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Randomizing Regulatory Approval for Diversification and Deterrence

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Abstract

Modern societies legislate numerous requirements for regulatory approval of private activities. This paper develops two arguments for randomizing regulatory approval: diversification and deterrence. Diversification may be appealing when regulatory agencies make approval decisions under uncertainty. It enables an agency facing uncertainty to limit potential errors, much as portfolio diversification protects an investor who is uncertain of the returns to alternative investments. It also generates randomized experiments that may enable an agency to improve its decision making over time. The deterrence argument arises when the nature of an approval process affects private decisions to seek approval for contemplated activities. Randomization enables an agency to control the likelihood of approval. An agency may seek to choose an approval rate that encourages submission of applications for socially beneficial activities and deters applications for deleterious ones. To study the circumstances in which diversification and/or deterrence motivate randomized approval, the researcher brings to bear basic elements of normative public economics and decision theory.

1. Introduction

Modern societies legislate numerous requirements for regulatory approval of private activities. In the United States, pharmaceutical firms wanting to market new drugs require approval of the Food and Drug Administration, firms wanting to extract natural resources require approval of the Environmental Protection Agency, firms wanting to merge may require approval of the Federal Trade Commission or the Department of Justice, and entities wanting tax exempt status require approval of the Internal Revenue Service. Individuals require the approval of state governments to drive, vote, carry a concealed weapon, or marry. Firms and individuals wanting to use land for various purposes must comply with local zoning ordinances and obtain building permits. And on and on.

How should society evaluate regulatory approval processes? The legal system makes this the task of judicial review. However, judicial review has narrow scope. Aside from consideration of constitutionality, it is supposed to take as given the statutes that underlie an approval process. Moreover, it usually evaluates specific agency actions rather than entire approval processes.

The focus on specific actions is evident in the Administrative Procedure Act (APA), which provides the statutory foundation for judicial review of federal regulation in the United States. The APA uses this language to describe who has a Right of Review (5 USC § 702): "A person suffering legal wrong because of agency action, or adversely affected or aggrieved by agency action within the meaning of a relevant statute, is entitled to judicial review thereof. The section on Scope of Review states (5 USC § 706):

> "the reviewing court shall decide all relevant questions of law, interpret constitutional and statutory provisions, and determine the meaning or applicability of the terms of an agency action. The reviewing court shall—(1) compel agency action unlawfully withheld or unreasonably delayed; and (2) hold unlawful and set aside agency action, findings, and conclusions found to be—(A) arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law; (B) contrary to constitutional right, power, privilege, or immunity; (C) in excess of statutory jurisdiction, authority,

> or limitations, or short of statutory right; (D) without observance of procedure required by law; (E) unsupported by substantial evidence in a case subject to sections 556 and 557 of this title or otherwise reviewed on the record of an agency hearing provided by statute; or (F) unwarranted by the facts to the extent that the facts are subject to trial de novo by the reviewing court."

Thus, the Act construes judicial review as a procedure that begins when a legal person (an individual or firm) questions some agency action and that subsequently scrutinizes this action.

Society should evaluate regulatory approval more broadly than through judicial review alone. The atomistic scrutiny of agency actions performed in judicial proceedings misses considerations that become evident when one views approval processes holistically. Among these is that society may want to randomize approval decisions. This paper develops two arguments for randomizing regulatory approval: diversification and deterrence.

Diversification may be appealing when regulatory agencies make approval decisions under uncertainty. For example, the Food and Drug Administration may be unsure whether it should approve a New Drug Application, the Federal Trade Commission may be unsure whether it should approve a merger proposal, or a local planning commission may be unsure whether it should approve an application to build a new structure. In these and other settings, it may be socially desirable for an agency to diversify, randomly granting approval to some applicants and denying it to others who are observationally similar. Diversification enables an agency facing uncertainty to limit potential errors, much as portfolio diversification protects an investor who is uncertain of the returns to alternative investments. Moreover, diversification generates randomized experiments that may enable an agency to improve its decision making over time. I have previously developed these static and dynamic arguments for policy diversification in Manski (2009). I apply them to regulatory approval here.

