Regulatory Fog: The Informational Origins of Regulatory Persistence

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Regulation, even inefficient regulation, can be incredibly persistent. We propose a new explanation for regulatory persistence based on "regulatory fog", where regulation obscures information about the effects of deregulation. This paper presents a dynamic model of regulation, in which the environment is stochastic such that the imposition of regulation can either be efficient or inefficient, and in which the regulator's ability to observe the underlying need for regulation is reduced when regulation is imposed. As compared to a full-information benchmark, regulation is highly persistent, even if there is a high probability of transition to a state in which regulation is inefficient. This regulatory persistence decreases welfare and dramatically increases the proportion of time the economy spends under regulation. The ability to perform deregulatory experiments can improve outcomes, but only if they are sufficiently inexpensive and effective, and regulation will still remain more persistent than in the full-information benchmark.

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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 can not correct its behavior by learning from its errors. - Crozier, 1964

1 Introduction

One common solution to market imperfections such as externalities and market power is regulation, but regulation itself is costly. Administration and enforcement requires overhead. Lobbying and avoidance dissipate rents. Centralized control distorts investment and innovation.[1]

Furthermore, once applied, regulation tends to be very persistent, often outliving its usefulness. Deregulation of transportation, power, and communication networks often generate large productivity gains both within the industry and in the broader economy. 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. This persistence can magnify the costs of regulation which might otherwise be optimal in the short run, since the gains today must we weighed off against a potentially long tail of future inefficiencies.

Why does regulation end up being so persistent? We propose a new explanation for regulatory persistence based on "regulatory fog," where regulation obscures information about the likely effects of deregulation. Our view is that regulatory persistence is a natural byproduct of optimal static regulation — that regulation *itself* carries the seeds of its own persistence by altering the dynamic information generated in the economy. In stochastic environments, where the optimal policy varies over time, this regulatory fog can lead to the persistence of policies which have become suboptimal. This dynamic inefficiency is an important cost of regulation not often taken into account in the regulatory debate.

To illustrate the idea of regulatory fog, consider the regulation of a monopolistic market. The producer and consumers adjust in response to regulation and market conditions. Some of these adjustments are the very targets of the regulation: a monopolist increases quantity, reduces pollution, or ceases the use of misleading marketing. But adjustments on other dimensions will also occur. Consumers will adjust their consumption patterns both over

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

time and between substitutable/complementary goods. The monopolist will alter investment rates and mix. Prices will be distorted in other markets. Entry and exit in the regulated market or neighboring markets may occur. Because these adjustments are so far reaching and subtle, and will certainly depend on the underlying state of the world, unpacking all the consequences of deregulation may be extremely difficult.

Given this complexity, in stochastic environments where the optimal policy varies over time, a perfectly public-interested regulator is likely to have a very difficult time determining when to remove regulation. In cases where the consequences of a market failure are severe, the regulator might be unwilling to take a risk since the benefits of deregulation are not demonstrable while the historical potential cost of deregulation are salient. In these cases, regulation could persist indefinitely despite its inefficiency.

In this paper, we build a dynamic model of regulation in which the underlying need for regulation varies stochastically, and the presence of regulation affects the regulator's ability to observe the state of the world. Even in an environment where the regulator maximizes public interest, regulation is more likely to persist indefinitely in this environment than in a full-information benchmark. For most reasonable parameter values, regulatory fog increases both the length of time an individual regulatory spell lasts and the proportion of time spent under regulation. Regulatory fog also increases the probability that deregulation ends in disaster, leading to a substantial negative effect on total welfare.

In additional to full-scale deregulation, policy makers often have available a range of smaller scale policy experiments they could conduct. We next generalize the regulatory environment to allow for small-scale experimentation, which may be less costly than full deregulation but will provide a weaker signal about the counterfactual environment. We characterize the regulator's induced preferences over regulatory experiments, including his optimal trade-off between costliness and effectiveness. Although these alternatives weakly reduce regulatory persistence, the value of information is non-linear, so experimentation is adopted only when the experiment is informative and the cost of experimentation is reasonably low.

The difficulty in finding direct empirical evidence of regulation sustained by regulatory fog is self-evident. However, the strong 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 and the industry, and safety procedures.[2] Leaving aside the efficiency of the enactment, the longevity of these regulations is mysterious. These were extremely inefficient regulations, as become apparent upon their removal in 1978.[3] 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), for example, demonstrated that fares between San Francisco and Los Angeles were less than half those between Boston and Washington, D.C., despite the trips being comparable distances. Similar results obtained when looking at flights within Texas. There was no discernable increase in riskiness, delay, or evidence of so-called "excessive competition."

The dissemination of these large-state market results proved to be a major catalyst for deregulation.[4] 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 these studies.

The successful deregulation of airlines opeThe 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, a glimpse of the unregulated intra-state market spurred a successful deregulation, which in turn prompted deregulation of related industries.

