game with regulatory fog. Good firms always use the efficient technology while bad firms do so if and only if regulated. Let*

$$\tau \equiv \frac{\left[\delta + \frac{1-\delta}{\rho_{GB}+\rho_{BG}}\right]}{1-\delta[\tilde{\varepsilon} - \rho_{GB}]} > 1. \tag{12}$$

Once regulation is applied the first time the regulator's optimal policy falls into one of the following cases:

1. *If $d \leq \rho_{GB}\tau$: the regulator always regulates.*

2. *If $d > \rho_{BB}$: the regulator never regulates.*

3. *If $\rho_{GB}\tau < d \leq \rho_{BB}$: Let ϵ^* be the solution to the implicit function:*

$$\epsilon - d + \delta[\epsilon V_B + (1-\epsilon)V_G - V^*(P(\epsilon))] = 0. \tag{13}$$

The regulator regulates for $k^* > 0$ periods after the bad state is revealed and does not regulate after the good state is revealed, where k^* is the first k such that $P^{k+1}(1) \leq \epsilon^* \leq P^k(1)$.

As with the full information benchmark, our goal is to relate the proportion of time spent under regulation to the cost of regulation d. As the length of regulatory intervals (k^*) is a weakly decreasing function of ϵ^*, it is useful to first determine how ϵ^* changes with respect to d.

Corollary 1 *The threshold ϵ^* is increasing in d.*

The intuition for Corollary 1 can be seen in Figure 1. As d increases, the direct cost of deregulation decreases. This leads the cost curve to shift downward, which shifts ϵ^* to the right. At the same time, an increase in d increases the cost of regulating which is detrimental to society when the true state of nature is good. This additional cost of regulation increases the value of information for all $\epsilon \in (0, 1)$ leading the value of information curve to expand upward. As both of these effects makes $G(\epsilon)$ smaller, the overall effect is an unambiguous increase in the inspection cutoff.

As k^* is a weakly decreasing function of ϵ^* it follows:

Corollary 2 *k^* is weakly decreasing in d.*

Having characterized the regulator's strategy under regulatory fog, the next section compares the equilibrium outcomes to those in the full-information benchmark.

3 Comparison with Full Information

Regulatory fog has two fundamental consequences in our model, and each affects both the time under regulation and overall social welfare. First, the regulator's belief about the underlying state evolves over time from a belief in which regulation is (almost) certainly optimal to a belief in which there is a greater likelihood that regulation is inefficient. For most cases this process naturally leads to regulatory inertia since delay (i) reduces the chance of deregulatory disasters and (ii) increases the value of information from deregulating.

Second, while beliefs are evolving over time, beliefs under regulation always remain above $\tilde{\epsilon}$. This contrasts markedly with the full-information regulator, who will update to the more optimistic ρ_{GB} after observing a good state, even while regulating. A decision maker considering whether to deregulate is faced with the potential of a deregulatory disaster, wherein the removal of regulation in the bad state leads to losses. This potential for disaster can lead to permanent persistence, particularly in environments where the decision maker is relatively myopic.

3.1 Permanently Persistent Regulation

We begin by studying the range of parameters for which regulation persists indefinitely. As with the full-information benchmark, regulation is fully persistent if the normalized cost is low relative to the probability of transition from the good to the bad state. However, as the most optimistic beliefs that arrive in equilibrium are more pessimistic, deregulation carries additional risk, which is represented by τ in Proposition 3. Since $\tau > 1$, regulatory fog strictly increases the set of parameters for which regulation persists permanently.

As τ is a decreasing function of the discount rate δ, myopic regulators are more affected by regulatory fog. Purely myopic regulators ignore the value of information from deregulation and are willing to deregulate only if the probability of being in the bad state falls below the cost of regulation. Institutions that induce short-sighted preferences by regulators, such as having short terms in office, are expected to lead to more regulatory persistence. Consistent with this prediction, Smith (1982) finds that states with legislators having longer terms are more likely to deregulate the licensure of professions. We could find no paper that looks specifically at the term length of regulators and deregulation, but Leaver (2009) shows that electricity regulators with longer terms will review rates more frequently and lower them more frequently.

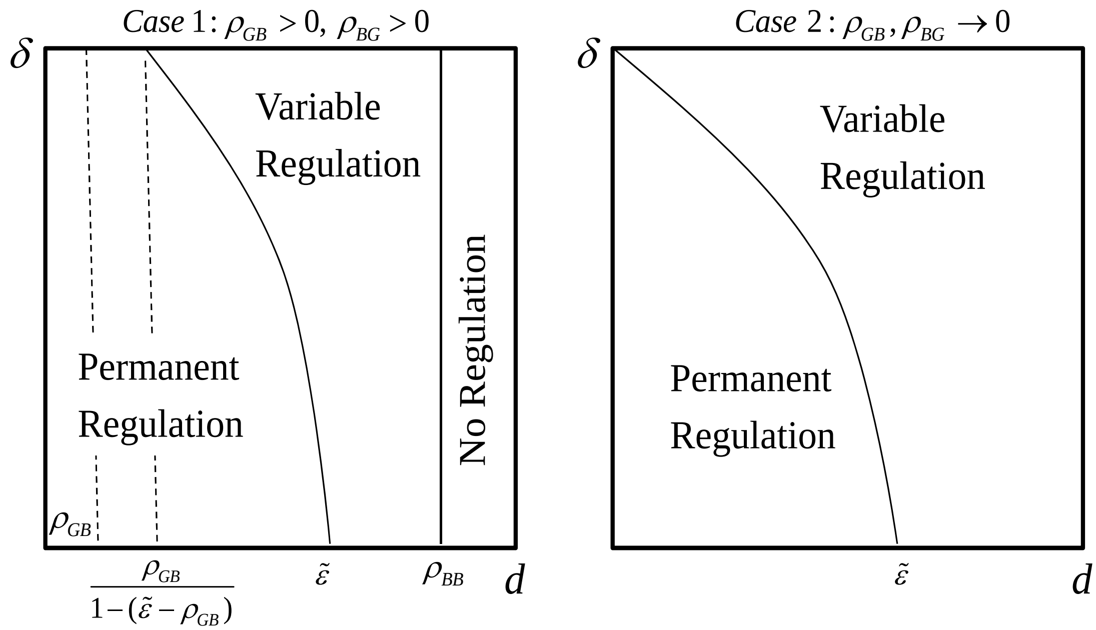
Permanent regulation under regulatory fog exists even as the underlying states become highly persistent. Figure 2 shows the region of permanent regulation both for the case of discretely positive transition probabilities and for the case where ρ_{BG} and ρ_{GB} converge to zero, but where $\tilde{\epsilon} \in (0, 1)$. In the full-information case, regulators always have an incentive to deregulate in the good state as ρ_{BG} and ρ_{GB} converge to zero. In the presence of regulatory fog, however, the most optimistic belief achievable in equilibrium is $\tilde{\epsilon}$, which may be quite pessimistic in the limit. Referring back to Proposition 3, $\tau\rho_{GB} \to 0$ as $\rho_{GB} \to 0$ if and only if $\delta = 1$. Otherwise it is bounded away from zero, and so for low costs, regulation will persist indefinitely, even though one deregulatory episode could lead to the (near) permanent removal of regulation.