The deterrence argument for randomization arises when the nature of an approval process affects private decisions to seek approval for contemplated activities. It is reasonable to think that a person will seek approval if he perceives that an activity may have positive private net benefit and that the approval process is not too onerous. Factors that may deter a person from seeking approval include the time and financial cost of preparing application material, the person's perception of the time that the agency will take to make a decision, and the person's perception of the likelihood that the agency will grant approval. Randomization enables an agency to control the likelihood of approval and, hence, to influence private decision making. In particular, an agency may seek to choose an approval rate that encourages submission of applications for socially beneficial activities and deters applications for deleterious ones. I have previously considered the deterrence argument for randomized action by public agencies in the context of police search for evidence of crime (Manski, 2006). Regulatory approval is broadly similar but differs in various respects.

Diversification and deterrence conceptually are features of a regulatory approval process rather than properties of particular agency actions. Hence, these concepts cannot be appreciated in judicial proceedings that consider agency actions in isolation. Indeed, an agency action to randomly grant or deny approval to a given applicant may appear "arbitrary, capricious, [or] an abuse of discretion" under the APA when the action is considered in isolation, but it may actually be justifiable as part of a well-motivated regulatory strategy of diversification and/or deterrence.

To study the circumstances in which diversification and/or deterrence motivate randomization of approval, I bring to bear basic elements of normative public economics and decision theory. Normative economic analysis begins with specification of a social welfare function to embody the abstract idea of the public interest. One then seeks to characterize the welfare achieved by alternative policies. The alternatives may include various regulatory approval processes. Such processes have a welfare-economic rationale if persons acting on their own may choose to engage in private activities that lower social welfare. Approval processes may deter or prevent such activities.

Suppose that one knows the welfare achieved by each feasible policy. Then a standard exercise in normative public economics is to determine an optimal policy, namely one that maximizes welfare. Policy evaluation is more subtle in settings with uncertainty. Given partial knowledge of the welfare achieved by alternative policies, one may not be able to determine an optimal policy. To cope with uncertainty, decision theory suggests a two-step process. The first step is to eliminate dominated policies, ones that are clearly inferior. The second is to apply some criterion to choose an undominated policy. There is no optimal way to choose among undominated alternatives, but there are various reasonable ways.

The analysis in this paper considers a relatively simple setting with an additive social welfare function and no social interactions across private activities. Section 2 makes the further simplifying assumption that the approval process has no effect on decisions to seek approval; thus, applications for approval are *exogenous*. In this context, randomizing approval may have a diversification motive but has no deterrent effect. Section 3 studies regulation when the approval process may affect decisions to seek approval; thus, applications are *endogenous*. In this environment, randomization may be motivated by deterrence.

The most direct antecedents to the present analysis are my previous studies of diversification and deterrence in other policy settings (Manski, 2009, 2006). I would also call attention to a recent working paper of Tetenov (2013), who develops a decision-theoretic deterrent argument for the common use of statistical hypothesis testing to assess the clinical trial data that pharmaceutical firms provide in drug approval processes. Using the results of hypothesis tests to judge the effectiveness of a new drug implements a particular form of randomized approval.

More distant antecedents are research of Baron and Myerson (1982) and Armstrong and Vickers (2010). Baron and Myerson studied regulation of a monopolistic firm whose costs are unknown to the regulator. One feature of their analysis is that the regulator may find it optimal to randomly decide whether to permit the firm to do business at all. Armstrong and Vickers studied the nature of optimal discretion for a principal to give to an agent when the agent may have a choice of project. The principal's problem is to specify verifiable attributes that a chosen project must possess. This abstraction might be interpreted as a regulatory approval process in which the agency permits a person to undertake any private activity that meets specified criteria. Randomization of approval is not a feature of the regulatory setting they studied.

Legal scholars have occasionally considered policy randomization and have offered several rationales. Duxbury (2002) emphasizes the normative fairness of lotteries as decision mechanisms in some settings. Abramowicz, Ayres, and Listokin (2011) offers the familiar statistical argument that randomized experiments promote learning. Vermoulle (2013) cogently critiques the APA presumption that judges can effectively determine when a regulatory action under uncertainty is "arbitrary, capricious, [or] an abuse of discretion." The diversification and deterrence arguments for randomization made in this paper appear not to have received attention within the legal community, nor has formal decision theory been used to evaluate policy alternatives.

