A MODEL OF THE OPTIMAL COMPLEXITY OF RULES

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Abstract

Rules often are complex in order to distinguish different types of behavior that may have different consequences. Individuals confronted by complex rules may expend resources to determine how the rules apply to their acts or may choose how to act without regard to the complexity (i.e., based upon their estimate of the likelihood that different sanctions will apply to their act). A social authority must spend additional resources when applying complex rules in particular cases. This paper models the effects of complexity on individuals' decisions to acquire information and decisions concerning how to act, considers how optimal sanctions depend on complexity, and determines when more complex rules improve welfare.

A Model of the Optimal Complexity of Rules

Louis Kaplow*

The complexity of a set of rules often refers to the number and difficulty of distinctions the rules make.[1] A tax on wage income is more complex in this sense the more deductions for various expenses are permitted. Environmental protection regulation is more complex the more types of pollutants or sources of pollution are distinguished. In each case, the more difficult it is to determine the applicable category -- whether the difficulty involves understanding the rules themselves or ascertaining the relevant facts -- the greater complexity is said to be.

Although such complexity frequently is discussed as though it were an unmitigated evil, upon the least reflection it is generally understood that complexity provides the benefit of allowing rules to be more precisely tailored to acts, which allows better control of behavior. Thus, an environmental regulation with finer distinctions may be able to prevent more of the most harmful pollution or avoid imposing excessive costs in the effort to control less harmful pollutants. Complexity, of course, is costly. First, actors seeking to comply with more complex rules will be induced to expend resources to learn how the rules apply to their contemplated acts. To the extent acquiring information is costly, however, some will ignore the complexity and act based on their estimates concerning the rules that may apply. Second, the social authority typically will have to expend additional resources in applying more complex rules, as in each case it will be more costly to determine whether a violation occurred or how serious was the violation.

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[1] This paper will not address the frequently discussed but analytically uninteresting case of rules that are complex simply because they are written less clearly than is feasible.

Section 1 presents a simple model designed to capture these features of complexity. Section 2 analyzes how more and less complex rules affect behavior, including the decision to acquire information about acts and the decision concerning how to act. Optimal sanctions for regimes with more and less complex rules are derived, and the level of achievable welfare for each regime is compared. Concluding remarks are offered in section 3.

1. The Model

Risk-neutral individuals each decide whether to commit an act. Individuals' benefits from acts, which differ, are not observed by the social authority, which only knows the distribution of individuals' benefits. Some acts cause a high level of harm and others a low level of harm. All individuals know the probability of detection and applicable penalties for the more and less harmful type of acts, as well as the portion of acts that are of the more harmful type. Individuals can determine whether their act is of the more or less harmful type only if an expenditure is made.[2]

The social authority determines the magnitude of monetary sanctions, which are assumed to be socially costless. Different sanctions may be applied to the different types of acts only if an expenditure is made after individuals are apprehended. For simplicity, it is assumed that the probability of apprehension is given.[3]

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[2] The complexity modeled here involves individuals' difficulty in determining how rules apply to their acts. A different model would be appropriate if individuals knew the rules but had to make additional expenditures, as in record keeping, to benefit from a more complex rule. (Note that in such a model, additional distinctions may reduce complexity. For example, the exclusion of most forms of imputed income from the income tax avoids the need to gather the information necessary to measure such income. But one could recast the question, as in this case the difficulty is not in distinguishing imputed income from explicit income but in distinguishing imputed income from inaction; making the latter distinction is costly.)

[3] For reasons explored in Shavell (1989), this assumption may be approximately correct for many acts, as when detection resources simultaneously determine the probability of detection for many types of acts. If the probability could be set independently for the particular pair of acts, the optimum would involve the maximum feasible sanction for the more harmful act (and possibly also for the less harmful act) and a probability of detection such that the expected sanction for the more harmful act is somewhat less than that given by the model here with a fixed probability, when the

The following notation is employed:

h^i = per capita harm of act of type i, i = 1, 2; $h_1 > h_2$.

θ = portion of population whose acts are of type 1.

b = individuals' benefits from acting.

f(b) = continuous distribution on [0,B], independent of harm of act; F(b) is the c.d.f. of f(b).

c = individuals' cost of determining the type of their act.

p = probability that harmful acts are detected.

s^i = sanction for detected harmful acts.