[2]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)

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

[4]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 **?**

Our theory of regulatory fog should be contrasted with the political economy literature in which rent seeking by entrenched groups is the primary driver of policy persistence. Coate and Morris (1999) develop a model in which actors make investments in order to benefit from a particular policy. In their model, once these investments are made, the entrenched firms have an increased incentive to pressure the politician or regulator into maintaining the current policy. Similar dynamics can be found in Brainard and Verdier (1994) which studies political influence in an industry with declining infant industry protection.

While 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 dynamics of (de)regulation. 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. This effect is the essence of regulatory fog. As the political economy literature studies more generic policy, it ignores this important effect of regulation.[5]

Asymmetric information has been interacted with rent seeking models by Fernandez and Rodrik (1991). In their paper, uncertainty about 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 many 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 his 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 policies generate about the underlying state of the world. We attribute inaction to policy-makers' need to "wait for the fog to clear" which

[5]Contrast, for instance, the persistence of the CAB regulation to the huge variation in the tax code over the same period Piketty and Saez (2007).

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 it can improve outcomes, it comes with its own set of problems that full deregulation avoids. Furthermore, the problem of regulatory persistence remains. Finally, we conclude.

2 Model

Consider an economy which is home to a single producer who produces a single unit of output each period 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: a low-pollution technology which delivers profit π_0, and a high-pollution technology which delivers a profit of π_i.

There are two possible types of producers, Good (G) and Bad (B). Type-G sellers have $\pi_i = \pi_G < \pi_0$ and always produce using the low pollution technology. Type-B sellers have $\pi_i = \pi_B > \pi_0$ and thus have incentives to produce using the high pollution technology barring intervention.

Net of the social value of the producer's profits, the citizens' suffer an externality cost of -1 if the producer in their community uses the high-pollution technology. A welfare-maximizing regulator recognizes this cost and can enforce low-pollution production by regulating the production facilities, ($R \in \{0, 1\}$) where regulation costs the regulator $-d$ but induces type-B sellers to use the low-pollution technology.[6] Assume that $1 > d$, so the regulator prefers to pay the inspection cost rather than simply accept the pollution externality, if he knows the producer is type-B. The regulator is risk and loss neutral and has a discount

[6]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 high-pollution method. The type-B producers will produce using the high-pollution technology unless the inspection level is high enough. Specifically, they will use low-pollution technology as long as

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

Let p^* represent the the probability which makes this hold with equality, and $d = c(p^*)$.

rate of δ, and will regulate if indifferent.[7]

In each period, one of two states are possible which determine the producer's type. In the Bad state, the probability that a producer is of type-B is 1. In the Good state, the probability that a producer is of type-G is 1. Both the good and the bad state are positively recurrent. Transitions between the two states follow a Markov process with transition matrices:

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

where $\Sigma_j \rho_{ij} = 1$ and $\rho_{i,j}$ is the probability from changing from state i to j before the next period. Both the good and the bad states are persistent with $\rho_{BB} \in (.5, 1)$, $\rho_{GG} \in (.5, 1)$ and 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. The firm observes the policy environment and the state before choosing their production technology. At the end of the period, the level of pollution is observed.

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

(2)

	Good State	*Bad State*
Regulation	$-d$	$-d$
No Regulation	0	-1

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 his prior. When he deregulates, he will learn the state for certain, since if the state is bad firms will pollute. This difference in information generated by different policy implementations is the information cost we explore throughout the paper.

[7] 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.

2.1 Full Information Benchmark

Before developing the optimal policy for the regulator, it is useful to determine the optimal policy when the 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.

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 he does not observe the state before he makes his regulatory decision for the period, but he does learn what the state was at the end of the period, even if he chooses to regulate. The following proposition characterizes the policy function of an optimal regulator:

Proposition 1 *Assume the state is revealed each period, regardless of the regulation regime. Then the regulator's optimal strategy falls into one of the following cases:*

1. *If* $d \leq \rho_{GB}$*, the regulator's optimal choice is to regulate every period, regardless of the state last period. Regulation is infinitely persistent.*
2. *If* $\rho_{GB} < d \leq \rho_{BB}$*, the regulator's optimal choice is to regulate after the bad state and 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* $d > \rho_{BB}$*, the regulator's optimal choice is to never regulate, even after a bad state. Regulation never occurs.*

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. d reflects the cost of regulation relative to the cost incurred in the unregulated bad state. When this cost is small relative to the probability of transitioning to the bad state, the regulator will regulate in every period regardless of the state last period. 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 pollution, the regulator prefers to take his 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 his interest to adapt his 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 optimal. Even in this full-information environment, there is some regulatory persistence. If the regulator regulates this period, he 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 low-pollution 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.