2. Approval of Exogenous Applications

I consider here a relatively simple yet subtle regulatory setting. Each period (perhaps a year), an agency receives a new set of applications requesting approval of a private activity. The agency is required to act on each application, granting or denying approval. I suppose that other aspects of the application process – including the information that the agency requests on an application and the time it takes to reach a decision—are predetermined. The agency wants to make approval decisions that maximize an additive social welfare function, which places a social value on each approved activity and sums their values. There are no social interactions in the sense that the value of each approved activity does not depend on what other activities are approved.

An important further simplifying assumption in this section is that applications are *exogenous*. That is, the decisions of persons to seek approval for contemplated activities are unaffected by the manner in which the agency makes approval decisions. This assumption will be dropped in Section 3.

In the present setting, the ideal policy is to approve the applications for activities with positive social value and reject the remainder. This policy can be implemented if the regulatory agency knows which activities have positive value, but not otherwise. In general, an agency observes some attributes of proposed activities by inspecting the applications that persons submit. However, it may not know enough to determine with certainty which proposed activities are beneficial. Then the agency cannot implement the ideal policy. The best that it may be able to do is to separate the applications into observationally similar groups and approve all the applications in a group if their mean social value is positive. However, implementation of even this policy is infeasible if the agency is unsure whether the mean social value of each group of applications is positive.

An appealing feasible approval process may combine profiling with diversification. Profiling calls for *systematically* different treatment of cases that differ in their observed attributes. Diversification calls for *randomly* different treatment of cases having the same observed attributes. Profiling may be good policy when an agency knows something about how the social value of activities varies across groups of cases that observationally differ. I will give two distinct rationales for diversification, one static and the other dynamic. Sections 2.1 and 2.2 discuss each in turn, drawing on Manski (2009).

2.1. The Static Rationale for Diversification

Financial diversification is a familiar recommendation for portfolio allocation. A portfolio is diversified if an investor allocates positive fractions of wealth to different investments. Analogously, regulatory approval is diversified if, given a group of observationally similar applications, an agency randomly approves some positive fraction and rejects the rest. In both cases, diversification enables a decision maker facing uncertainty to limit the consequences of making inferior choices. An investor or agency having full knowledge would not diversify.

Economists have long used the expected utility criterion to motivate financial diversification. Consider an investor who places a subjective probability distribution on investment returns, whose utility function places decreasing marginal value on each additional dollar earned, and who maximizes expected utility. A classical result is that such a *risk-averse* investor may choose a diversified portfolio. Analogously, a risk-averse regulatory agency may diversify its approval decisions.

Manski (2009) considers treatment choice under ambiguity (aka deep uncertainty), when a planner choosing treatments for a group of observationally similarly persons does not place a subjective distribution on treatment response. The idea of treatment choice encompasses both portfolio allocation by an investor, where treatments are alternative investments, and the approval process of a regulatory agency, where treatments are decisions to grant or deny approval.

I specifically study treatment choice using the minimax-regret criterion. The regret of a treatment allocation is the loss in welfare resulting from choice of this allocation rather than the best allocation. The best allocation yields zero regret, so a planner would like to minimize regret. However, a planner making choices under ambiguity does not know the best allocation. The minimax-regret criterion selects an allocation that minimizes the maximum regret that could potentially materialize.

I show that a planner who does not know which of two treatments is best and who uses the minimax-regret criterion always diversifies, assigning a positive fraction of persons to each treatment. In the context of regulatory approval, an agency that applies the minimax-regret criterion to a group of observationally similar cases would approve a positive fraction and reject the rest. The minimax-regret criterion yields a specific fraction of applications to be approved. Suppose that, given the information available to it, the agency places a negative lower bound A and a positive upper bound B on the mean social value of the activities proposed in the group of observationally similar applications. Then the minimax-regret criterion would approve the fraction $B/(B - A)$ of these applications. See Manski (2009, Eq. 8).

A caveat is that my formal derivation of this simple result makes the idealized assumption that the group of observationally similar persons is infinite in size. Then the Law of Large Numbers ensures that statistically independent approval of each application with ex ante probability B/(B − A) yields the desired approval rate B/(B − A) ex post. I conjecture that the result holds well as an approximation in practical settings where the group is finite but sufficiently large.

2.2. Adaptive Diversification in a Stationary Environment

Section 2.1 considered a static setting in which an agency decides how to treat the applications submitted in one time period. Now suppose that the agency makes approval decisions in a sequence of periods, facing new groups of observationally similar applications each period. Then the agency may be able to learn about the social value of proposed activities, using observations of the outcomes that occur when early applications are approved to inform decision making later on. The potential for learning is especially strong if the environment is stationary in the sense that each new group of observationally similar applications has the same mean social value.