3.2 Regulatory Cycles

Most of the interesting dynamics from our model come in cases where the costs of regulation d are moderate. In this parameter region, regulatory policy is characterized by transitions between regulation and deregulation, and these transitions are influenced by the underlying state.

As noted in Proposition 1, the transition from regulation to deregulation in the full information benchmark is based on the arrival time of the first good event and thus there is a direct relationship between persistence and the stochastic nature of the environment. As arrival times follow a geometric distribution, the expected length of a regulatory spell is $\frac{1}{\rho_{BG}}$, and the expected time under regulation is equal to the steady state probability $\tilde{\epsilon}$. Furthermore, for $d \in (\rho_{GB}, \rho_{BB})$, there is no relation between the cost of regulation and its persistence.

Figure 2: Permanent Regulation



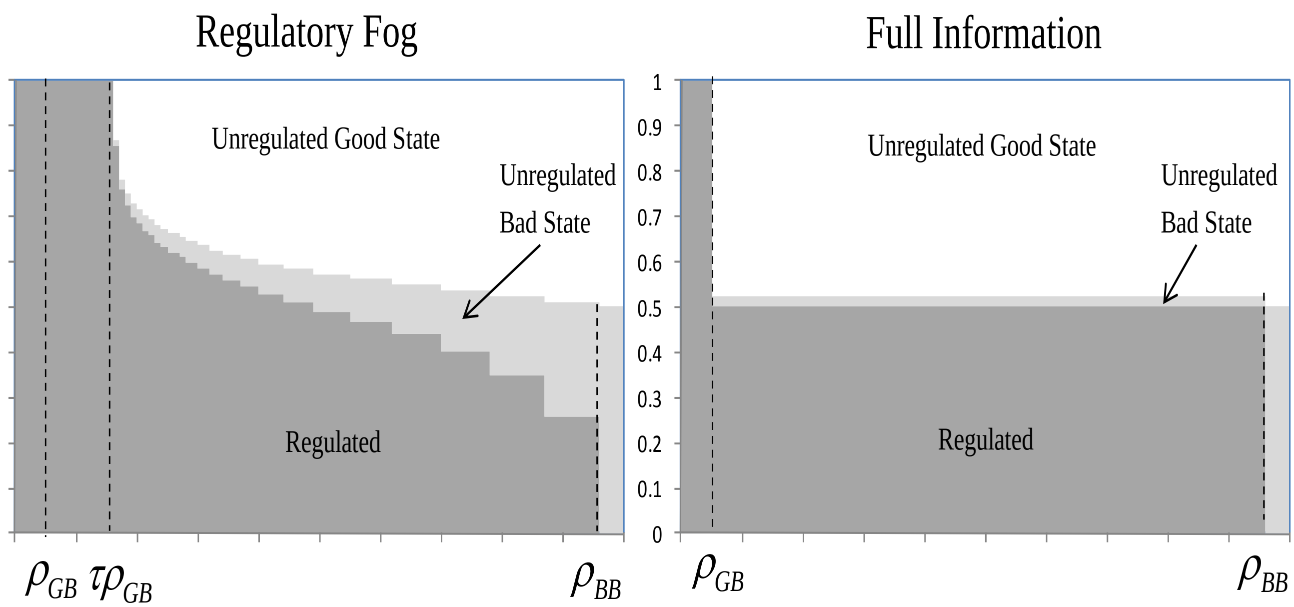
Unlike the full information case, regulation under regulatory fog is characterized by (often long) fixed periods of regulation followed by deregulation. Deregulation lasts until the arrival of the first bad event, at which point the regulatory cycle repeats. When the cost of regulation is just above $\tau\rho_{GB}$, regulation will eventually be removed, but since the threshold belief ϵ^* is quite close to the steady state, the regulatory spell can be quite lengthy (k^* is large). Consequently, a great proportion of the time will be spent under regulation. Likewise, when the cost of regulation is ρ_{BB}, the regulator is just indifferent between regulation and deregulation even after the bad state. In this case, $k^* = 1$ and the regulator cycles rapidly between regulation and deregulation. Thus for large costs, regulation actually ends up being less persistent under regulatory fog than in its absence.[13]

The overall effect of regulatory fog can best be seen by plotting the proportion of time spent in regulation and deregulation as a function of d. As can be seen in Figure 3 regulatory fog leads to more persistence for small and medium d, and less persistence for large d. This differential effect is driven by (i) the potential negative outcome from deregulating in the bad state and (ii) the information learned about the underlying state, which can benefit future

[13]In economic environments, we view the region of parameters for which rapid cycles of deregulation and regulation should occur to be quite rare. It is our view that regulator myopia and moderate to low regulation costs are typically the norm. In other fields such as medicine, however, there is suggestive evidence that both regions exist. Treatment for cancer, for instance, is characterized by cycles in treatment and careful monitoring. On the other hand, treatment for high blood pressure or depression are continuous with little variation in treatment over time.

decisions.

Figure 3: Proportion of Time in Each Regulatory State and Environment as a Function of The Cost of Regulation ($\rho_{GB} = \rho_{BG} = .05, \delta = .9$)



When d is small, the relative cost of deregulating in the bad state is large, leading to delayed deregulation in order to reduce the chance for a deregulatory disaster. As d grows, the value for being in the deregulatory good state grows, while the additional cost to deregulation shrinks. The decline in persistence does *not* mean that regulatory fog is less important in these circumstances. In fact, under regulatory fog and high regulatory costs the regulator simply replaces some of the time spent under regulation in the full-information environment with time spent in the unregulated bad state. As most deregulatory episodes are immediate failures, overall social welfare decreases.

The regulator's equilibrium payoffs in the full-information benchmark and under regulatory fog are presented in Figure 4. When the costs are very high or low, information has no value, since either regulation will always or never be applied. In these cases there is no cost of regulatory fog. Otherwise it imposes an information cost on the regulator which is linear up to $\tau\rho_{GB}$ and concave thereafter. Overall, welfare loss is greatest for intermediate values of d where there is both large amounts of policy persistence and high amounts of failed experimentation.

Referring back to Figure 4, the welfare cost of regulatory fog is maximized when the value functions have the same slope. The first order effect of increasing the cost of regulation is directly proportional to the fraction of time spent under regulation (properly discounted into the future), since regulation is costly only in periods when it is employed. In the full-information baseline this is the only effect of increasing d within the moderate range. Under regulatory fog increasing the cost of regulation may also lead to shorter regulatory spells, but by the envelope theorem this effect is second order. The slope of the two value functions is equal, then, when the expected fraction of time spent under regulation is the same, discounting the future. That result is formalized below:

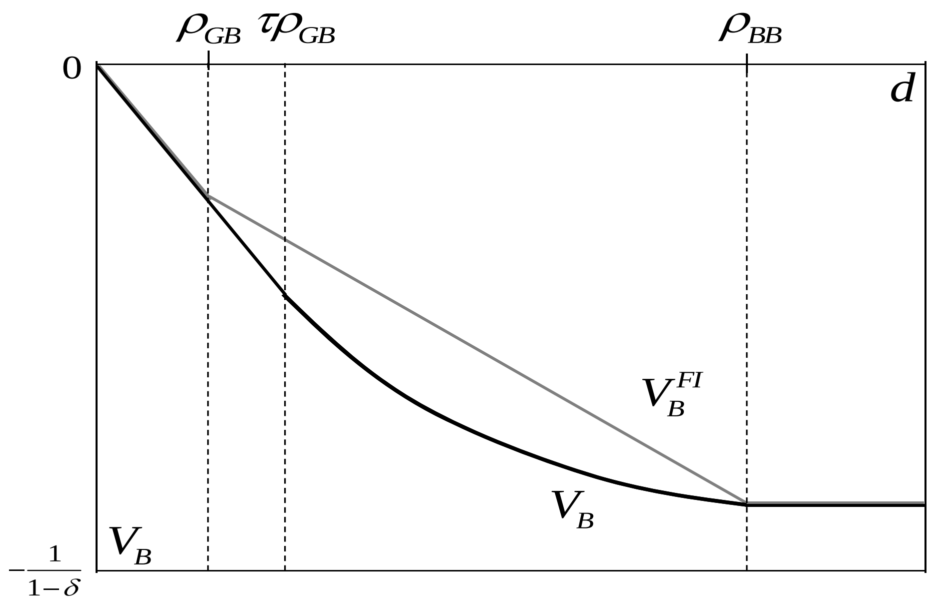
Remark 1 *The cost of regulatory fog is maximized when*

$$\frac{\rho_{BG}}{1-\delta} = \frac{\delta^{k^*-1}}{1-\delta^{k^*}}\Big[1-\delta(\epsilon^* - \rho_{GB})\Big], \tag{14}$$

where k^* and ϵ^* are defined as in Proposition 3. The cost of regulation which satisfies this condition, d^*, is strictly between ρ_{GB} and ρ_{BB}, and decreases in ρ_{GB} and ρ_{BB}.

The primary point to take away from this remark is that when regulation is more persistent under regulatory fog (the case we feel holds more often), the cost of fog is increasing in the cost of regulation. This occurs despite the fact that the relative persistence of fog decreases as d increases.

Figure 4: The Cost of Regulatory Fog ($\rho_{GB} = \rho_{BG} = .05, \delta = .9$)



4 Policy Experiments

Just how bad a problem is regulatory fog? In the preceding sections we have left the regulator with the stark choice between full regulation and full deregulation and shown that, in such a world, regulatory fog leads to persistent regulation and significant welfare losses. We might wonder, however, just how bad the information problem is in an environment with a broader policy space. After all, some information may leak through even in a relatively strict regulatory regime. Furthermore, we may wonder why a regulator cannot make small alterations to regulatory policy to generate new information without suffering the potentially disastrous consequences of full deregulation in the bad state. This section studies the regulator's optimal policy when she has access to experimentation; a broader set of policy options which may be less efficient than full regulation but which are potentially more informative.

The experiments we consider in this section vary from deregulation in two ways. First, experimentation can be conducted while maintaining regulation, but these experiments may have an additional cost which is borne by society. These costs reflect both the direct overhead costs of measurement and the indirect costs of implementing mechanisms which, although more informative, deviate from the optimal mechanism, and are thus less efficient.

Informative mechanisms will often be very different from the static mechanism, and thus the indirect costs of experimentation are unlikely to be trivial. In the case of regulation which reduces moral hazard, for instance, simply reducing inspection leads to a large change in actions, and would be tantamount to deregulation. Thus in this case, a regulatory experiment which maintains regulation broadly must be more complicated than simply cutting back on the degree of monitoring. In a broader context, dynamic mechanisms will typically involve screening mechanisms, which must distribute information rents, or encourage inefficiency, in a subset of the population.

The second difference from full deregulation is the *imprecise* information attained from the small scale experiment about the underlying state. This imprecision comes from two sources. First, there are basic statistical problems associated with sampling a small selection of firms or markets. Even a perfect and unbiased experiment will have some sampling variance. There is also a risk that an improperly designed experiment may lead to spurious results. Second, the very circumscribed nature of the experiment may limit its usefulness. If firms expect the experiment to be temporary, for example, they may react very differently than they would with a deregulation of indefinite length. The partial equilibrium response of agents to a deregulatory experiment may be very different from the general equilibrium response which would result from full deregulation.

To illustrate this idea, consider a regulator who wants to know the probable effects of a general lowering of immigration restrictions and experiments by relaxing the immigration restriction, thus allowing easier immigration to certain regions. Her experiment may give biased results for many reasons. If the demand for entry to the areas chosen was not representative of overall demand, she may under- or over-estimate the demand for entry. More importantly, the demand for entry to the selected regions may be directly affected by the partial nature of the experiment. If it is known to be a temporary loosening, immigrants may quicken their moves as compared to how they would react to indefinite deregulation, in order to arrive within the window. Footloose immigrants with relatively weak preferences across regions may demand entry into newly opened areas at a much higher level than they would if the deregulation was more general. This effect would, of course, lead a naive regulator to overestimate the consequences of deregulation. The true effect would depend on the elasticities of substitution across regions, which may be unknowable.[14]

The tradeoffs inherent in experimentation dictate its relative value in mitigating information inefficiencies. When the cost of experimentation is close to zero, experimentation will nearly always be used. Permanent regulation will arise only for parameters where it is

[14]The immigration example is not merely a thought experiment. In 2004, the EU expanded to include the so-called "A8" countries of Czech Republic, Estonia, Hungary, Latvia,Lithuania, Poland, Slovakia, and Slovenia. Accession nationals were formally granted the same rights of free immigration as nationals of extant members. As the accession approached there was widespread worry in the more-developed EU15 countries that they would experience a huge spike of immigration from new member states, with new immigrants competing for jobs, depressing wages, and disrupting social cohesion. In response, the Treaty of Accession allowed EU15 members to impose "temporary" restrictions on worker immigration from the A8 countries for up to seven years after the accession. In the years immediately after accession only the UK, Ireland, and Sweden allowed open access to their labor markets, while the remaining A15 members maintained relatively strict work permit systems. A similar pattern held when Bulgaria and Romania (the "A2" group) were admitted to the union in 2006.

Prior to the opening an estimated 50,000 A8 and A2 nationals were residing in the UK, out of about 850,000 in the EU15 at large (Brücker, Alvarez-Plata and Siliverstovs 2003). Predictions of expected flows to the UK from the A8 ranged from 5,000 to 17,000 annually (Dustmann, Fabbri and Preston 2005). In reality, the immigrant flows were much larger than that. Even by the strictest definition — those who self-identify upon arrival that they intend to stay for more than a year — A8 immigration was 52,000 in 2004, 76,000 in 2005, and 92,000 in 2006 (Office for National Statistics 2006). Using estimates based on the Eurostat Labour Force Survey, Gligorov (2009) finds that net flow of A8 worker immigrants between 2004 and 2007 was just under 500,000.

