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The essential economics of threshold-based incentives: Theory, estimation, and evidence from the Western States 100☆

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ABSTRACT

Many public and private entities utilize incentive systems in which improvements in measured performance are rewarded only when the agent crosses some pre-specified threshold. This paper comprehensively analyzes the effects of these incentive systems on effort, the net benefits of effort, and the accuracy of information about agents' performance, and lays out methods for estimating each. These methods are then used to reveal the motivations, physiological limits, and racing strategy of ultramarathoners trying to complete a one hundred mile race in under twenty-four hours.

1. Introduction

Rewards linked to passing a pre-determined performance threshold are a prevalent feature of economic life. In business, such thresholds separate workers who qualify for a performance bonus from those who do not. In education, they distinguish acceptable from unacceptable performance for students, schools, and school districts. In the law, they classify certain offenses, such as drug possession or theft, into misdemeanors and felonies. There are thresholds for the collapse of ecosystems and for statistically significant research results. And research in behavioral economics, accounting, and psychology establishes that firms and individuals treat certain numerical values of performance, such as round numbers, as "focal points" that they then strive to meet.

This simple change from a standard, continuous reward structure dramatically affects its incentive properties. When the link between effort and reward is certain, the marginal benefit of improved performance is nil unless one crosses the threshold. When it is uncertain, as is more typical, expected marginal benefits rise and then fall in the neighborhood of

☆ This paper completes a trilogy on the economics of threshold-based incentives. In the application here, the threshold has strong incentive effects that conform to theory. In the application in a companion paper, Grant and Green (2013), there are no incentive effects at all. A related paper, Grant (2010), sketches out thresholds' effects on the distribution of performance when there is perfect measurement and population heterogeneity in the structural parameters. Color versions of all figures are available in the online version of this article.

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the threshold. Either way incentive effects vary nonmonotonically and discontinuously with proximity to the threshold. That is, we can think of thresholds' incentive effects not as a parameter, but as a function that depends on behavioral and physiological primitives.

This opens up a world of possibilities, both theoretical and empirical, that have yet to be fully explored. We have neither fully catalogued thresholds' theoretical properties nor developed the most suitable methods of estimating their effects, as discussed in Section 2 below. This paper remedies these gaps in the literature, fleshing out the fundamental predictions of theory and developing natural, rigorous methods of taking them to data.

Threshold incentives admit two general lines of inquiry. The first, how effort responds to the incentive, can be considered reduced-form, as it requires no knowledge of the behavioral primitives underlying this response. Here, as Section 3 shows, simplicity rules: little structure is needed to lay out essential theoretical predictions, test for the presence of threshold incentives, or estimate their effects on behavior. Using structural estimation, however, one can also uncover behavioral primitives and examine thresholds' normative implications. As Section 4 shows, paramount here is the presence of uncertainty, which is needed for thresholds to have beneficial normative properties and for structural parameters to be identified. Both lines of inquiry apply to our empirical application, in Section 5, to one of the most dramatic effort provision problems found anywhere: a one hundred mile race runners try to complete in under twenty-four hours.

We hope this paper helps the profession realize the full potential of this class of incentives, in both senses of the word. Among labor supply problems, thresholds' striking behavioral predictions, normative properties, and empirical power are unparalleled. The existence and effects of the thresholds endemic in economic life are phenomena that deserve further exploration.

2. Thresholds as a class of incentive problems

Despite these features, thresholds have not been considered a distinct class of incentive problems deserving of concentrated study. Thresholds' ubiquity, unique characteristics, and unusual properties merit such a distinction.

The pre-determined location of thresholds distinguishes this class of incentive problems from those in which only relative performance matters, such as labor market tournaments (for example, Knoeber and Thurman, 1994) or elections (see Grant and Toma, 2008, and many cites therein), which have been heavily studied. In a complementary paper, Dubey and Geanakoplos (2010) show that, in games of status, in which only one's relative rank matters, and binary effort, a binary evaluation system can yield greater aggregate effort than a continuous system, and grading on a curve is never superior.

Thresholds also contrast with regression discontinuity studies, which measure the ex-post effect of an intervention by comparing outcomes on either side of an institutionally-imposed threshold separating those receiving treatment from those going without. Here, instead, the threshold is an incentive mechanism; the resulting discontinuity in effort, and its location, arise through optimizing behavior. Accordingly, regression discontinuity techniques are unsuitable for our purposes.

Threshold incentives are more closely related to the "reference point utility functions" developed in behavioral economics. As laid out by Heath et al. (1999), these have three characteristics: a reference point around which utility is evaluated; loss aversion, in which losses below the reference point receive more weight than gains of an equivalent amount; and diminishing sensitivity, or changes in utility, as one moves further from that reference point. Thresholds can be viewed as a limiting case of these utility functions, in which utility gains at the threshold are discrete, marginal utility is a delta function, and loss aversion vanishes. When appropriate, this additional specificity provides structure that strengthens estimation and testing.

Threshold incentive problems thus encompass intrinsically and extrinsically motivated behavior; the extrinsic rewards for passing can be market-determined, based on the average qualifications of those who pass, or administratively imposed. As we now show, examples of each abound, spanning the public and private sectors and most sub-fields of applied microeconomics. Several have developed literatures, which are summarized in Table 1.

Intrinsic rewards

- In health, the timing of pregnancy and childbirth is influenced by thresholds separating one year from the next. The rewards can be intrinsic, as for the Year of the Dragon in east Asia (see Sim, 2015), or extrinsic, as in the U.S., where the number of dependents for tax purposes are determined by calendar year (see Deckert-Conlin and Chandra, 1999).
- In sport, reference points abound for many performance statistics, such as achieving a batting average of 0.300. For amateurs, at least, the rewards for achieving these statistics are intrinsic.
- In environmental economics, there are thresholds of degradation below which an ecosystem "loses resilience" and collapses (Perrings and Pearce, 1994; Muradian, 2001). The existence value of such an ecosystem is an intrinsically valued public good.

Extrinsic, administratively imposed rewards

- In education, thresholds in class performance have long separated passing and failing students; under many accountability regimes they now serve a similar purpose for schools and school districts. Studies have investigated whether and how students or schools near the threshold utilize extra effort in order to increase their chances of passing.