Diversification is advantageous for learning in a stationary environment because it generates randomized experiments yielding data on the common mean social value of each period's applications. As time passes and data accumulates, the agency can revise the fraction of cases that it approves. I have called this idea *adaptive diversification*.

The *adaptive minimax-regret* (AMR) criterion offers a simple way to implement adaptive diversification. The agency applies to each new set of applications the minimax-regret criterion using the knowledge available at the time. The result is a diversified allocation whenever the agency is unsure whether the mean social value of the applications is positive. The criterion is adaptive because, as outcome data accumulate, the agency may increase the lower bound A and/or decrease the upper bound B that it places on mean social value. It accordingly modifies the fraction B/(B − A) of applications that it approves. With sufficient learning, the lower bound may eventually rise above zero or the upper bound fall below zero. Henceforth, the agency would always grant approval in the former case and deny it in the latter.

2.3. Diversification and Equal Treatment of Equals

Recommending that an investor choose a diversified portfolio is uncontroversial. I have, however, found it controversial to propose diversification of treatments to humans. I have frequently received comments that observationally similar persons should receive the same treatment. The concern is that treatment diversification violates the ethical principle calling for "equal treatment of equals." In the context of regulatory approval, this principle presumably would mandate that an agency deciding on a group of observationally similar applications should either grant or deny all of them.

Sections 2.1 and 2.2 did not address this ethical concern. The additive social welfare function assumed there is in the *consequentialist* tradition of public economics. That is, policy choices matter only for the outcomes they yield. Equal treatment of equals is a *deontological* consideration. That is, it supposes that actions have intrinsic value, apart from their consequences. I address this concern here.

Diversification is consistent with the equal-treatment principle in the *ex ante* sense that all observationally similar persons have the same probability of receiving a particular treatment. It violates the principle in the *ex post* sense that different persons ultimately receive different treatments. Thus, equal treatment holds ex ante but not ex post.

Democratic societies ordinarily adhere to the ex post sense of equal treatment. Americans who have the same income, deductions, and exemptions are required to pay the same federal income tax. The Equal Protection clause in the 14th Amendment to the U. S. Constitution is held to mean that all persons in a jurisdiction are subject to the same laws, not that all persons have the same chance of being subject to different laws.

Nevertheless, some important policies adhere to the ex ante sense of equal treatment but explicitly violate the ex post sense. American examples include random tax audits, drug testing and airport screening, random calls for jury service, and the Green Card and Vietnam draft lotteries. Public school systems receiving more applications for student enrollment in desirable schools than space permits sometimes use lotteries to allocate students across schools. In the realm of regulatory approval, the Food and Drug Administration uses hypothesis tests to judge the effectiveness of new drugs. As observed by Tetenov (2013), this implements a form of randomized approval because randomization of treatment assignment in clinical trials implies that the findings of trials are random. These various policies that randomize public decisions have not been prompted by the desire to cope with uncertainty that motivates treatment diversification. Yet they do indicate some willingness of society to accept policies that provide ex ante equal but ex post unequal treatment.

Democratic societies come close to the dynamic rationale for treatment diversification when they permit performance of randomized experiments. Randomized experiments are undertaken to learn about treatment response. Combining ex ante equal treatment with ex post unequal treatment is precisely what makes randomized experiments informative. The current practice of randomized experiments differs from the treatment diversification of Section 2.2 in that democracies do not ordinarily compel participation in experiments. Concern with compulsion has been particularly strong in medical trials, which advertise for volunteers and go to lengths to obtain informed consent from experimental subjects.

3. Approval of Endogenous Applications

In this section I retain all the structure of Section 2 except for the assumption that applications are exogenous. Applications are *endogenous* if the decisions of persons to seek approval are affected by the manner in which the agency makes approval decisions. Suppose that a person acting on his own would choose to engage in some private activity. Suppose that submission of an application entails personal financial cost or effort. Then a person who wants to engage in an activity but is unsure whether approval will be granted may rationally decide not to submit an application. The less likely the person thinks approval to be, the larger the deterrent effect.