One of the most cited explanations for the underestimate of immigration flows to the UK was not sufficiently accounting for the effects of the maintenance of immigration restrictions by the remaining 80-percent of the EU15 (Gilpin, Henty, Lemos, Portes and Bullen 2006). The traditional destinations for migrant workers from Eastern Europe, Germany and Austria, were closed off by the temporary continuance of immigration restriction. Instead of waiting for these countries to open up, the migrants instead came to the UK (and Ireland and Sweden, to a lesser degree). Not only is it hard for other Western European countries to learn much from the UK's experiment, since they are not identically economically situated, but it's even hard for the UK to learn much about what completely free immigration across the EU would mean for itself. The observed patterns are likely an overestimate of the effect the UK should expect from open borders, but the degree of overestimation will depend on how many of the migrants were crowded in by restriction elsewhere and how many legitimately preferred coming to the UK.

predicted in the Full-Information baseline. As the cost of experimentation rises, however, or as its informativeness declines, policy makers may eschew experimentation, opt for deregulation instead, or neither. In these cases the broader policy environment provides no relief from regulatory fog.

4.1 Optimal Policy with Regulation and Policy Experiments

Consider an augmentation of the base model presented in section 2 that expands the set of actions available to the regulator in each period. In addition to regulating or deregulating, the regulator may instead opt for a third option of performing a deregulatory experiment. When performing the experiment, the regulator continues to perform the primary regulatory function at cost d, and pays an additional cost of $c \geq 0$ to fund and monitor the experiment. The case of basic regulation with some costless information revelation is simply $c = 0$.

We consider the simplest signal structure from experimentation which captures the notion of imprecise information. An experiment can either be a success or a failure which depends on the underlying state and on chance. If the state is bad, the regulatory experiment will always be a failure. If the state is good, the regulatory experiment will succeed with probability α, and will fail with probability $(1 - \alpha)$.

A regulator observing a failed experiment can not determine whether this failure was due to a randomly failed experiment or a bad state of the world. Denote the updated beliefs from a failed experiment as $\hat{\epsilon}$. Then:

$$\hat{\epsilon} = \frac{\epsilon}{\epsilon + (1 - \epsilon)(1 - \alpha)}. \tag{15}$$

A regulator observing a successful experiment will know she's in the good state for certain.

Let $E(\epsilon) \in \{0, 1\}$ represent the regulator's experimentation strategy when she believes the state is bad with probability ϵ, where $E = 1$ indicates experimentation and $E = 0$ indicates no experimentation. Let $V(R, E|\epsilon)$ be the regulator's value function playing regulation strategy R and experimentation strategy E with beliefs ϵ. Define $V^{**}(\epsilon)$ as the value function of a regulator who chooses the maximizing regulation and experimentation regime, and let $\{R^{**}(\epsilon), E^{**}(\epsilon)\}$ be that maximizing strategy. Since experimentation yields strictly less information than regulation and has an additive cost, deregulating and experimenting in the same period is never optimal.

Given maximization in all subsequent periods for any belief ϵ, the value for regulation, deregulation, and experimentation are respectively:

$$
\begin{aligned}
V(R=1,E=0|\epsilon) &= -d+\delta V^{**}(P(\epsilon)), \\
V(R=0,E=0|\epsilon) &= \epsilon[-1+\delta V^{**}(P(1))]+(1-\epsilon)[\delta V^{**}(P(0))], \\
V(R=1,E=1|\epsilon) &= -d-c+[\epsilon+(1-\alpha)(1-\epsilon)][\delta V^{**}(P(\hat{\epsilon}))]+(1-\epsilon)\alpha[\delta V^{**}(P(0))].
\end{aligned}
$$

As before, $V(R=1,E=0|\epsilon)$, $V(R=0,E=0|\epsilon)$, $V(R=1,E=1|\epsilon)$, and $V^{**}(\epsilon)$ are all continuous and weakly decreasing in ϵ. Further, since $1>d>0$, and $d+c\geq d$, deregulation is optimal at $\epsilon=0$ and regulation is optimal at $\epsilon=1$.

Our solution strategy is similar to the base case in that we look for a cutoff belief ϵ^{**} such that the regulator prefers experimentation to regulation when $\epsilon<\epsilon^{**}$. If this belief exists and is (1) greater than the cutoff point ϵ^* for which deregulation is better than regulation and (2) small enough that $P(\hat{\epsilon}^{**})>\epsilon^{**}$, optimal policy calls for experimentation each time the regulator's belief falls below ϵ^{**} and deregulation if this experimentation is a success. As $\hat{\epsilon}<1$, a regulator who is unsuccessful in experimentation will wait for a shorter amount of time before experimenting again. Thus optimal policy will typically be characterized by a long initial regulation period followed by cycles of experimentation and shorter regulatory spells.

On the other hand, if $\epsilon^{**}<\epsilon^*$, the regulator's optimal policy involves only deregulation. In this case experimentation will never be used, and optimal policy is identical to that found in section 2.

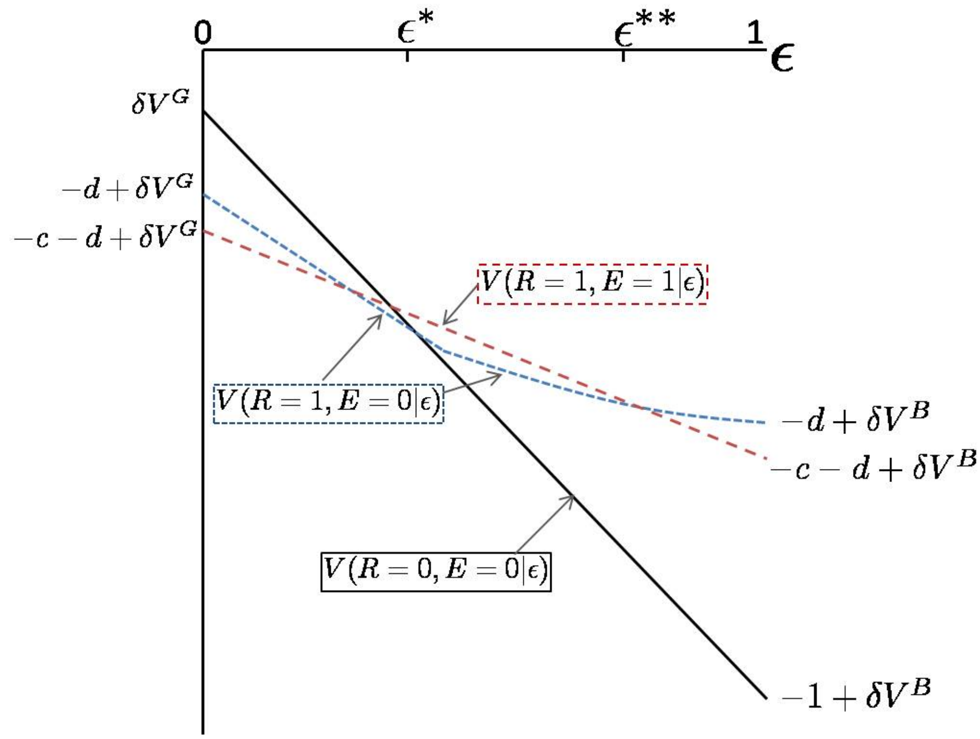
Finally, there is also a hybrid case which can occur if $P(\hat{\epsilon}^{**})<\epsilon^{**}$ and $\epsilon^*\leq\epsilon^{**}$. In this case a regulator may find it in her interest to continuously experiment at ϵ^{**} and below, but eventually deregulate if her beliefs fall below a secondary threshold. This case only occurs if α is extremely low or d is very high. We view this case as most relevant when thinking about situations in which regulators may be privy to external information in each period and return to the special case in section 4.2.