As the state space has only two states, 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 $\epsilon \in [0, 1]$,

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

$P(\epsilon)$ 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 he 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 $V_B = V^*(P(1))$ and $V_G = V^*(P(0))$. 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 guarantees the existence of a belief that makes the regulatory 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

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

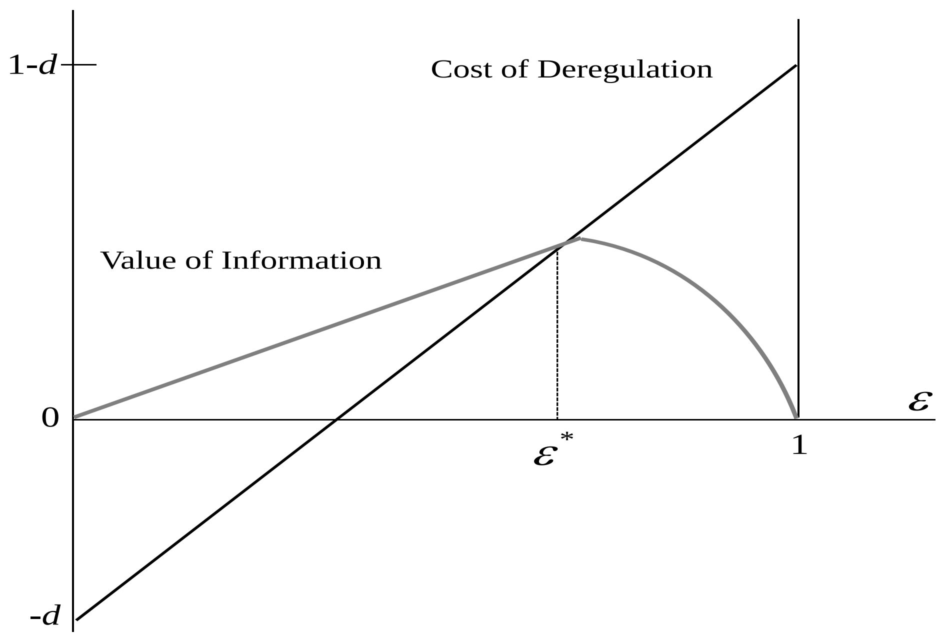
as the difference in value between regulation and deregulation given beliefs ϵ. Substitution for (4) and (5) in equation (16) yields:

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

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 that he is in the good state for sure or that he is in the bad state for sure and can act accordingly.

Figure 1 shows the current period cost of deregulation and the value of information over the domain of ϵ. As can be seen in the diagram, 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 $G(\epsilon) = 0$.

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



In this dynamic setting the value of information relates strongly to the static models of ¡¿ and ¡¿ 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. On 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. For $\epsilon > P^{-1}(\epsilon^*)$, the regulator has an incentive to maintain regulation for at least one period. The longer the delay in search, the lower the expected cost of search. The value of information thus decreases non-linearly in this domain due to the non-linearity in the updating operator $P^k(\centerdot)$.

Proposition 2 provides some structure to the solution to 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 optimal inspection regime. First, assume that $\epsilon^* < \rho_{BG}$. 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 obtain if $d < \rho_{GB}$, just like in the Full-Information benchmark.

Looking at the more interesting case, assume that $\epsilon^* > \rho_{BG}$ 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, he observes the bad state, he updates his posterior to $P(1)$ at the start of the next period and begins the regulation phase again. If, on the other hand, he finds himself in the good state, he does not inspect again until he experiences the bad state.

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

For $\epsilon^* \in (\tilde{\epsilon}, \rho_{BB}]$, 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 periods of regulation punctuated by deregulation experiments at fixed intervals. If $\epsilon^* \leq \tilde{\epsilon}$, the regulator's beliefs will converge to the stationary state which is above the cutoff belief necessary for experimentation. 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 permanent regulation and partial regulation cases, 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 $V(I = 1|\epsilon^*) = V(I = 0|\epsilon^*)$. Since $\epsilon^* > \tilde{\epsilon}$, $P(\epsilon^*) < \epsilon^*$ and thus $I^*(P(\epsilon^*)) = 0$. 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 *Assume the state is revealed at the end of each period if and only if the regulator does not regulate. Then, there exists a unique pure strategy equilibrium for the regulation game considered above. Good firms never pollute while bad firms pollute if and* *only if unregulated. 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's equilibrium policy is to regulate forever. Regulation is infinitely persistent.*

2. *If $d > \rho_{BB}$, the regulator's equilibrium policy is to never regulate, even after a bad state. Regulation never occurs.*

3. *If $\rho_{GB}\tau < d \leq \rho_{BB}$, the regulator's equilibrium policy is to regulate for $k^* > 0$ periods after the bad state is revealed and not regulate after the good state is revealed, where k^* is the first k such that $P^{k+1}(1) \leq \epsilon^* \leq P^k(1)$ and ϵ^* is the solution to the implicit function:*

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

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 inspecting when the true state of nature is good. This increases the value of information leading to an increase in the value of information over all ϵ. 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 beliefs about the underlying state evolves over time from a belief in which regulation is (almost) certainly optimal to beliefs 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 permanently faced with the potential of a deregulatory disaster, where the removal of regulation in the bad state leads to losses. This potential for disaster can lead to permanent persistence, particularly for environments in which the decision maker is relatively myopic.

