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# Market signaling with grades

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## Abstract

We consider a signaling model in which receivers observe both the sender's costly signal as well as a stochastic grade that is correlated with the sender's type. In equilibrium, the sender resolves the trade-off between using the costly signal versus relying on the noisy grade to distinguish himself. We derive a necessary and sufficient condition—loosely, that the grade is sufficiently informative relative to the dispersion of (marginal) signaling costs across types—under which the presence of grades substantively alters the equilibrium predictions. Specifically, separating equilibria do not survive stability-based refinements. Instead, the prediction depends on the prior distribution over the sender's type. For example, with two types it involves full pooling when the distribution places sufficient weight on the high type and partial pooling otherwise. Finally, the equilibrium converges to the complete-information outcome as the distribution tends to a degenerate one—resolving a long-standing paradox within the signaling literature.

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## 1. Introduction

Signaling models typically assume that observable, costly actions are the only channels that can convey information about the sender. These models implicitly overlook the existence of

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*grades*.<sup>1</sup> A *grade* refers to any imperfect public message about the sender's type (e.g., test scores, analyst ratings, product reviews). Grades are prevalent in many environments that have been modeled as signaling games, such as education (Spence [10]), financial markets (Leland and Pyle [11]), advertising (Kihlstrom and Riordan [12]), and warranties (Gal-Or [13]).

In this paper, we study how strategic agents behave when both channels are available for information transmission. Specifically, we consider a signaling environment in which receivers observe a stochastic grade in addition to a costly action chosen by the sender. The likelihood of each grade depends on the sender's privately-known type and (potentially) on his chosen action. After observing the chosen action and the realized grade, receivers take actions in response. The purpose of this exercise is to understand how the presence of grades affects equilibrium behavior in signaling games as well as the implications for policy and applied work.

To fix ideas, consider an amended version of Spence's job-market signaling model: a worker, who is privately informed whether his productivity is high or low, chooses an education level (his action); potential employers observe the worker's education level and, in addition, his performance on a test (his grade) prior to making offers.<sup>2</sup> Our first insight is that, in the presence of an informative test, some degree of pooling on the education level is more plausible than the widely adopted prediction of separation.<sup>3</sup> The economic intuition for this result is that if the worker were to choose the separating level of education, attempting to convince the market that he is the high type, employers would infer that he is eager to de-emphasize the results of the test. The low type has more incentive to do this since he expects a worse outcome on the test. Choosing a very high level of education would therefore backfire, leading employers to infer that the worker is more likely to be the low type. Clearly, then, the worker will not choose the separating level of education.

Instead, the high type must resolve the trade-off between how much to exploit his cost advantage (i.e., that education is less costly to him) and how much to rely on his expected grade advantage (i.e., the test). The more informative the test, the stronger is the high type's grade advantage. We derive a condition (*RC-Informativeness*) that states precisely when the test is informative enough relative to the cost advantage to induce some reliance on it. More specifically, we show that separating equilibria do not survive stability-based refinements when the test is RC-Informative. In addition, the presence of grades changes the relative payoffs in pooling equilibria. When types pool on the costly action, the grade contains additional information about the worker's ability. Therefore, in contrast to pooling equilibria in the model without grades, a high type expects to earn a higher wage than a low type who obtains the same level of education.

Our second key insight is that the addition of grades can resolve the discontinuity of the equilibrium prediction as the prior converges to degeneracy. Regardless of whether grades are available, in the complete-information game where the worker's type is common knowledge, the unique equilibrium outcome involves no education. However, by introducing even the *slightest* possibility that the worker is a lower type, the unique stable outcome of the gradeless model involves the high-type worker choosing a non-trivial level of education to distinguish himself from

<sup>1</sup> See Riley [1] for an extensive survey. Exceptions include Weiss [2], Fang [3], Feltovich et al. [4], Kremer and Skrzypacz [5], Angeletos et al. [6], Angeletos and Pavan [7], Alos-Ferrer and Prat [8], and Daley and Green [9], see Section 2 for further discussion.

<sup>2</sup> More generally, employers may observe the worker's entire transcript and any other academic distinctions.

<sup>3</sup> Without grades, the least cost separating equilibrium is the unique stable outcome in this model and its well-known generalizations (Cho and Kreps [14], Cho and Sobel [15], Ramey [16]).

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