γ = social cost of determining the type of an act.[4]

All values are measured in monetary equivalents.

2. Analysis of Complexity

2.1. When the Social Authority Does Not Distinguish Acts

If the social authority does not distinguish among the types of acts, and thus applies the sanction $s = s^1 = s^2$, individuals will not make the expenditure c to determine their type of act, and they will commit their act if and only if

(1) $b > ps$.

The social authority is assumed to choose s so as to maximize the sum of individuals' utilities. Social welfare can be expressed as

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sanction is chosen optimally (and is not constrained). This economizes on enforcement expenditures. Because of the benefit of saving enforcement expenditures, the optimum may involve less of a difference in sanctions than in cases in which some difference is optimal (including the possibility of no difference) compared to the model examined here. Because the value of differentiation in such cases will be less than for the model studied in the text, for a wider range of parameter values it will not be optimal for the social authority to spend the resources necessary to distinguish the two acts.

[4] For simplicity, this formulation is assumed and the methods by which a social authority may induce individuals to reveal the harmfulness of their act are not considered. Presumably, any process will involve some cost that varies with the number of acts committed, and thus will have most of the properties discussed below.

$$(2)\quad W = \int_{ps}^{B} (b - \bar{h})f(b)db,$$

where $\bar{h} = \theta h^1 + (1-\theta)h^2$. Individuals who do not act -- of type $b \leq ps$ -- receive no benefit and cause no harm. Those who act receive the benefit b and cause the expected harm $\bar{h}$. The first-order condition for the optimal sanction is

$$(3)\quad \frac{dW}{ds} = pf(ps)(\bar{h} - ps) = 0, \text{ or}$$

$$(4)\quad s = \frac{\bar{h}}{p}.^{5}$$

That is, the expected sanction, ps, should equal the expected harm.

2.2. When the Social Authority Distinguishes Acts

When the social authority distinguishes the types of acts, individuals have three choices: act, do not act, and acquire information. Note that if individuals rationally acquire information, they will act if and only if their act is of the type subject to the lower sanction, which will be the less harmful act when sanctions are optimal.[6] (If they would act upon learning that their act is subject to the high sanction, then it would necessarily be desirable to act if their act had been subject to the low sanction, so information has no value and would not have been acquired because they simply would have chosen to act. If they would not act if their act is subject to the low sanction, information would also have no value, as they could have refrained from acting without acquiring information.)

If information is not obtained, and individuals act, the effect on expected utility is

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[5] The possibility that $f(ps) = 0$ at the optimum is ignored here and below.

[6] If one considered the set of sanctions such that $s^2 > s^1$ and modified the derivations to follow accordingly, the conditions for the optimal sanctions under this assumption would be the same as in (12) and (14), and inspection of those expressions immediately indicates that $s^1 > s^2$, which contradicts the possibility that an optimum may involve $s^2 > s^1$.

(5) $b - p\bar{s}$,

where $\bar{s} = \theta s^1 + (1-\theta)s^2$. If information is not to be obtained, an individual will act if and only if (5) is positive. If an individual obtains information and acts accordingly (that is, acts if and only if informed that the act is of type 2, the less harmful type), the effect on expected utility is

(6) $(1-\theta)(b - ps^2) - c$.

Thus, an individual for whom (5) is not positive will obtain information if and only if (6) is positive, which is true when

(7) $b > ps^2 + \frac{c}{1-\theta}$.

The threshold level of benefits (that for which (7) holds as an equality) exceeds the expected sanction ps^2 (incurred when the act of type 2 is taken) by the cost of information, inflated to take into account the likelihood that, ex post, the information will be worthless (that is, when the information leads one not to act, which is what would have been the choice if information had not been obtained). Similarly, an individual for whom (5) is positive will obtain information if and only if (6) exceeds (5), which is true when

(8) $b < ps^1 - \frac{c}{\theta}$.

The threshold level of benefits is less than the expected sanction ps^1 (which is avoided when one's act is of type 1) by the cost of information, inflated to take into account the likelihood that, ex post, the information will have been worthless.

