25. *Signaling Models*

Honest people don't hide their deeds.

—Emily Brontë

In this chapter, we study *signaling models*. These models identify conditions under which people send costly signals to reveal information or their type. A person might signal wealth by purchasing an expensive piece of art, physical stamina by climbing a mountain, or empathy by posting support for causes on social media. Signaling to reveal status has always been a part of human nature. In the nineteenth century, Thorstein Veblen refined our understanding of signaling with his development of the concept of conspicuous consumption: he observed that rather than buy goods that bring direct enjoyment or practical utility, people often make choices to signal their social status. Veblen would take delight in our modern icons of conspicuous consumption, such as the Maybach Landaulet, an automobile that retailed for nearly $1.5 million, ten-year-old bottles of Cristal that sell for over $1,500 a bottle, and Leica cameras that sell for tens of thousands of dollars.

Conspicuous consumption endures because we care what others think of us, and what we consume signals our status to others.[1] We do not see others in their entirety, so we rely on what they wear, drive, and consume to make inferences about their hidden attributes. If we see someone driving an expensive car, we can infer that she has wealth. A person donating to a charitable organization signals generosity—no selfish person would take such an action. A person announcing her PhD in theoretical biology on social media signals her intelligence and work ethic. Almost all actions have some degree of signaling. When politicians vote whether to go to war or to impose sanctions on another country, they signal ideologies. Politicians with longer-term goals, such as running for president, may cast votes that send the best signals rather than those that produce the best policy.

In this chapter, we first study a discrete signaling model, in which an individual can either send a signal or not. Individuals differ in their costs of sending the signal. For signals to function, they must be costly or verifiable. That will be a central take-away from this chapter. For example, an employer may have a plum assignment in Barcelona, Spain, for the summer and want to select from a collection of new hires, all of whom list Spanish-language skills on their resumes. Claiming to speak Spanish is a *costless signal*. Instead, the employer could create a language badging program where earning the badge entails giving an hour-long presentation in Spanish. For the employees who can speak Spanish, this signal (the presentation) has low cost. For those employees not fluent in Spanish, the costs of preparing an hour-long talk would be prohibitive. In the formal language of signaling models, the badge *separates* the people who speak Spanish from those who do not.

We then cover a continuous signaling model, in which signals can vary in their magnitude. A summer camp may have only one position for a lead kayaker and want someone with incredible stamina. The camp director might then ask two applicants for the position to kayak as far as they can over the next ten hours. The stronger of the two kayakers could choose a distance that the weaker kayaker cannot achieve, guaranteeing that the test separates. Both models give us conditions for when signals will separate and when they will not. They therefore give us deeper insights than anecdotal accounts of people, animals, politicians, and governments signaling, by providing explicit characterizations of when they signal and how costly those signals are. For example, the models will make clear why students work so hard to signal their worthiness for college and medical school. In the conclusion, we discuss the contributions of signaling models as well as some other implications. We also discuss how signaling occurs in ecology, anthropology, and business.

Discrete Signals

We begin with a *discrete signaling model,* in which a person decides whether to take an action or not. You can buy an expensive watch to prove wealth. You can major in physics to prove your intelligence. You can swim the English Channel to prove your physical health. You cannot go halfway: you either send or do not send the signal. The model assumes two types of people, denoted as *strong* and *weak*. The types could correspond to physically fit or unfit marine recruits, or monolingual and bilingual employees.

The cost of sending the signal, which might be engaging in a fitness regimen for a month for a potential marine or the aforementioned presentation in Spanish for the job applicants, depends on a person's type. Strong potential marines find it less costly to complete the fitness regimen. In the model, we assume that everyone who sends the signal shares equally in the total benefit. This assumption can be interpreted in either of two ways. In some cases a resource might be split among those who send the signal. For example, everyone who donates $1,000 to a school (a signal of generosity) may get their name on the wall. In other cases, such as for the marines and job applicants, the winner(s) of some prize may be randomly chosen from the set of people who send the signal.

The model supports three types of outcomes: *pooling,* where everyone sends the same signal; *separating,* where each type sends a unique signal; and *partial pooling,* where some types separate and others do not.

Discrete Signals Model

A population of size N consists of S **strong** types and W **weak** types whose costs of sending a signal are c and C respectively, with $c < C$. Those members of the population who send the signal equally divide a benefit of $B > 0$. The model has three possible outcomes:

Pooling image: Both types signal.

Separating ($c <$ image and image $< C$): Strong types signal.

Partial pooling ($c <$ *image* $< C <$ *image*): Strong types and a fraction of the weak types signal.

In the model, we assume that individuals make optimal choices given the actions of others. That is, we treat this as a game and solve for an equilibrium. In the pooling equilibrium, everyone sends the signal. This equilibrium exists when the benefit is high and the cost for the weak type to send the signal is low. The exact condition is that the benefit divided by the number of people must exceed the cost for the weak type. Suppose that a benefactor donates $1 million for student scholarships to be split among all graduates of a high school with 100 students. Suppose that 50 of the students are weak and 50 are strong and that a strong student can graduate from high school by studying two hours per week, while a weak student must put in ten hours. We can approximate the costs of studying to be $2,000 for the strong students and $5,000 for the weak students. If all 100 students graduate, each receives a $10,000 scholarship. Given these assumptions, it makes sense for both types of students to study.