Figure 5 represents the value functions for each policy, as a function of the probability of being in the bad state. In the first panel, experimentation is relatively effective ($\alpha\approx 1$) and inexpensive (small c) and so the equilibrium strategy of the regulator will follow the experimental cycles outlined above. In the second panel experiments are less effective ($\alpha<<1$), so they are never utilized in equilibrium.

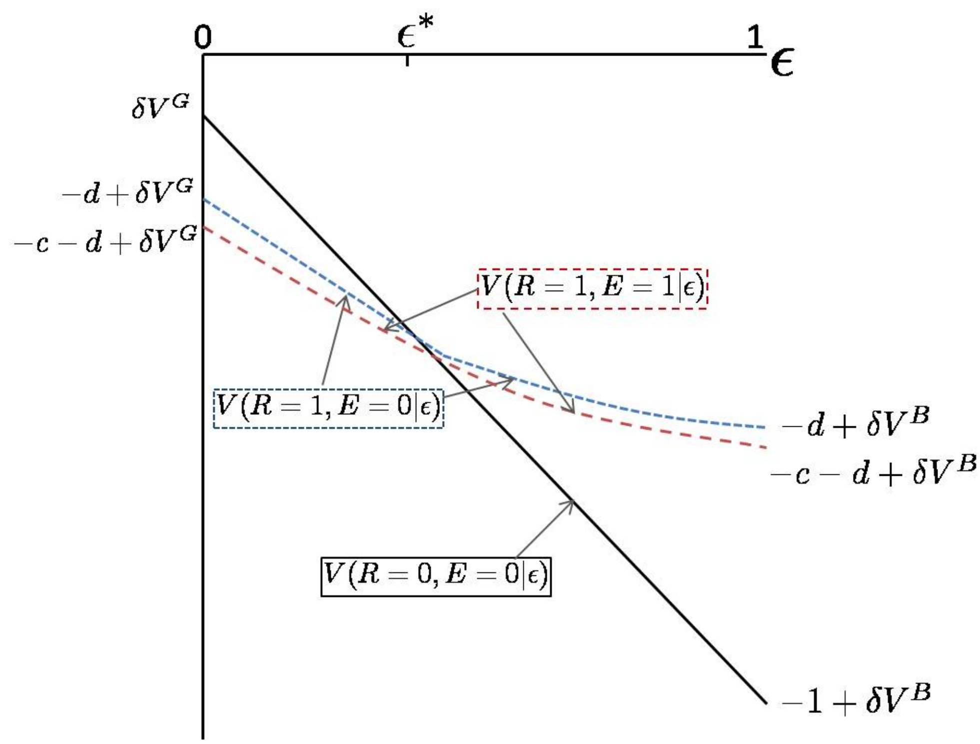
Note the shape of the three value functions. The values at each extreme belief (ϵ equal to 0 or 1) are easy to pin down as there is no uncertainty about the state, and thus no information consequences for various policies. For intermediate values:

Figure 5: Value Functions of Deregulation, Regulation, and Experimentation

(a) $\alpha \approx 1$: Experimentation in Equilibrium



(b) $\alpha << 1$: No Experimentation in Equilibrium



1. *Deregulation:* The value of deregulating is linear in ϵ, since it is a weighted average of the value of deregulating in the good and bad states.

2. *Regulation:* The value of regulating is linear for low ϵ, since it amounts to waiting one period and then deregulating, but becomes convex and flatter for higher ϵ, as the optimal continuation includes waiting for more and more periods.

3. *Experimentation:* The value of experimentation is weakly convex with a curvature dictated by α. If it were not for the cost of running the experiment, the value of experimentation would always be above that of regulation, as the regulator also receives an informational benefit. Furthermore, if experiments are perfectly effective ($\alpha = 1$), the value of experimentation is also linear, since it is also a weighted average of the value of being in the good and bad states, but without the one-time consequences of being in a deregulatory bad state. As experiments become less and less effective, the value function for experimentation become more convex. Once $\alpha = 0$ it is simply a downward shift of the regulation value function.

Just as in the base model, the added cost of experimentation results in a larger set of parameters for which regulation is permanent, relative to the full-information baseline. If $\epsilon^{**} < \tilde{\epsilon}$, the regulator's future value from experimentation is never high enough to justify the additional costs of being in the bad state. Letting ϵ^{**} converge to $\tilde{\epsilon}$ from above and assuming $\epsilon^* < \epsilon^{**}$, regulation is permanent if $d \leq \rho_{GB}\tau'$, where

$$\tau' \equiv 1 + \left(\frac{c}{\alpha}\right)\left(\frac{1}{\kappa(1-\tilde{\epsilon})}\right) > 1. \tag{16}$$

As is evident in the last term on the right hand side, permanent regulation is mitigated if the cost of experimentation — which has precision bounded at $\alpha(1-\tilde{\epsilon})$ — is low relative to the value of information, which is bounded at $\frac{\rho_{GB}}{\kappa}$. As $\tilde{\epsilon}$ is the lowest belief which can be observed, the value of information is maximal at this point. Thus if experimentation does not have a positive net present value at the steady state, it never will. The following proposition summarizes these relationships.

Proposition 4 *Assume the regulator has access to deregulatory experiments, at cost* c*, which will succeed with probability* α *in the good state and probability* 0 *in the bad state. Then, there exists a unique pure strategy perfect Bayesian equilibrium for the regulation/experimentation game considered above. Good firms never pollute while bad firms pollute if and only if unregulated. Let* τ *be defined as in Proposition 3 and let* τ' *be defined as above.*

Once regulation is applied for the first time, the regulator's optimal policy falls into one of the following cases:

1. *If* $d \leq \rho_{GB} * min\{\tau, \tau'\}$*, the regulator regulates every period and never experiments.*

2. *If* $d > \rho_{BB}$*, the regulator never regulates or experiments, even after a bad state.*

3. *If* $\rho_{GB} * min\{\tau, \tau'\} < d \leq \rho_{BB}$*, the regulator regulates for* k^{**} *periods and then either deregulates or experiments. If the optimal choice is to deregulate, then* $k^{**} = k^*$ *from Proposition 3. If the optimal choice is to experiment, then* k^{**} *is the first* k *such that* $P^{k+1} \leq \epsilon^{**} \leq P^k(1)$ *and* ϵ^{**} *is the solution to the implicit function:*

$$(17) \quad c + \delta V^{**}(P(\epsilon)) - [\epsilon + (1-\alpha)(1-\epsilon)][\delta V^{**}(P(\hat{\epsilon}))] - (1-\epsilon)\alpha[\delta V^{**}(P(0))] = 0$$

Figure 6 shows the impact of experimentation for different regulation costs, d, and experimentation costs c.

For low regulation costs (below $\tau\rho_{GB}$), deregulation is never used on its own, but only after a successful experiment, and the optimal policy decision is between permanent regulation and experimentation. When experimentation is costless, it will be used as long as deregulation is ever attractive ($d > \rho_{GB}$). As regulation becomes more expensive, the value of information increases leading to a greater value for experimentation and a concomitant increase in the acceptable costs.