I examine how a regulatory agency might reasonably make approval decisions when applications are endogenous. The analysis of Manski (2009) does not apply, so I give a self-contained formal treatment. Section 3.1 considers optimal decision making by an agency that knows the social benefits of private activities, the social cost of preparing and processing applications, and the deterrent effect of alternative approval rules. Section 3.2 considers decision making when the agency does not have sufficient knowledge to solve the optimization problem.

3.1. Optimal Approval Decisions

3.1.1. The Optimization Problem in Generality

To begin, let there exist a population of persons, each of whom considers whether to apply for approval of a private activity. Let v_j be the social value of the activity that person j wants to undertake. Let c_j be the social cost associated with preparation and processing of an application, including the private cost incurred by j and the public cost borne by the regulatory agency. Let x_j describe the content of the application that j would submit, if he were to submit one. The agency knows the content of submitted applications when making approval decisions.

I assume for simplicity that (v_j, c_j, x_j) have predetermined values. A more general analysis would recognize that, in some regulatory settings, persons may be able to vary the content of submitted applications with their perception of the agency's approval rule. For example, the drug approval process of the Food and Drug Administration may affect the information that pharmaceutical firms provide when submitting New Drug Applications.

Let X denote the space of all values that x can take. The agency chooses a vector of approval rates $\delta \equiv [\delta(x), x \in X]$, where $\delta(x)$ is the fraction of applications of type x that the agency would approve. The agency can profile, making $\delta(x)$ vary systematically with x. Applications with the same content are observationally similar and, hence, are not amenable to profiling. However, the agency can randomly differentiate among these applications, approving $\delta(x)$ of them and rejecting $1 - \delta(x)$.

Finally, let $z_j(\delta)$ be a binary variable indicating the application decision that person j would make if the agency were to choose the vector δ of approval rates. That is, $z_j(\delta) = 1$ if j would submit an application and $z_j(\delta) = 0$ otherwise. The application decision of person j is exogenous if $z_j(\delta)$ does not vary with δ. Then it suffices to write z_j rather than $z_j(\delta)$. The application decision is endogenous if $z_j(\delta)$ varies with δ.

Approval rates have a deterrent effect on applications if $z_j(\delta)$ increases with δ. That is, person j does not submit an application if approval rates are low but does submit one if approval rates are sufficiently high. It may be reasonable to assume that the application decision of person j depends only on the approval rate $\delta(x_j)$ for applications of his own type x_j. Then deterrence means that there exists a threshold $\lambda_j \in (0, 1)$ such that $z_j[\delta(x_j)] = 0$ if $\delta(x_j) < \lambda_j$ and $z_j[\delta(x_j)] = 1$ if $\delta(x_j) > \lambda_j$.

With this background, we can express the welfare $W(\delta)$ achieved by any approval vector δ when welfare is additive. Each person who does not submit an application contributes zero to welfare. If person j submits an application, society bears cost c_j. If the agency approves the application, society receives value v_j from the activity that is subsequently undertaken. The welfare function adds these terms across the population, yielding

$$(1)\quad W(\delta) \equiv \sum_{x \in X} P(x)\cdot P[z(\delta) = 1|x]\cdot\{\delta(x)\cdot E[v|x, z(\delta) = 1] - E[c|x, z(\delta) = 1]\}.$$

Here P(x) denotes the fraction of persons with applications of type x. P[z(δ) = 1|x] is the fraction of these persons who would choose to submit an application if the approval vector were δ. The mean social cost associated with the submitted applications is E[c|x, z(δ) = 1]. The mean social value associated with these applications is E[v|x, z(δ) = 1]. This quantity is multiplied by δ(x), the fraction approved.

An optimal approval vector solves the problem

$$(2)\quad \max_{\delta \in \Delta} W(\delta),$$

where Δ indexes all possible approval vectors. This problem is highly complex in general, but it simplifies somewhat if the application decisions of persons of type x depend only on the approval rate δ(x) for these applications. Then welfare is additively separable in x and maximum welfare is achieved by solving the collection of sub-problems

$$(3)\quad \max_{\delta(x) \in [0, 1]} P\{z[\delta(x)] = 1|x\}\cdot\{\delta(x)\cdot E\{v|x, z[\delta(x)] = 1\} - E\{c|x, z[\delta(x)] = 1\}\}, \qquad x \in X.$$

These problems are still too complex to permit a general analysis, so I will focus on an illustrative class of cases in Section 3.1.3 below.