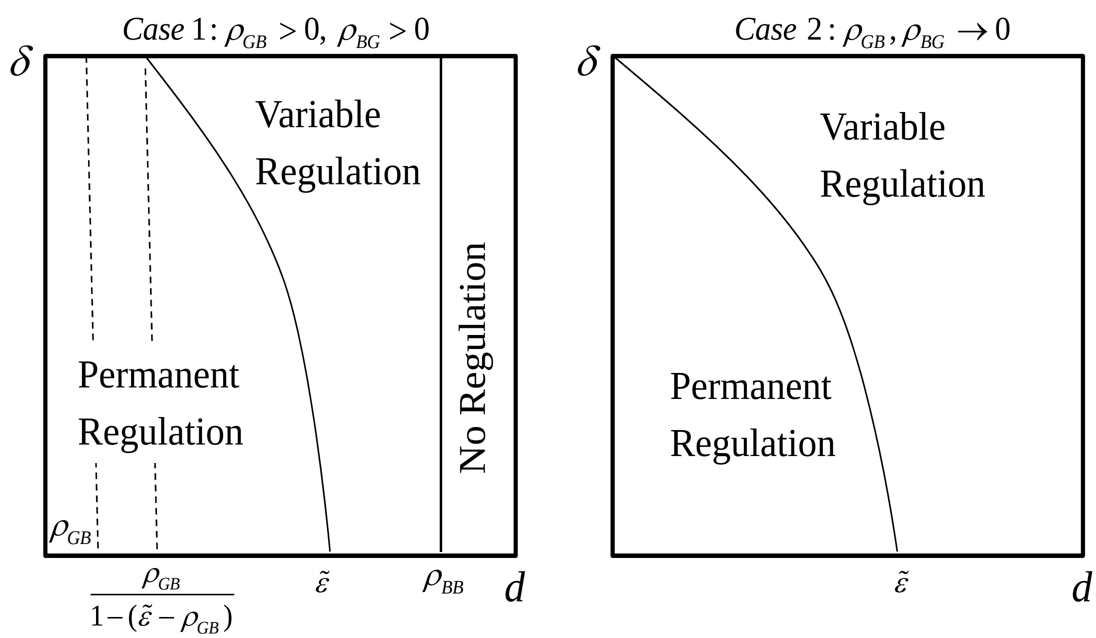
3.1 Permanently Persistent Regulation

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 of regulation is low relative to the probability of transition from the good to the bad state. However, as there is now the potential for a deregulatory disaster, 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 δ, more 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. Thus, as the regulator becomes more myopic, the range for which permanent regulation is optimal becomes large. 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.[8]

In addition to being exacerbated by short-sightedness, permanent regulation under regulatory fog is also quite robust as the states become highly persistent. Figure 2 shows the region of permanent regulation both for the case of finite 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 that could be arrived at 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 $\delta = 1$. 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 permanent removal of regulation.

Figure 2: Permanent Regulation



[8]We could find no papers 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.

3.2 Regulatory Cycles

Much of the most interesting dynamics from our model come from cases in which the cost of regulation, d, is moderate. In this parameter region, regulatory policy is characterized by periods of regulation and deregulation which are influenced by the underlying state. As noted in Proposition 1, the transition from regulation and deregulation in the full information benchmark is based on the arrival time of the first bad event. 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.

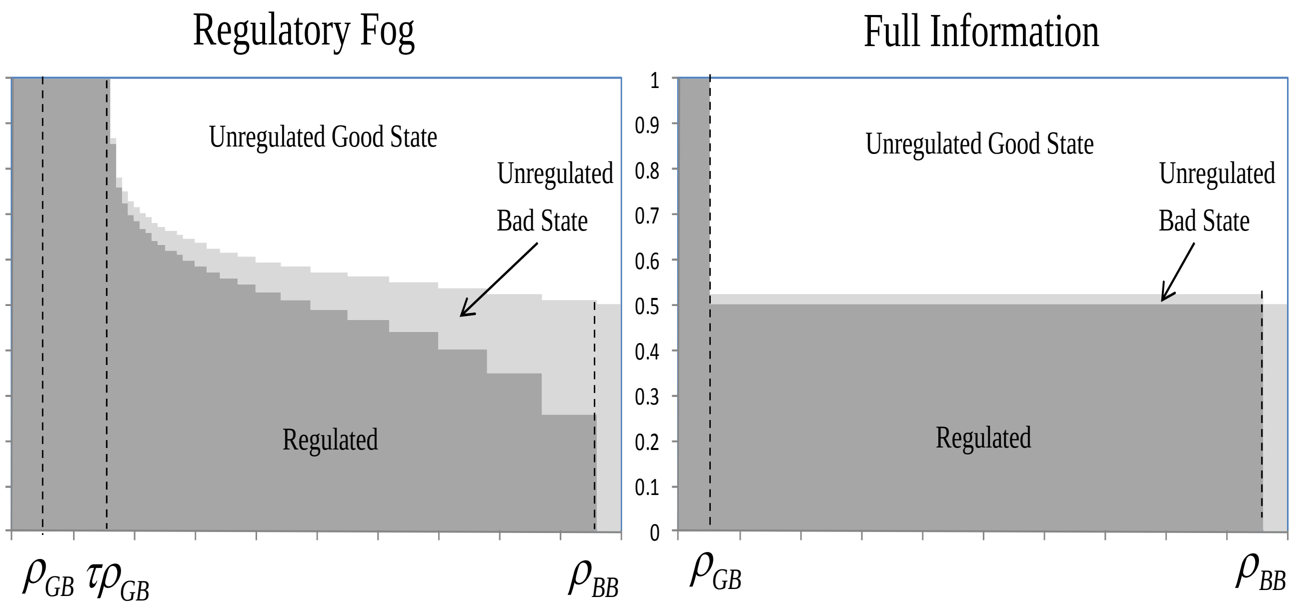
Unlike the full information case, in which there is a direct relationship between persistence and the stochastic nature of the environment, regulation under regulatory fog is characterized by fixed periods of regulation followed by some period of deregulation. When the cost of regulation is just above $\tau\rho_{GB}$ regulation will eventually be removed, but since the threshold belief ϵ^* is quite close to the steady state, the regulatory spell will be quite lengthy (k^* is large). As a result, 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 of regulation, regulation actually ends up being less persistent under regulatory fog than in its absence.[9]