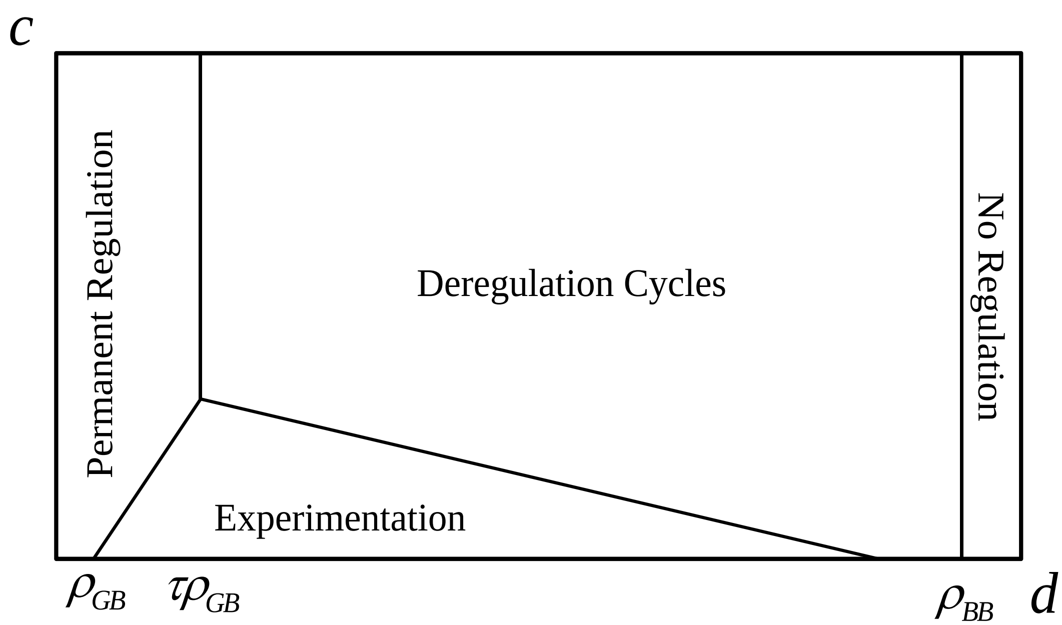
For moderate to high regulation costs ($d > \rho_{GB}\tau$), a regulator always deregulates eventually, and thus her decision is between implementing a strict policy of regulation and deregulation cycles or a policy which also includes experimentation. As d increases, the relative cost to deregulating declines and thus deregulation becomes strictly more attractive. As d approaches ρ_{BB}, the rush to deregulate leads to the abandonment of experimentation. The intuition here is that if the regulator plans to deregulate next period, even after a failed experiment, there is no reason to pay for an experiment.[15]

4.2 The Value of Experimentation

Obviously, the ability to experiment has no value to the regulator when it is never used in equilibrium, and has some positive value when used. When used, its value will depend in intuitive ways on the cost of running the experiment and the precision of information that it

[15] For very pessimistic beliefs, the update after a failed experiment is actually more optimistic than the prior belief, since the natural progression of the Markov process is quite large for beliefs far from the steady state. For example, it's easy to check that $P(\hat{\rho}_{BB}) < \rho_{BB}$ for any α.

Figure 6: Experiments vs. Deregulation ($\rho_{GB} = \rho_{BG} = .05, \delta = .9, \alpha = .5$)



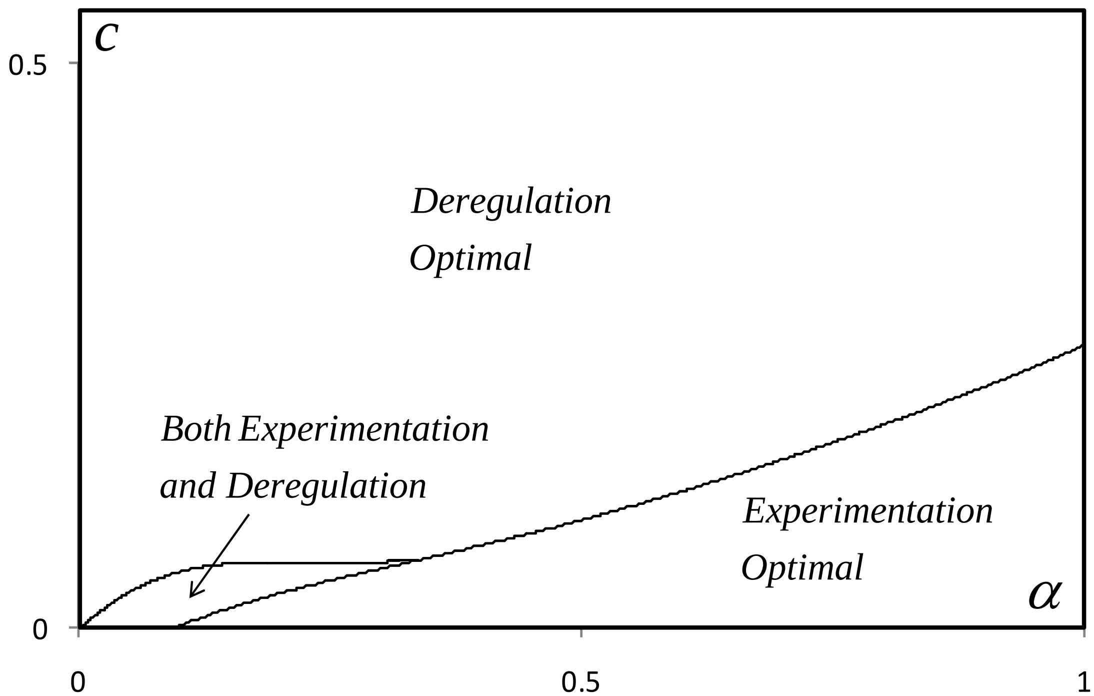
uncovers. While the cost of experimentation acts linearly on the value of experimentation, the precision of information does not. As $\frac{1}{\alpha}$ is multiplicative, experiments with low precision have very limited value to the policy maker. In these cases, the regulator finds it in her interest to never use experimentation, or to use it only in conjunction with periodic deregulation.

Figure 7 shows the range of parameters for which experimentation and simple deregulation are preferred in $\{\alpha, c\}$ space. As the value of deregulation is a constant in this space, there exists an iso-efficiency "indifference" curve along which the value of the optimal strategy using experimentation is exactly equal to the optimal strategy without it. As the value of experimentation is increasing in α and decreasing in c, policies which are to the southeast of this curve are preferred to policies consisting only of deregulation. One way to interpret this curve, $c(\alpha)$, is as the regulator's "willingness to pay" for an experiment of a certain precision. It follows that any experiment falling below the line would net him a surplus at least proportional to the distance below the line.[16] This surplus is the (net) value of experimentation.

When α is small, recall that there may be cases in which $P(\hat{\epsilon}^{**}) < \epsilon^{**}$ and thus the regulator's beliefs are improving even after a failed experiment. In these cases, optimal regulation may call for both experimentation and eventual deregulation. As can be seen in Figure 7, the region for which this occurs is for α and c very small. We view this case

[16]It would be exactly proportional if the experimenting strategy was unchanged by the reduced cost, but the optimizing regulator may also decide to start experimenting more often, further improving his payoff.