Suppose, though, that we reduce the size of the scholarship pool to $200,000. Now, if all of the students graduated, each would receive only $2,000. Studying is no longer in the weak students' self-interest. It still makes sense for the strong students, who now each receive $4,000. That amount is still not sufficient to induce even a single weak student to graduate (the second condition in the box above). In this case, the scholarship offer produces separation.

Last, suppose that the scholarship pool contains $400,000. Once again, if everyone graduated, the weak students would receive less than their $5,000 cost of studying. It follows that they would not all choose to study. However, if none of them studied, the strong students would each receive $10,000. That amount would be enticing to the weak students. In equilibrium exactly 30 of the weak students graduate along with all 50 strong students. In total, 80 students graduate, and each receives $5,000, the costs of studying for a weak student. We refer to this outcome as partial pooling, as only a portion of the weak students pool with the strong students.

The partial pooling equilibrium is more complicated than the others as it requires coordination among the weak students. We could assume that there exists some process by which weaker students communicate to others that they plan to take actions that ensure graduation. Or, we could assume that the weaker students put in just enough effort so that whether they graduate is a random event such that, on average, 30 of them graduate. This second scenario seems less plausible. In general, we should interpret partial pooling equilibria as benchmarks, as what would happen if people optimized. Whether a partial pooling equilibrium is attained likely depends on the situation, in particular, on whether people can communicate intended actions.

Continuous Signals

In the partial pooling equilibrium of the discrete signals model, the strong types may feel frustration. If they could send a strong signal, they could separate fully from the weak types and earn a higher payoff. To include that possibility in the model, we can alter our assumptions and allow the strong types to choose the magnitude of the signal they send. This requires only slight modification in our model. We reinterpret the costs of sending the discrete signal as a cost per unit of the continuous signal. We assume that for any fixed amount of the signal, the strong types have a lower per-unit cost of signaling.

To create separation in this new model, the strong types must be willing to choose a magnitude that is prohibitively costly for the weak types, yet still worth sending given the benefits and the costs. Reasoning through the model, we find that at least some of the strong types, though not necessarily all, can separate themselves from the weaker types.

Surprisingly, the magnitude of the signal the strong types must send becomes smaller as the size of the strong group increases. This occurs because the benefits to a weak type of sending the signal decrease in the size of the strong group. Being part of a larger group provides fewer benefits. The condition for full separation implies that it will be more likely when there are few strong types or when the strong types have much lower costs of signaling.

Separation with Continuous Signals

A population of size *N* consists of *S* **strong** types and *W* **weak** types with per-unit costs of signaling *c* and *C* > *c*, respectively. The individuals who send the largest signal split a benefit *B*. Any signal of magnitude image

separates the strong types. If $CW \geq cN$, then all of the strong types separate. If not, a partial pooling equilibrium exists in which a portion of the strong types signal.[2]

This model can explain why expensive watches and jewelry function as signals of wealth. A person's house or car also signals her wealth, but people cannot carry their houses and cars around with them at all times. Clothes can signal wealth as well, but may not be able to create separation. For a few hundred dollars, a person could dress like someone of significant wealth. Watches and jewelry, because of their high costs, are more effective as signals. A poor or middle-class person could not afford a $10,000 watch. By wearing one a person proves she has wealth. The benefit she derives may be that people treat her with more respect—assuming that people see wealth as correlating in some way with importance (an inference we might question).

The Uses and Value of Signals

We signal in an attempt to reveal hidden attributes to others. We take actions to signal our fitness, wealth, intelligence, and generosity. Sometimes our actions produce signals as by-products. A person who competes in marathons for the pure joy of running signals fitness and dedication even if that was not her intent. The signaling model provides an alternative lens for interpreting a large number of actions. Did a person choose to attend an event, master a skill, or purchase an item out of personal interest, or to signal a type? We might not be able to distinguish between the two cases.

Signaling models also provide alternative explanations for empirical regularities—even for the value of earning a college diploma. Data on incomes show that college graduates earn significantly higher salaries. We could infer that the higher wages result from skills and knowledge acquired at college. That data also show that math and science majors earn even higher salaries. From that we could infer that the skills learned in those majors have greater economic value. However, if we look at the tasks that math majors perform, we may find that few use calculus. Moreover, almost no one interviewing for a job is ever asked the derivative of the cosine function or to explain Boyle’s law. In light of that, we might infer that college degrees in general and science and math degrees in particular represent signals of a person’s ability to acquire knowledge. The higher pay that graduates receive stems entirely from the signaling value of degrees rather than what the graduates have learned.[3]

Consider the signaling required to become a doctor. Students must pass classes in physics, organic chemistry, and calculus. But do doctors use any calculus? Has your doctor ever looked in your ears and nose and then scratched a calculus equation on her notepad? Of course not. Knowledge of calculus, for the most part, may not be relevant to being a doctor, but it may be a good signal of the ability to master a corpus of knowledge. If so, passing calculus becomes a useful signal even though the subject material has little direct relevance.