It is interesting to compare the maximum welfare achieved by regulatory approval with the welfare that would occur if society were instead to universally prohibit a class of private activities or universally permit them without an application process. Universal prohibition, assuming that persons do not attempt to circumvent it, yields zero welfare. Universal permission, assuming that all persons undertake their desired activities, yields welfare E(v).

Welfare with an optimal approval vector may, in principle, be larger or smaller than welfare with universal prohibition or permission. The two universal policies share the advantage that society does not incur the cost of preparing and processing applications. They share the disadvantage of not allowing profiling and randomization, which regulatory approval make possible.

3.1.2. Profiling and Randomization as Features of Optimization

The potential usefulness of profiling is evident from comparison of (1) and (2) with the choice problem that a regulatory agency would face if it were not able to vary approval decisions with the content of applications. Suppose that the agency were constrained to select a single fraction, say λ, and set δ(x) = λ for all values of x. Then the welfare function and maximization problem would reduce to

$$(4) \quad W(\lambda) \equiv P[z(\lambda) = 1]\cdot\{\lambda\cdot E[v|z(\lambda) = 1] - E[c|z(\lambda) = 1]\},$$

$$(5) \quad \max_{\lambda \in [0, 1]} W(\lambda).$$

This is a constrained version of problem (1)–(2), so maximum welfare in (5) can logically be no higher than the maximum achievable with profiling. The present maximum is strictly less than that achievable with profiling if the optimal approval vector with profiling makes δ(x) vary with x.

The potential usefulness of randomized approval of applications with the same covariates is more subtle to demonstrate. First observe that randomization is not optimal if applications are exogenous. Then P[z(δ) = 1|x], E[v|x, z(δ) = 1], and E[c|x, z(δ) = 1] do not vary with δ. The welfare function reduces to

$$(6) \quad W(\delta) \equiv \sum_{x \in X} P(x) \cdot P(z = 1|x) \cdot [\delta(x) \cdot E(v|x, z = 1) - E(c|x, z = 1)].$$

Inspection of (6) shows that, for each $x \in X$, the agency should set $\delta(x) = 1$ when $E(v|x, z = 1) > 0$ and $\delta(x) = 0$ when $E(v|x, z = 1) < 0$. All approval rates yield the same welfare when $E(v|x, z = 1) = 0$.

Randomized approval may be optimal if $P[z(\delta) = 1|x]$, $E[v|x, z(\delta) = 1]$, and $E[c|x, z(\delta) = 1]$ vary with δ. Welfare function (1) is too complex to permit a general analysis but special cases are tractable. Section 3.1.3 studies a class of cases in which persons submit applications when the expected private benefit exceeds the private cost. Deterrence occurs because the expected private benefit of application is proportional to the probability that the application will be approved. The analysis below shows when randomized approval is optimal and determines the specific approval rate that the agency should choose.

3.1.3. Optimal Approval in an Illustrative Class of Cases

In this section I suppose that five conditions hold for each value of x. These are

(a) The social cost of application is a positive constant across persons of type x. Thus, there exists a $c_x > 0$ such that $c_j = c_x$ for all persons of type x. Moreover, private cost equals social cost.

(b) Activities have larger private than social values, with private value equaling social value plus a positive constant. Thus, the private value of person j's activity is $v_j + \beta_x$, where $\beta_x > 0$.

(c) Each person knows the probability $\delta(x)$ that the agency would approve his application.

(d) Each person chooses to submit an application if the expected private benefit of doing so exceeds the cost.

Thus, $z_j[\delta(x)] = 1$ if $\delta(x)(v_j + \beta_x) > c_x$ and $z_j[\delta(x)] = 0$ otherwise.

(e) The distribution of social value for the activities of persons of type x is Bernoulli, with known mass points (v_{x0}, v_{x1}) and probabilities $[P(v = v_{x0}|x), P(v = v_{x1}|x)] = (1 - \eta_x, \eta_x)$, where $0 < \eta_x < 1$. The mass points satisfy the inequalities $c_x - \beta_x < v_{x0} < 0 < c_x < v_{x1}$. These inequalities imply that private value exceeds private cost for all persons, but social value exceeds social cost only for persons with $v = v_{x1}$.