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 decisions.

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

[9] 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.

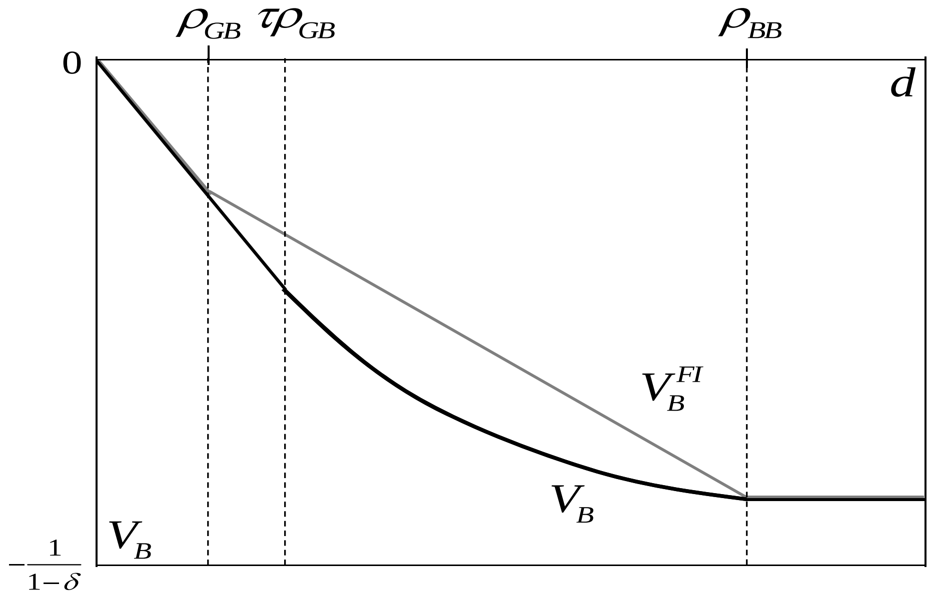
Figure 3: Proportion of Time in Each Regulatory State and Environment as a Function of The Cost of Regulation ($\rho_{GB} = \rho_{BG} = .05, \delta = .9$)



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 be applied or never be applied. In these cases, there is no cost of regulatory fog. Otherwise, regulatory fog imposes an information cost on the regulator which is linear up to $\tau\rho_{GB}$ and concave after. 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.

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 that world, regulatory fog leads to very persistent regulation with significant losses in welfare. We might wonder, however, just how bad the information problem is in an environment with a broader policy space. After all, why can the regulator not simply make small alterations to regulatory policy to generate new information without suffering the potentially disastrous consequences of fully deregulating in the bad state? This section studies the regulator's optimal policy when he has access to experimentation, a broader set of policy options which are less efficient than full regulation but which are potentially more informative.

Experiments vary from deregulation in two ways. First, experimentation can be conducted while maintaining regulation, but these experiments 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 are more informative but deviate from the optimal mechanism and are thus less efficient. Informative mechanisms will often be very different than the static mechanism, and thus the indirect costs of experimentation are unlikely to be trivial. In our pollution example, for instance, simply reducing inspection leads to a large change in the actions of the companies, and would be tantamount to deregulation. A regulatory experiment which maintains regulation broadly must be more complicated than simple 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 fact that small scale experiments will lead to informative but *imprecise* information 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, unbiased, experiment will have some sampling variance. There is also always 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 by allowing easier immigration to certain regions. His experiment may give him biased results for many reasons. If the demand for entry to the areas he chose was not representative of the demand, overall, he may under- or over-estimate the demand for entry. Even 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 of the elasticities of substitution across regions, which may unknowable.[10]

[10]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

The tradeoffs inherent in experimentation dictate its relative value in mitigating information inefficiencies. When the cost of experimentation is close to zero, experimentation will always be used and thus permanent regulation will arise only in cases where it is never optimal to deregulate. However, as the costs of regulation rises or as its informativeness declines, policy makers will eschew experimentation and opt for deregulation instead. In these cases, the broader policy environment provides no relief from regulatory fog.