Figure 7: Experiments vs. Deregulation ($\rho_{GB} = \rho_{BG} = .05, \delta = .9, d = .5$)



as describing situations in which the regulator may learn about the state of nature despite the imposition of regulation, but it occurs with a very low probability. As $P(\hat{\epsilon})$ is always greater than $P(\epsilon)$, the time between deregulation experiments is increasing in the likelihood of external information. Thus, the possibility for external signals can actually increase the persistence of regulation even though it unambiguously improves welfare.

The observation that the optimal experimentation frontier can be expressed as an iso-efficiency "indifference" curve provides a method by which alternative policies can be evaluated. Consider a collection of N experiments, indexed by $i = 1, 2, ..., N$, which are available for the regulator to choose among. Each experiment consists of a (c_i, α_i) combination, and we will assume that the regulator must choose one to use and stick with that choice whenever he decides to experiment. Then this framework provides a way of analyzing the regulator's optimal choice among these experiments. The frontier in Figure 7 is merely one (particularly salient) indifference curve for experiments. For any experiment (c_i, α_i) below that frontier we could identify a similar increasing curve $c_i(\alpha)$ which includes that experiment ($c_i(\alpha_i) = c_i$) and for which the regulator is indifferent among all the experiments on the curve. Optimal choice for the regulator, then, simply amounts to choosing the experiment on the lowest indifference curve. Since $(0, 0)$ is always in the set of experimental options, if all other options are above the curve in Figure 7, the optimal choice is simply to never experiment. If the feasible set of experiments are convex, the familiar tangency condition for indifference curves and the budget frontier will characterize the optimal choice. Of course, all the natural statics would follow from this characterization: more precise experiments should be preferred if the marginal cost of precision falls (budget curve gets less convex) and more precise experiments should be chosen as the marginal value of precision increases.[17]

As the cost of deregulation is a function of d, the location of the frontier between deregulation and experimentation is also a function of the cost of regulation. As we saw from Proposition 4, experiments are never used for $d < \rho_{GB}$ or $d > \rho_{BB}$, so the regulator would never be willing to pay for information in those cases (i.e., $c(\alpha)$ is flat at zero). Furthermore, as was outlined in Remark 1, the costs of regulatory fog are most severe for intermediate costs of regulation due to the high frequency of failed policy experiments and the burden of regulation. It is precisely in these states that the willingness to pay for information is highest, and thus $c(\alpha)$ is highest for intermediate d. As $c(0) = 0$ for all d, the iso-efficiency curves for experimentation will become steeper as d approaches the value which maximizes the cost of regulatory fog. It follows that the value of an additional unit of precision is always highest when d is closest to the point which maximizes the losses due to regulatory fog in the baseline case.

5 Conclusions

Models of regulatory persistence are typically based on the role that agency and lobbying play in influencing final policy. We argue that in many environments, regulation generates the seeds of its own persistence by altering the information observable about the environment — a phenomenon we refer to as regulatory fog. Under a stark policy environment of regulation and deregulation and in a broader environment where experimentation is also allowed, we find that the effects of regulatory fog can be quite severe. Regulatory fog can lead to permanent

[17] While we have concentrated our analysis on the case of temporary experiments, it should be noted that a similar exercise could be done in order to compare various sorts of regulation, which differ with respect to how much information they let through. Imagine, for example, two methods of regulating. The first is exactly like the regulation described above. It costs d_1 to implement but shuts down all information. The other costs $d_2 > d_1$ to implement but reveals the good state as good with some probability, $\alpha > 0$. The difference between this way of posing the problem and the way we describe experiments is that the choice over regulatory regimes would be made ex-ante, and the higher price of the informative regulation would need to be paid every period that regulation is imposed, instead of a temporary premium for a temporary experiment. The most natural way of modeling the choice would depend on the technology at hand. If switching among regulatory regimes is very costly, this second model may be more appropriate. Nevertheless, the results are quite similar using this alternative approach. We would again end up with indifference curves in the (d, α) space with roughly the same shape as those appearing in Figure 7, and the tradeoffs that guide optimal choice amongst regulatory regimes would be quite similar to those discussed here.

regulation for a broad range of parameters, particularly by myopic regulators. For most reasonable parameter values, fog delays deregulation and causes the economy to stay in the regulated state more often than the underlying environment warrants alone. Finally, fog can lead to deregulatory disasters which can greatly diminish overall social welfare.

Although we have chosen to explore regulatory fog in an environment with a perfectly public-interested regulator, the information and political economy channels are quite complementary. In an interest group model such as Coate and Morris (1999), information asymmetries between regulated firms and consumers are likely to generate significant pressure from regulated firms who are enjoying the protections of a regulated monopoly, but limited pull by consumers who are uncertain as to the final outcome of deregulation. Likewise, in an environment with politically charged regulation, partisan policy makers may be likely to develop policies which deliberately eliminate information in order to limit the ability of competing parties to overrule legislation in the future.

While we have framed the policy decision from the perspective of a centralized planner, decentralization is of limited use when separated districts are symmetric and competitive. As pointed out by Rose-Ackerman (1980) and generalized by Strumpf (2002), the potential policy experiments in other districts provides incentives for policy makers to delay their own deregulatory policies and can, in many cases, actually lead to more regulatory persistence.[18] Further, just like in the experimentation example, spill-overs from one district to another are likely to reduce the informativeness of experimentation and may ultimately make unilateral policy decisions fail.

Finally, although this analysis has focused on regulation, we believe regulatory fog is a general phenomenon which affects a wide variety of economic environments. Many economic institutions such as monitoring, certification, intermediation, and organizational structures are designed to alter the actions of heterogeneous agents which, in the process, affects the dynamic information generated. These dynamic effects are likely to influence both the long-term institutions which persist and the overall structure of markets and organizations.

6 Appendix

6.1 Proofs from Main Text

<u>Proposition 1:</u>

[18] This theme is echoed in the social learning literature where social learning leads to strategic delay in experimentation. See, for example, Gale (1996); Moscarini, Ottaviani and Smith (1998); Veldkamp (2005); and Peck and Yang (2010).

Proof. The information consequences and the continuation values of regulation and deregulation are identical, so everything turns on the current period's payoff. The payoff of regulation is always $-d$, while the expected payoff of deregulation is $-\epsilon$. This means the optimal policy is to regulate if $\epsilon > d$ and otherwise deregulate. After observing the good state, the regulator's beliefs are ρ_{GB} and after observing the bad state, they are ρ_{BB}. So the optimal strategy falls into the regions outlined in the proposition.