In summary, individuals of type $b \in [0, ps^2 + c/(1-\theta)]$ do not act, those of type $b \in (ps^2 + c/(1-\theta), ps^1 - c/\theta]$ purchase information and act if and only if informed that their act is of type 2, and those of type $b \in (ps^1 - c/\theta, B]$ act without first obtaining information. Note that this statement assumes that the value of the first endpoint of the interval for the types who purchase

information does not exceed that of the second. This is equivalent to the assumption that

$$(9) \quad c \leq p\theta(1-\theta)(s^1-s^2).$$

That is, the difference in expected sanctions, $p(s^1-s^2)$, weighted by the uncertainty of one's estimate without information, $\theta(1-\theta)$, must exceed the cost of information. Otherwise, no one would purchase information, in which case all individuals of type $b \in (p\bar{s},B]$ would act and all others would not. Because the s^i are chosen by the social authority, its actions determine which description of individual behavior applies.

To examine social welfare, begin by considering the range of sanctions such that (9) holds. (Rather than entering this constraint explicitly, it presently is assumed that the constraint is satisfied at the optimum; the assumption will be relaxed below.) Social welfare in this case can be expressed as

$$(10) \quad W = \int_{ps^2+\frac{c}{1-\theta}}^{ps^1-\frac{c}{\theta}} [(1-\theta)(b - h^2 - p\gamma) - c]f(b)db + \int_{ps^1-\frac{c}{\theta}}^{B} (b - \bar{h} - p\gamma)f(b)db.$$

The first term measures the contribution to welfare of those who acquire information: they act if and only if their act is the less harmful type (which has probability $1-\theta$), and in that case receive their benefit b, cause harm of h^2, and result in the social authority bearing the cost of differentiation γ with probability p; regardless of the type of their act, they incur the information cost c. The second term measures the contribution to welfare of those who simply act. The integrand is the same as in (2), except that, with differentiation, undeterred individuals impose an expected differentiation cost of $p\gamma$.

The first-order condition for s^1 is

$$(11) \quad \frac{dW}{ds^1} = pf(ps^1-\tfrac{c}{\theta})\theta(h^1 + p\gamma - ps^1) = 0, \text{ or}$$

$$(12)\quad s^1 = \frac{h^1 + p\gamma}{p}.$$

The effect of raising s^1 is to move individuals from the group that acts without acquiring information (and thus regardless of the harmfulness of their act) to the group that acquires information (and thus acts only if their act causes harm of h^2). The rate at which individuals move between the two groups is $pf(ps^1-c/\theta)$. For each individual that moves, the probability is θ that they are of type 1 and thus will not act. This change in decision avoids the total expected social harm of the act, which is both the harm from the act itself, h^1, and the expected social cost of processing an additional case, $p\gamma$. The benefit forgone, $ps^1 - c/\theta$, is that of the marginal individual. Finally, one must subtract the cost of acquiring information, c, which is incurred with certainty (and thus not weighted by θ). Because of the manner in which the cost of information is reflected in the benefits of the marginal individual, c does not appear in (12).

The first-order condition for s^2 can be expressed as

$$(13)\quad \frac{dW}{ds^2} = pf(ps^2+\frac{c}{1-\theta})(1-\theta)(h^2 + p\gamma - ps^2) = 0, \text{ or}$$

$$(14)\quad s^2 = \frac{h^2 + p\gamma}{p}.$$

The effect of raising s^2 is to move individuals from the group that purchases information (and acts if of type 2) to the group that does not act. The interpretation of (13) is similar to that of (11). Here, for those whose decisions are changed ($1-\theta$ of the individuals who move from one group to the other), the total expected social harm of act 2, $h^2 + p\gamma$, is avoided. In addition, the marginal individual forgoes the benefits of act 2, $ps^2 + c/(1-\theta)$, and, for all individuals who switch groups, the cost c is avoided. Because of the manner in which the cost of information is reflected in the benefits of the marginal individual, c does not appear in (14).