4.1 Augmenting the Base Model

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 his primary regulatory function at cost d, and pays an additional cost of $c > 0$ to fund and monitor the experiment.

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

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 labor market, 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 Brcker, 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 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 be 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 the the UK.

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 :

$$\hat{\epsilon} = \frac{\epsilon}{\epsilon + (1-\epsilon)(1-\alpha)}. \tag{14}$$

Let $E(\epsilon) \in \{0,1\}$ represent the regulator's experimentation strategy when he 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 $d+c > d$, 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 greater than the cutoff point ϵ^{*} for which deregulation is better than regulation, 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.

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 part 2.[11]

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 ($\alpha << 1$), and so they are never utilized in equilibrium.

Note the shape of the three value functions. The values at each extreme ϵ (0 and 1) are easy to pin down because there is no uncertainty about various policies and thus no information consequences for various policies. The value of deregulating is linear in ϵ, since it is a weighted average of the value of deregulating in good state and the value value of deregulating in the bad state. The value of regulating is linear for low ϵ, since in amounts to waiting one period and then deregulating, but it flattens out for higher ϵ, as the optimal continuation includes waiting for more and more periods.

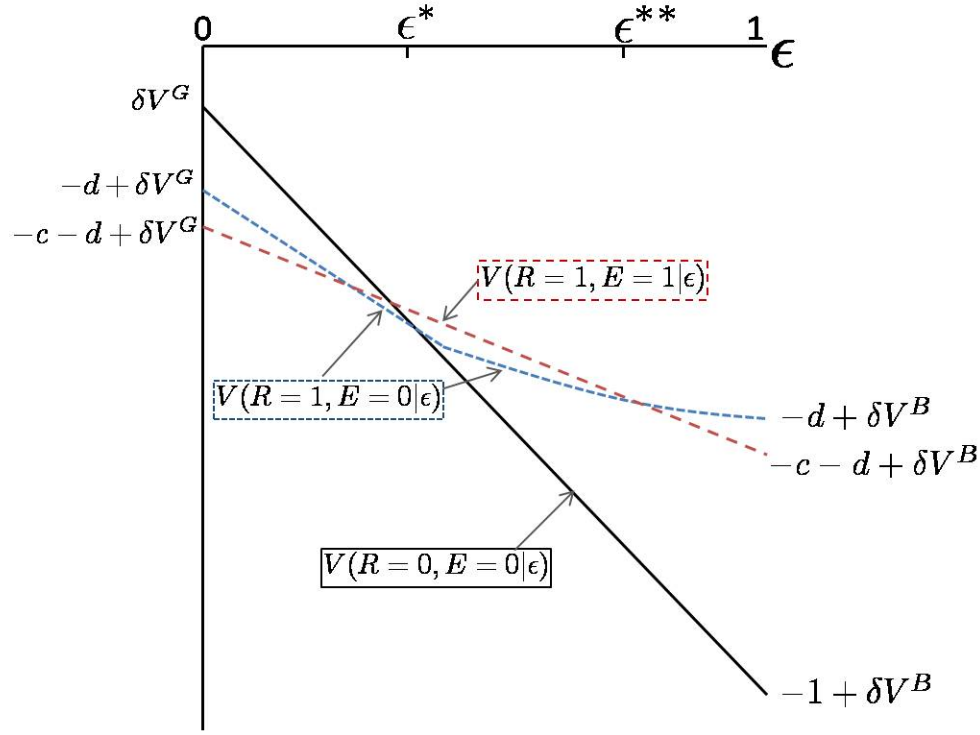
If it were not for the cost of running the experiment, the value of experimentation would always be above that of regulation, since the regulator also receives an informational benefit. Furthermore, if experiments are perfectly effective ($\alpha = 1$), the value of experimentation is also linear, since it is also a weighted average of the value of being in the good state and the value of being in the bad state, 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 bows downward, become more and more convex. Once $\alpha = 0$ it is simply a downward shift of the regulation value function.

Given ϵ^{**} and ϵ^{*}, we next check to see whether these beliefs fall below the steady state belief $\tilde{\epsilon}$. If they are both below this value, the regulator finds it optimal to regulate indefinitely. If, on the other hand, one of the beliefs is above the cutoff value, optimal regulation involves cycles.