When constructing institutions or rules in which people send signals, we would prefer the actions that produce signals build useful skills. To be a successful doctor, a person must be able to memorize facts. To signal the ability to memorize, one could require that applicants memorize the capitals and currencies of every country. Success would signal a candidate’s ability to memorize but would be functionally useless. When rushed to the emergency room with a strange feeling in your stomach, you would not care if your doctor knew that Bratislava is the capital of Slovakia, but you would want your doctor to know the various parts of the digestive system. For this reason, medical boards require that doctors pass exams on anatomy. Passing anatomy signals the ability to memorize. More important, knowing the parts of the body is useful for those who do pass. Thus, passing the anatomy exam provides a *functional signal*.

Summary

The signaling model can be applied widely. As already noted, the peacock’s feathers signal robust health. Otherwise, the decorative fans of feathers have little functional value. They may, in fact, be worse then useless. Far better that the peacocks had chosen to develop stronger talons. Strong talons would be more difficult for peahens to notice from afar, so tail feathers won out evolutionarily.[4] The colorful rear ends of male fruit flies serve a similar function as the peacock's feathers, as does the chirping of grasshoppers and birds. Chirping takes energy. Only a well-fed grasshopper can devote time to chirping rather than chasing down food. Hence, chirping functions as a signal.

Human societies engage in a variety of actions to signal their fitness. Anthropologists differentiate between three forms of costly signals: *unconditional generosity, wasteful subsistence behavior,* and *craft traditions*.[5] The potlatch, a ritual carried out by the indigenous people of the Pacific Northwest, may be the most salient example of signaling generosity. To celebrate an event, say a birth or death, a chieftain would give away (or destroy) great amounts of wealth and would challenge other chiefs to match those amounts. Failure to match was a loss of prestige. Giving away wealth can be seen as socially good, but burning it is wasteful.

Wasteful subsistence behavior occurs whenever people, typically men, choose to engage in hunting behaviors with lower expected payoffs than harvesting seeds or berries. The men do so because they earn extra respect. The successful hunter signals his strength and bravery, which could be useful in other settings. The successful berry picker signals good eyesight and patience—useful traits, to be sure, but not as predictive of certain types of fitness as turtle-hunting skill. A study of the Meriam, who live on a group of islands of northern Australia, found that male turtle hunters had more than twice as many surviving offspring at age fifty as non-turtle-hunters.[6]

Relatedly, many craft traditions involve commitments that require sufficient time and resources. These activities can result in useful objects—blankets, for example. Craft traditions also involve the making of ceremonial objects that have little practical value. Some anthropologists interpret their creation as signaling. The meaning that accrues to such objects—they can be endowed with substantial cultural significance—need not depend on their functionality.

Some advertising also can be interpreted as costly signaling. By purchasing an expensive Super Bowl commercial, a company signals legitimacy. It implies that it believes consumers will like its product enough for the company to earn back the cost of the advertisement in profits. For example, imagine that two manufacturers each introduce a new coffeemaker. One of the manufacturers knows it has a superior product. The other knows that despite the best efforts of its engineers, its product is likely to break down and leave customers less than satisfied. This second manufacturer expects to have 20% of its products returned.

Millions of people may buy a coffeemaker during a given year. Without advertising, the two firms might well split the market. Suppose that the manufacturer of the better product spends $2 million on an advertisement to signal the quality of its product. The manufacturer anticipates that early purchasers will buy the product and, in the long run, that this will lead to more sales. The manufacturer may well have a version of the Polya Process model in her head. In contrast, the manufacturer of a lousy product would not take out such an advertisement because its product has little chance of large sales. Spending money to signal product quality is sometimes referred to as *burning money*. Burning money attracts buyers much as the peacock's feathers attract mates.

In all of these cases, signaling involves a cost. Those who send the signal find that the benefits of identifying their greater wealth, ability, or even generosity are reduced by the cost of the signal. In addition, the time and effort spent signaling can be thought of as opportunity costs: resources could have been used in some other way, perhaps creating greater social surplus. For example, a teenager may spend hours deciding which clothes to wear so as to signal his social awareness or devote time to nonproductive activities that he believes will improve his chances of acceptance at an elite college.

To make signaling less socially costly, we try to make signals as functional as possible. Better to have young people signal their physical fitness and bravery by playing team sports, where they learn rules of sportsmanship and collective interests, than to have them risk death jumping motorcycles. As previously noted, better to require doctors to memorize human anatomy than a random collection of J. R. R. Tolkien's Elvish languages. Nevertheless, try as we might, wasteful signaling will persist. Our challenge is to use models—in particular, the tools of mechanism design—to construct institutions and protocols so that the signals people send are as functional as possible.