In summary, the optimal expected sanction in this case for both acts just equals the full expected social cost of the respective act, and, accordingly, the difference in these optimal expected sanctions is simply the difference in the expected harms of the acts. These relationships hold despite the fact

that the relevant margins of behavior concern whether individuals will acquire information (and act accordingly) rather than simply whether or not to act, as was true when solving (2). The reason is that, in this model, the private and social costs of information are equal, so the optimum simply involves each individual confronting the full expected cost of the act itself; individuals then acquire information (and accordingly choose acts) efficiently, given their initial lack of information and the cost of information.[7]

Return now to the assumption behind expression (10), which requires that (9) holds at the optimal sanctions defined by (12) and (14). In order for this to be true, it must be that

$$(15)\quad c \leq \theta(1-\theta)(h^1 - h^2).$$

This expression is more likely to hold the greater is the difference between h^1 and h^2 and the closer is θ to .5 (that is, the greater is the uncertainty concerning the type of act).[8]

Now consider the range of sanctions for which (9) does not hold, in which case social welfare can be expressed as

$$(16)\quad W = \int_{p\bar{s}}^{B} (b - \bar{h} - p\gamma)f(b)db.$$

Note that this expression is the same as that in (2), for the case in which the social authority does not distinguish types of acts, except that (16) has $p\bar{s}$ rather than ps as the lower limit of integration and the integrand in (16) subtracts $p\gamma$, the expected cost of differentiation for those who act. In (16), the two sanctions are fungible in controlling behavior; all that matters is the value of $\bar{s}$. Obviously, if s^1 and s^2 are such that (9) does not hold, the social expenditure on differentiation is a waste because the same behavior

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[7] These issues are discussed more fully in Kaplow (1989c).

[8] The right-hand side of (15) is half of the measure of dispersion known as the mean absolute deviation (equivalent to the variance, but taking the absolute value of deviations from the mean rather than squaring them), reinforcing the intuition that, the greater the variation in harm produced by an act, the higher is the cost of information consistent with an optimum at which individuals purchase information.

can be induced without differentiation by choosing $s = \bar{s}$. In this case, the optimal single sanction is as given by (4).

To complete the characterization of the optimum, one possibility remains. When the solutions to (10), given by (12) and (14), are such that (9) fails -- that is, the case in which (15) fails -- one must consider whether welfare can be higher for some pair of differentiated sanctions that satisfies (9). In particular, consider raising s^1 or lowering s^2 from the values given in (12) and (14) just to the point that (9) does hold, and ask whether this corner solution to (10) could be optimal.[9] Clearly it cannot, for at the point at which (9) just holds, no one acquires information and differentiation thus has no effect, which implies that expressions (10) and (16) are equivalent. Thus, the reasoning indicating that the solution to (16) cannot be an optimum also demonstrates that this corner solution cannot be an optimum. In conclusion, then, if (15) fails, differentiation is never optimal. Note that this is true regardless of the cost of differentiation per case (γ), so long as that cost is positive.

2.3. Whether Distinguishing Acts Improves Welfare

To determine whether differentiation is optimal when (15) holds, one can subtract the level of welfare given by (2) from that given by (10), where each expression is evaluated with sanctions at their respective optima. (For the discussion to follow, s, s^1, and s^2 denote the sanctions given by (4), (12), and (14), respectively.) Assuming that $ps^2 + c/(1-\theta) \leq ps \leq ps^1 - c/\theta$,[10] this

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[9] One need only consider this corner solution, as it is clear from (11) and (13) that welfare is increasing (decreasing) in each sanction when the sanction is below (above) its optimal level. Thus, for any sanctions satisfying (9) as an inequality, there will exist sanctions satisfying (9) as an equality that produce greater welfare.

[10] From (4) and (12), it can be demonstrated that, if $ps > ps^1 - c/\theta$, (15) does not hold, even if γ is arbitrarily small. Consistent with (15) holding, however, it will be the case that $ps^2 + c/(1-\theta) > ps$ whenever $c \in (\theta(1-\theta)[h^1-h^2] - (1-\theta)p\gamma, \theta(1-\theta)[h^1-h^2])$ -- which is more likely the larger is γ and the smaller is θ. In this case, the expression for welfare will be analogous to that given in (17): the first term for this other case will be strictly negative rather than positive, the second term will be the same, except that the lower limit of integration will be $ps^2 + c/(1-\theta)$ rather than ps, and the third term will be the same.