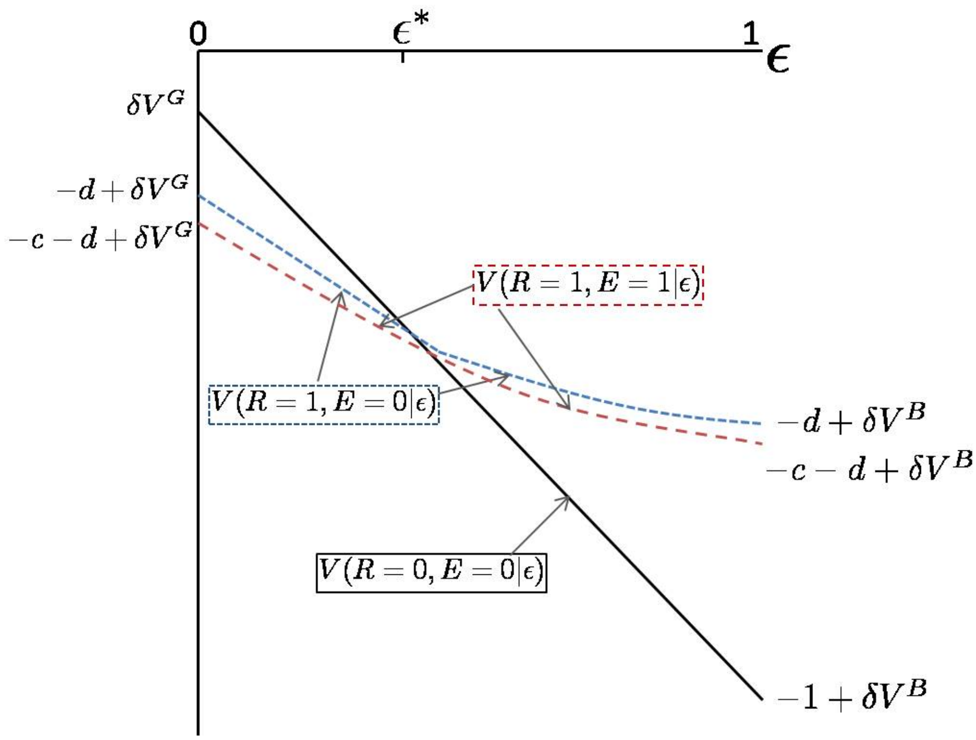
[11] There is a third case which can occur if $P(\hat{\epsilon}^{**}) < \epsilon^{**}$ and $P(\hat{\epsilon}^{*}) \leq \epsilon^{*}$. In this case a regulator may find it in his interest to experiment at ϵ^{**} but eventually deregulate if his beliefs fall below ϵ^{*}. As this case only occurs if α is extremely low and d is high we do not provide a formal analysis.

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

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



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



4.2 Optimal Policy with Experimentation

Just as in the base model, the added cost of experimentation results in a larger set of parameters for which regulation is permanent. 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

$$\tau' \equiv 1 + \left(\frac{c}{\alpha}\right)\left(\frac{1}{\kappa(1-\tilde{\epsilon})}\right) > 1. \tag{15}$$

As evident in the last term on the right hand side, permanent regulation is mitigated if the cost of experimentation is low relative to the value of information, which has a precision bounded at $\alpha(1-\tilde{\epsilon})$ and value bounded at $\frac{\rho_{GB}}{\kappa}$. If experimentation does not have a positive net present value at the steady state, it never will.

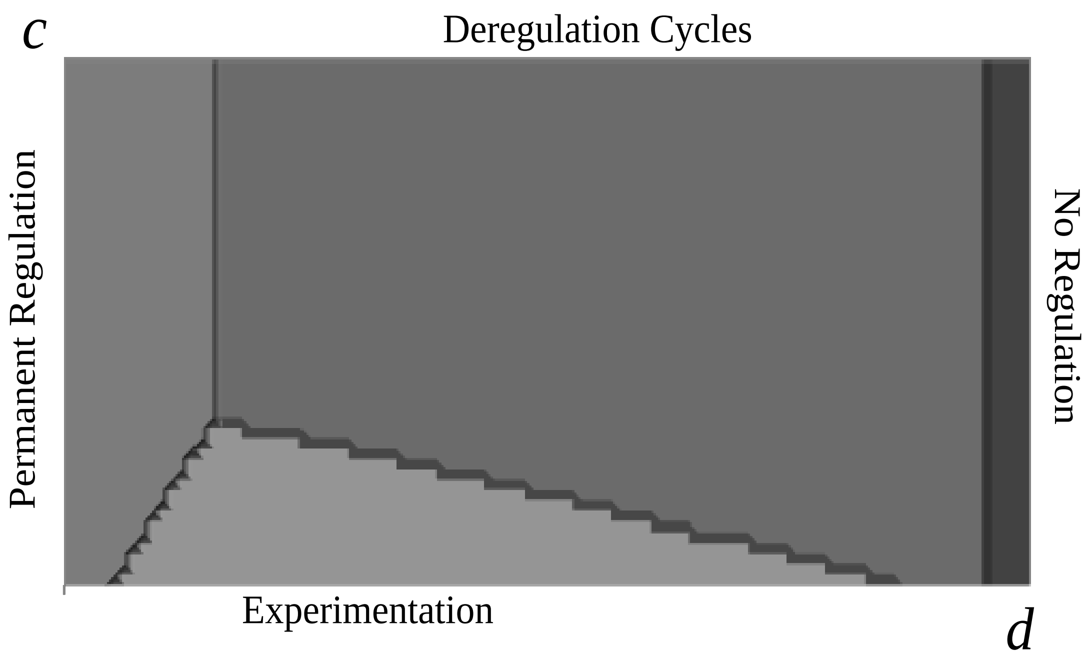
Figure 6 shows the relative importance of experimentation for different regulation costs, d, and experimentation costs c. As can be seen, for low experimentation costs and low regulation costs, there exists a region in which the policy decision is between permanent regulation and experimentation. As d grows, the value of information increases leading to a greater value for experimentation.