To begin the analysis, observe that the inequalities in condition (e) imply that the ideal social outcome would be to receive and approve an application from every person whose activity has social value v_{x1} and to receive no applications from persons whose activities have value v_{x0}. This outcome is not achievable because the regulatory agency does not observe the social values of individual activities. It only knows the fractions $(1 - \eta_x, \eta_x)$ of activities that have social values (v_{x0}, v_{x1}).

What the agency can do is choose the approval rate so as to influence application decisions. Applications behavior varies across three ranges of values of $\delta(x)$:

(i) If $\delta(x) \le c_x/(v_{x1} + \beta_x)$, no one submits an application. Hence, welfare equals zero.

(ii) If $c_x/(v_{x1} + \beta_x) < \delta(x) \le c_x/(v_{x0} + \beta_x)$, persons with $v = v_{x1}$ submit applications. Hence, welfare equals $\eta_x[\delta(x)v_{x1} - c_x]$. Welfare increases with $\delta(x)$, attaining maximum value $\eta_x c_x[v_{x1}/(v_{x0} + \beta_x) - 1]$ when $\delta(x) = c_x/(v_{x0} + \beta_x)$. This maximum is positive if $v_{x1} > v_{x0} + \beta_x$ and non-positive otherwise.

(iii) If $\delta(x) > c_x/(v_{x0} + \beta_x)$, everyone submits an application. Hence, welfare equals $\eta_x[\delta(x)v_{x1} - c_x] + (1 - \eta_x)[\delta(x)v_{x0} - c_x]$. If $\eta_x v_{x1} + (1 - \eta_x)v_{x0} > 0$, welfare increases with $\delta(x)$, attaining maximum value $\eta_x v_{x1} + (1 - \eta_x)v_{x0} - c_x$ when $\delta(x) = 1$. This maximum is positive if $\eta_x v_{x1} + (1 - \eta_x)v_{x0} > c_x$ and non-positive otherwise.

If $\eta_x v_{x1} + (1 - \eta_x)v_{x0} \leq 0$, welfare decreases with $\delta(x)$, with supremum $\eta_x c_x[v_{x1}/(v_{x0} + \beta_x) - 1] + (1 - \eta_x)c_x[v_{x0}/(v_{x0} + \beta_x) - 1]$ as $\delta(x)$ approaches $c_x/(v_{x0} + \beta_x)$. This supremum is smaller than the maximum in range (ii).

It follows that the optimal approval rate can take one of three values: 0, $c_x/(v_{x0} + \beta_x)$, or 1. The optimal rate is 0 if $v_{x1} \leq v_{x0} + \beta_x$ and $\eta_x v_{x1} + (1 - \eta_x)v_{x0} \leq c_x$. Randomized approval, setting $\delta(x) = c_x/(v_{x0} + \beta_x)$, is optimal if $v_{x1} > v_{x0} + \beta_x$ and $\eta_x c_x[v_{x1}/(v_{x0} + \beta_x) - 1] > \eta_x v_{x1} + (1 - \eta_x)v_{x0} - c_x$. Otherwise, the optimal rate is 1.

The finding that $c_x/(v_{x0} + \beta_x)$ is the best randomized approval rate formalizes a simple intuition. This is the highest approval rate that encourages submission of applications for activities with high social value and deter activities with low value. The algebra shows that $c_x/(v_{x0} + \beta_x)$ is the global optimum if the parameters $(c_x, \beta_x, v_{x0}, v_{x1}, \eta_x)$ of the regulatory setting satisfy certain inequalities. When these inequalities are not satisfied, either universal prohibition or universal approval is optimal.

Observe that the findings of this section all condition on the covariates x. Thus, it may be optimal to reject all applications with some values of x, approve all the ones with other values of x, and randomly approve various fractions of those with yet other values of x. Thus, randomized approval occurs within a regulatory system that profiles applications.

3.2. Policy Choice under Uncertainty

Finding an optimal approval vector requires considerable knowledge. The general determinants of welfare include $\{P(x), P[z(\delta) = 1|x], E[v|x, z(\delta) = 1], E[c|x, z(\delta) = 1]\}$ for $x \in X$ and $\delta \in \Delta$. Placing structure on the welfare function reduces the required knowledge but it remains significant. An agency that assumes applications are exogenous needs to know the signs of the conditional means $E(v|x, z = 1)$, $x \in X$. An agency assuming the five conditions of Section 3.1.3 needs to know the parameters $(c_x, \beta_x, v_{x0}, v_{x1}, \eta_x)$, $x \in X$.