difference in welfare is

$$(17)\quad \int_{ps^2+\frac{c}{1-\theta}}^{ps} [(1-\theta)(b - h^2 - p\gamma) - c]f(b)db + \int_{ps}^{ps^1-\frac{c}{\theta}} [\theta(h^1 - b) - (1-\theta)p\gamma - c]f(b)db$$

$$- \int_{ps^1-\frac{c}{\theta}}^{B} p\gamma f(b)db.$$

The first term in (17) refers to those who would acquire information and then act only if their act is of the less harmful type in the regime with differentiation, but who would be deterred altogether in a regime with a single sanction. From (14), the value of the integrand is zero at the lower limit of integration, so this term is positive. The intuition is that the condition for the optimal s^2 insures that the marginal type, $ps^2 + c/(1-\theta)$, is that for whom not acting and acquiring information to decide whether to act produces equivalent welfare. The second term in (17) refers to whose who would acquire information in the regime with differentiation, but who simply would act in a regime with a single sanction. From (12), the value of the integrand is $-p\gamma$ at the upper limit of integration, while the integrand is positive at the lower limit (which follows from the analysis of the first term, since the integrand of the second and first terms are equal when evaluated at ps). Thus, the term is of indeterminate sign. Here, the optimal s^1 insures that the marginal type, $ps^1 - c/\theta$, is that for whom simply acting and acquiring information produces equivalent welfare, but simply acting entails the expected differentiation cost $p\gamma$ which is not present for this type in the regime that does not differentiate. For the same reason, the third term is negative. It measures the expenditures on differentiation on those individuals who act (regardless of the harmfulness of their act) in both regimes.

As one would expect, there is no simple answer to the question whether differentiation (more complexity) improves welfare. Clearly, as γ approaches zero, differentiation will be desirable: the first and second terms in (17) indicate positive behavioral effects (taking into account the cost of acquiring information by those induced to do so). Note that this result holds

independent of the value of c, although the degree of the benefit will depend on c, and if c is so high that (15) does not hold, no one would acquire information and differentiation will be a undesirable no matter how low is γ.[11] And, as γ becomes large, the cost of differentiation will exceed its benefits. No simple expression for a critical value of γ can be derived because, in (17), the optimal sanctions s^1 and s^2 themselves depend on γ.

A lower cost of information (c) will make it more likely that differentiation is desirable and will result in a higher level of welfare when differentiation is desirable. The derivative of (17) with respect to c is simply $-[F(ps^1-c/\theta) - F(ps^2+c/(1-\theta))]$: The marginal effect on welfare of a fall in c through changing marginal individuals' behavior is zero (because optimal sanctions are determined to insure this), while the inframarginal effect (that is, on individuals who would acquire information in any event) of a lower cost is positive.

In addition, the greater is the difference in the harmfulness of the two types of acts, the greater will be the value of differentiation.[12] The derivative of (17) with respect to h^1 is $\theta[F(ps^1-c/\theta) - F(ps)]$, and that with respect to h^2 is $-(1-\theta)[F(ps) - F(ps^2+c/(1-\theta))]$. Again, the marginal effects though changes in individuals' behavior net to zero. The inframarginal effect of a higher h^1 derives from the fact that some individuals undeterred in a regime with a single sanction will be induced to acquire information and, as a result, refrain from committing the more harmful act in the regime that applies a higher sanction to the more harmful act. The greater is h^1, the greater is this benefit. (Similarly, the regime with differentiation induces some individuals, who otherwise would not act, to acquire information and act if their act is of the less harmful type; the greater is h^2, the less is this benefit.)

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[11] As indicated in note 10, the expression in (17) will not be valid if $ps^2 + c/(1-\theta) > ps$, which is true whenever $c \in (\theta(1-\theta)[h^1-h^2] - (1-\theta)\gamma, \theta(1-\theta)[h^1-h^2])$. But, as γ approaches zero, this interval vanishes.

[12] As in the discussion of (15), one might have suspected that differentiation is more valuable the closer θ is to .5. But the derivative of (17) with respect to θ cannot readily be signed without specifying the parameters of the model, and this is also the case for the second derivative, so no direct characterization is possible.

Finally, as is clear from the discussion of (17), the more individuals are concentrated in the range indicated by the limits of integration of the first term (or in the range for the second term, but near the lower end) and the less are in the range for the third term (or for the second, near the upper end), the greater are the benefits of differentiation. The former group exhibit desirable behavioral effects relative to the costs of differentiation they impose, while the latter group exhibit no behavioral effect while imposing a cost (or a behavioral effect that is small relative to the cost). Obviously, individuals who would not acquire information or act under either regime have no effect on the welfare comparison.