When $d > \rho_{GB}\tau$, a regulator always deregulates eventually, and thus his 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.

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 limited value to the policy maker. In these cases, the regulator finds it in his interest to never use experimentation, or to use it in conjunction with periodic deregulation.

Figure 7 shows the value of experimentation to a policy which only uses deregulation in $\{\alpha, c\}$ space. As one might expect, experimentation policies trace out indifference curves which are increasing in α and decreasing in c. As the value of deregulation is a constant in this space, there exists an indifference curve in which the value of experimentation is the same as deregulation. If all potential experiments are above the indifference line, the

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



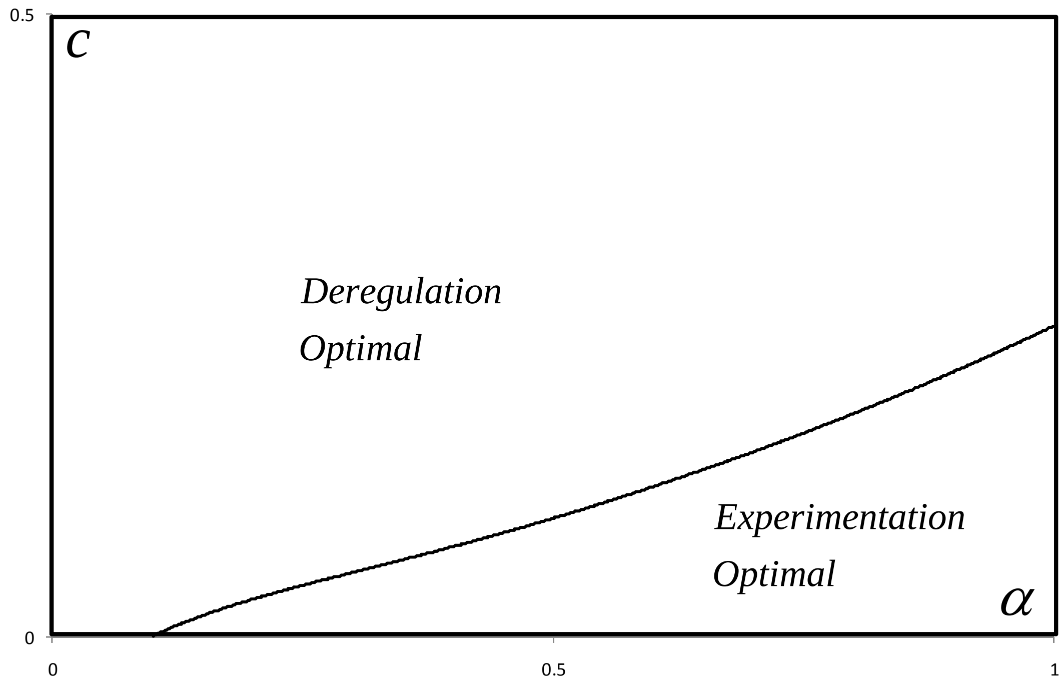
regulator strictly never experiments and only uses deregulation.[12]

One interesting interpretation is that the threshold c measures the policymaker's maximum willingness to pay for the information which would be delivered by the experiment. This threshold has important implications for policy analysts who propose conducting evaluations of regulatory programs. When designing program evaluations, there is usually a trade-off between cost and effectiveness. A program evaluator should choose the experimental design which maximizes the difference between the actual cost of evaluation and the regulator's threshold willingness to pay.

As with the baseline case, overall welfare loss is greatest for intermediate values of d where (i) experimentation requires very high levels of precision and low costs to be more productive than deregulation and (ii) there is both large amounts of policy persistence and high amounts of failed experimentation. Unless experimentation is costless, regulatory fog continues to increase the time the economy spends under regulation and has the potential to increase the parameter ranges for which regulation is permanently persistent.

[12]We include the region for which the policy maker both experiments and deregulates in the deregulation region.

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



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 dynamic 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 regulation for a broad range of parameters, particularly by myopic regulators. For most reasonable parameter values, fog delays deregulation — a phenomenon which leads 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. 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

PROPOSITION 1:

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 the 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. ■

PROPOSITION 2:

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

$$G(\epsilon) = V(R=1|\epsilon) - V(R=0|\epsilon). \tag{16}$$

$V(R|\epsilon)$ 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 would 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 (16),

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

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

$$\max\left\{ \begin{array}{c} -d + \delta[(-d + \delta V^*(P^2(\epsilon))] - \epsilon[-1 + \delta V_B] - (1-\epsilon)\delta V_G, \\ -d + \delta[P(\epsilon)[-1 + \delta V_B] + (1 - P(\epsilon))\delta V_G] - \epsilon[-1 + \delta V_B] - (1-\epsilon)\delta V_G \end{array} \right\}, \tag{17}$$

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

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

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 $epsilon^*$ increases. ■

<u>Proposition 3:</u> **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 a the Markov process, so the characterization in Lemma 1 gives the result for the intermediary case. ■

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