In the region of moderate costs, the probability of continuing regulation is exactly the probability of staying in the bad state, ρ_{BB}. So the probability of having a spell of length t is given by $\rho_{BB}^{t-1}(1-\rho_{BB})$. This is exactly the pdf of a random variable with a geometric distribution with parameter ρ_{BB}, which has a mean length of $1/(1-\rho_{BB})$. Finally, since the fraction of time spent under regulation has to be self-duplicating, it must be the steady state of the Markov Process. ■

<u>PROPOSITION 2:</u>

Proof. If the regulator is following the outlined strategy, the producer's proposed strategy is optimal since polluting in the unregulated state perfectly informs the regulator about the state of nature. Assume that the regulator is playing some optimal strategy $R^*(\epsilon)$ which induces a value function $V^*(\epsilon)$. For any ϵ define

$$G(\epsilon) = V(R = 1|\epsilon) - V(R = 0|\epsilon). \tag{18}$$

$V(R|\epsilon)$ is continuous and thus G is continuous. Since $G(0) < 0$, $G(1) > 1$, and G is continuous, there is some ϵ^* for which $G(\epsilon^*) = 0$. For the Proposition it would suffice to show that this ϵ^* is unique. In fact, we'll show that $G()$ is increasing, a stronger claim. Replacing for (4) and (5) in equation (18),

$$G(\epsilon) = -d + \delta V^*(P(\epsilon)) - \epsilon[-1 + \delta V_B] - (1-\epsilon)\delta V_G.$$

Replacing in turn for $V^*(P(\epsilon))$, this becomes

$$\max \left\{ \begin{array}{c} -d + \delta[(-d + \delta V^*(P^2(\epsilon))] - \epsilon[-1 + \delta V_B] - (1-\epsilon)\delta V_G, \\ -d + \delta[P(\epsilon)[-1 + \delta V_B] + (1 - P(\epsilon))\delta V_G] - \epsilon[-1 + \delta V_B] - (1-\epsilon)\delta V_G \end{array} \right\}, \tag{19}$$

where the first constituent of the maximand is the difference in returns when choosing to audit next period after auditing this period versus not auditing this period, and the second constituent is the return to not auditing next period after auditing this period versus not auditing this period. More generally, define $G^k(\epsilon)$ as the difference between the return for auditing for k periods and then following optimal strategies from then on and simply not auditing this period. I.e.,

$$G^k(\epsilon) = -d\sum_{j=0}^{k}\delta^{j-1} + \delta^k\{P^k(\epsilon)[-1+\delta V_B] + (1-P^k(\epsilon))\delta V_G\} - \epsilon[-1+\delta V_B] - (1-\epsilon)\delta V_G$$

Then for all k, $G^k(\epsilon)$ is differentiable and increasing. Furthermore

$$\lim_{k\to\infty} G^k(\epsilon) = -\frac{d}{1-\delta} - \epsilon[-1+\delta V_B] - (1-\epsilon)\delta V_G,$$

which is also increasing in ϵ. Finally, note that $G(\epsilon) = \max_k G^k(\epsilon)$, and since it is continuous it must also be increasing. Therefore, there is a unique ϵ^* where $G(\epsilon) \gtreqless 0$ if and only if $\epsilon \gtreqless \epsilon^*$, and that ϵ^* will, therefore, satisfy the requirements of the Proposition. ■

<u>Corollary 1:</u> **Proof.** We'll prove this using the implicit function theorem on $G(\epsilon)$. From the proof of Proposition 2, $G'(\epsilon) > 0$, and so it follows directly from the implicit function theorem that

$$sgn(\frac{\partial \epsilon^*}{\partial d}) = sgn(-\frac{\partial G(\epsilon, d)}{\partial d})$$

From the text $V_G = \kappa[-\frac{1}{\delta} + V_B]$, and so $\frac{\partial V_G}{\partial d} = \kappa\frac{\partial V_B}{\partial d}$.

The easier case occurs if $\epsilon^* \leq \tilde{\epsilon}$, then $P(\epsilon^*) \geq \epsilon^*$, and so $V(P(\epsilon^*)) = V_B = \frac{-d}{1-\delta}$. In this case,

$$G(\epsilon, d) = -d - \delta(\frac{d}{1-\delta}) - \epsilon(-1-\delta\frac{d}{1-\delta}) - (1-\epsilon)\delta[\frac{-\kappa}{\delta} - \kappa(\frac{d}{1-\delta})].$$

and so

$$\frac{\partial G(\epsilon, d)}{\partial d}) = -1 + \frac{\delta}{1-\delta}[-1+\epsilon+(1-\epsilon)\kappa] < 0.$$

If $\epsilon^* > \tilde{\epsilon}$, then $P(\epsilon^*) < \epsilon^*$, and so $V(P(\epsilon^*)) = P(\epsilon^*)(-1+\delta V_B) + (1-P(\epsilon^*))\delta V_G$. Replacing and simplifying,

$$\frac{\partial G(\epsilon^*, d)}{\partial d}) = -1 + \delta\frac{\partial V_B}{\partial d}\Big[\delta[P(\epsilon) + (1-P(\epsilon^*))\kappa] - [\epsilon^* + (1-\epsilon^*)\kappa]\Big].$$

Since regulation cannot be used more than once per-period, $\frac{\partial V_B}{\partial d} > -\frac{1}{1-\delta}$. Furthermore, since $P(\epsilon^*) < \epsilon^*$, $P(\epsilon^*) + (1-P(\epsilon^*)\kappa < \epsilon^* + (1-\epsilon^*)\kappa$, and so

$$\frac{\partial G(\epsilon^*, d)}{\partial d}) < -1 + \delta(\frac{-1}{1-\delta})(\epsilon^* + (1-\epsilon^*)\kappa)(\delta - 1) = -1 + \delta(\epsilon^* + (1-\epsilon^*)\kappa) < 0.$$

■

<u>Corollary 2:</u> **Proof.** Obvious from Corollary 1, since the $P()$ function is unaffected by

d, and ϵ^* increases. ■

Proposition 3: **Proof.** When $d > \rho_{BB}$ regulation is never static optimal, even after the most pessimistic beliefs that could arrive in equilibrium, so it will never be used. The argument for the $\tau\rho_{GB}$ cutoff for permanent regulation is given in the text. We know beliefs fall over time from $\epsilon = 1$ to $\tilde{\epsilon}$ via the Markov process, so the characterization in Lemma 1 gives the result for the intermediary case. ■

Proposition 4: **Proof.** All the results are straightforward except the derivation of the new cut-off τ'. Clearly, if experimentation is not used in equilibrium, the regulator's optimal strategy will look identical to that in Proposition 3, so we will limit our attention to the cases where experimentation is used prior to deregulation. At the cutoff ϵ^{**}, the regulator is indifferent between experimentation and regulation, so

$$\delta V^{**}(P(\epsilon^{**})) = -c + [\epsilon^{**} + (1-\alpha)(1-\epsilon^{**})][\delta V^{**}(P(\hat{\epsilon^{**}}))] + (1-\epsilon^{**})\alpha[\delta V^{**}(P(0))]. \tag{20}$$

Just as in the model without experimentation, $V^{**}(P(0)) = \kappa[-1/\delta + V^{**}(P(1))]$, and as ϵ^{**} approaches $\tilde{\epsilon}$ from above, $k^{**} \to \infty$ and thus

$$\lim_{k^{**}\to\infty} V_B = -d/(1-\delta). \tag{21}$$

At this limit, equation (20) becomes

$$V = -c - \kappa(1-\tilde{\epsilon})\alpha + [\tilde{\epsilon} + (1-\tilde{\epsilon})(1-\alpha)]V + \kappa(1-\tilde{\epsilon})V,$$

where $V = \frac{-\delta d}{1-\delta}$. Replacing for V and solving for d yields the cutoff in Proposition 4.

■

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