3. Concluding Remarks

(a) In this model, if the cost of applying more complex rules (γ) is sufficiently low, complexity tends to be desirable regardless of how substantial are the resources devoted by individuals to learn the rules (c). The reason is that individuals have the option of ignoring the complexity and basing their decision whether to act on the average sanction. Expenditures on information are made only when the value of such expenditures is sufficiently high; the private value of purchasing information equals the social value. Of course, the more individuals must spend on information, the less acquire it, making it more likely that the social authority's expenditures to distinguish acts will be a waste. Moreover, in models in which individuals may misestimate the value of information or in which information about rules allows one to circumvent the intended sanctions, this result need not hold. See Kaplow (1989c), Shavell (1988).

(b) The discussion thus far speaks of "sanctions" applied by a "social authority." The analysis, however, applies to any public or private rules that affect penalties or awards. Thus, in addition to rules of criminal law and regulation, one should include such rules as those for taxes and transfer payments, subsidies, and breach of contract, as well as any incentive scheme between a principal and an agent.

(c) The information costs (c and γ) in the model have a simple form, but can be interpreted as capturing a range of situations. Individuals' information about acts can consist of professional advice about rules (as from lawyers), time spent learning rules, and the time and expense in analyzing acts (as in determining the chemical composition of waste products from manufacturing).[13] The social authority's expenditures may be spent directly on ascertaining information in a sanctioning proceeding or indirectly on enforcement associated with a mechanism designed to induce individuals to reveal information when their acts are detected.[14] Notice that in this model it was not important that these expenses are borne by the social authority. For example, if individuals bear the entire cost γ (with probability p, as the expenditure must be made only if detected) and the sanctions defined by (12) and (14) omitted the $p\gamma$ term, behavior and social welfare would be unaffected.

(d) The model involves individuals' deciding whether to commit a single act rather than choosing among acts, which does not itself affect the results. One could, however, analyze additional forms of complexity in a model with many acts. For example, one form of complexity (often arising with tax rules) involves extremely detailed definitions designed to distinguish acts of different social value. A simple rule might be easy to circumvent through complex transactional forms that themselves are costly, while a more complex rule may induce individuals to forgo such avoidance activity and thus spend less on working through the governing rules.

(e) The model assumes that sanctions were socially costless to apply (aside from the expenditure on differentiation). It is not clear precisely how the results would change if this assumption were relaxed to allow for costly sanctions -- as when individuals are risk-averse or sanctions are

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[13] One could allow individuals to have different costs of information, or, in the extreme, assume that some are informed at the outset and others are not. See Kaplow (1989c). Also, one could consider different types of complexity involving different types of compliance costs. See note 2.

[14] The assumption that differentiation was perfect does not affect the results, as with risk-neutral individuals and no constraint on the level of sanctions, the sanctions defined in (12) and (14) could be adjusted to achieve the same behavior, so long as individuals at the time they act know only the average characteristics of the process that differentiates acts.

nonmonetary. With differentiation, fewer individuals subject to the high sanction commit acts, but those who act bear a greater sanction, and more individuals subject to the low sanction commit acts, but those who act bear a lower sanction. In addition, optimal sanctions with and without differentiation would be affected in ways that would further complicate the comparison. See Kaplow (1989a, 1989b).

(f) Complexity often is discussed as an evil to be minimized, as in commentary on the income tax. Of course, less complexity typically is better if the same substantive rules can be applied. But much complexity -- the type examined in this paper -- arises because of the benefits from rules that are more precisely tailored to particular behavior. To talk of minimizing complexity in this context is of little meaning -- the simplest rule would permit (or forbid) all acts. Moreover, higher aggregate compliance costs in this context are not necessarily an indication of the undesirability of a more complicated rule, because the level of costs actually incurred are a function of the level and type of activity that arises. For example, the more individuals spend before acting to determine the rules applicable to their acts, the more individuals' behavior will conform to the desired outcome. Thus, evaluations of complexity and measurements of compliance costs will be useful in formulating policy only if considered in connection with the effects of more highly differentiated rules on behavior.

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