When an agency has insufficient knowledge to optimize policy, decision theory counsels use of a two-step process to choose an approval vector. The first step is to eliminate dominated policies. The second is to apply some reasonable criterion to choose an undominated policy. Section 2 showed that study of regulatory approval under uncertainty is relatively straightforward when applications are exogenous. It is much more complex when applications are endogenous. I make some simple observations here, leaving in-depth analysis to future research.

3.2.1. Dominance

Findings on dominance depend on the specifics of the setting. No approval vector is dominated when applications are exogenous and the signs of the quantities $E(v|x, z = 1)$, $x \in X$ are unknown. Some may be dominated if applications are endogenous and the agency has sufficient partial knowledge. The analysis of Section 3.1.3 provides apt illustrations.

It was shown in Section 3.1.3 that setting $\delta(x) = c_x/(v_{x0} + \beta_x)$ yields greater welfare than any lower approval rate if $v_{x1} > v_{x0} + \beta_x$. One does not need to know anything about η_x nor the precise value of v_{x1} to reach this conclusion. It suffices to know the value of $c_x/(v_{x0} + \beta_x)$ and that the inequality $v_{x1} > v_{x0} + \beta_x$ holds. An agency having this partial knowledge can conclude that all approval rates smaller than $c_x/(v_{x0} + \beta_x)$ are dominated.

It was also shown that setting $\delta(x) = c_x/(v_{x0} + \beta_x)$ yields greater welfare than any higher approval rate if $\eta_x v_{x1} + (1 - \eta_x)v_{x0} \leq c_x$. One does not need to know the precise values of $(c_x, v_{x0}, v_{x1}, \eta_x)$ to reach this conclusion. It suffices to know that the inequality $\eta_x v_{x1} + (1 - \eta_x)v_{x0} \leq c_x$ holds. An agency having this partial knowledge can conclude that all approval rates larger than $c_x/(v_{x0} + \beta_x)$ are dominated.

3.2.2. Diversification with Endogenous Applications

When considering approval with exogenous applications in Section 2, I gave static and dynamic rationales for diversification. The simple form of diversification discussed there—randomized approval of observationally similar applications—does not work when applications are endogenous. With randomized approval, observationally similar persons who submit applications experience varying agency action. However, all observationally similar persons face the same approval rate and, hence, face the same deterrent effect of the approval process.

A version of diversification with endogenous applications may be possible if the application decisions of persons of type x depend only on the approval rate $\delta(x)$ for these applications. Suppose that the regulatory agency believes that persons with two distinct values of x, say x_1 and x_2, are behaviorally similar. Behavioral similarity means that if persons with these distinct values of x were to face the same approval rate, they would make the same applications decisions and would undertake activities with the same mean social values and costs. Formally, assume that $P[z(\lambda) = 1|x_1] = P[z(\lambda) = 1|x_2]$, $E[v|x_1, z(\lambda) = 1] = E[v|x_2, z(\lambda) = 1]$, and $E[c|x_1, z(\lambda) = 1] = E[v|x_2, z(\lambda) = 1]$ for all $\lambda \in [0, 1]$.

Now suppose that the agency applies different approval rates, say λ_1 and λ_2 to persons of type x_1 and x_2 respectively. Given the maintained assumptions, this practice achieves the static and dynamic rationales for diversification. In a given time period, it enables an agency facing uncertainty to limit the consequences of making inferior approval-rate choices. Over time, it enables the agency to learn what outcomes would occur if persons of type x_1 were to be subjected to approval rate λ_2, and vice versa.

4. Conclusion

This paper has developed two arguments for randomizing regulatory approval: diversification and deterrence. Diversification enables an agency facing uncertainty to limit potential errors and it generates randomized experiments that may enable an agency to improve its decision making over time. The deterrence argument arises when the nature of an approval process affects private decisions to seek approval for contemplated activities. Randomization enables an agency to control the likelihood of approval. An agency may seek to choose an approval rate that encourages submission of applications for socially beneficial activities and deters applications for deleterious ones.

I have used basic elements of normative public economics and decision theory to study the circumstances in which diversification and/or deterrence motivate randomization of approval. I see much scope to go beyond the relatively simple analysis presented here and examine more general regulatory settings in which agencies face uncertainty and applications are endogenous.

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