**Hidden Quality: Evidence from 100 Years of Innovation**

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Over the past century, goods have improved in most observable dimensions. Modern automobiles drive further on less fuel, more safely, while providing more services. Modern crops have vastly higher yields and clothing has higher thread counts. However, there is some evidence that at least some of these improvements in observed quality have come at the expense of dimensions of quality that consumers do not observe. Simple models would suggest that innovation improves visible dimensions, sometimes at the expense of hidden dimensions. A common policy response is to mandate that a subset of these dimensions be disclosed, but disclosure can increase the distortion of innovation away from dimensions that remain hidden, in some cases lowering welfare. This project models, and will assess, the impact of innovation and disclosure regulations on quality in an important industry.

Even simple goods have many dimensions of quality. For example, consider an orange. Its attributes include a nutrient profile, with nutrients we have discovered as well as ones we have yet to discover. These are many: the most commonly used nutrient database reported up to 146 components per food item in 2011, up from 113 components in 2001 and 79 in 1996.[1] But in reality, each nutrient in an orange is not just a number but a function of other variables, including time since harvest and exposure to light, heat, and chemicals. The orange also may contain residue from any pesticides or fertilizers used during production, or waxes used to improve durability during transit. There may also be unforeseen effects of genetic engineering. Even for simple goods, quality has a staggering number of dimensions.

Given this high dimensionality, it is not feasible to communicate all dimensions of quality when exchanging a good over a market. Verification is costly, there are cognitive costs associated with assessing each dimension, and dimensions may be shrouded (Gabaix and Laibson, 2006). As a result, consumers make decisions on surprisingly little information. Some dimensions are known at the time of purchase: a consumer buying an orange may observe its smell, the condition of its peel, its weight, and a label. After purchase, the consumer may experience its taste and appearance within the peel. Even an extremely informed consumer knows more only very coarsely: she may have memorized a subset of the nutrient profile from a few representative oranges tested in a government lab, and may have internalized some rules of thumb about nutrient depletion (vitamin C deteriorates in sunlight) or labels to avoid. Most dimensions of quality are effectively never known by the consumer.

Hidden dimensions of quality can have large economic significance. Electronics on standby mode represent up to 10% of residential electricity consumption, but little information is provided to consumers (Economist, 2006). Although air conditioning systems represent 5.5% of vehicle fuel use in the U.S. (Rugh et al., 2004), they were not included in fuel economy ratings until 2008, and are now included only in a limited way.

Given that consumers internalize these hidden dimensions, we might expect that consumers would learn them over time. This is certainly the case for some dimensions of quality; however, there is a large class of dimensions that are internalized but difficult to attribute. Attribution can be difficult because of a lag (micronutrient deficiency and radiation exposure have delayed effects) or because the consumer cannot disentangle multiple factors affecting an outcome (electronics draw substantial amounts of electricity in their idle state but consumers observe only aggregate power usage).

But hiddenness introduces a puzzle: why would firms provide hidden quality at all? One

[1] U.S. Department of Agriculture's National Nutrient Database for Standard Reference.

reason is that firms have some dynamic incentives: declines in hidden quality may eventually be detected, and lead to loss of brand perception, or lawsuits if laws were violated. A second reason is that the production technology provides a constraint: with a given technology there are only so many ways to manipulate quality. Given the option, orange farmers might decrease vitamin C content if it resulted in a more attractive peel, but this option may not be available. But if it is production technology that secures a given level of hidden quality, then innovation can ease these constraints. Innovation makes production technologies more flexible, which can have ambiguous effects on hidden quality and thus welfare.

This project contains two components:

In the first portion, I outline these effects in a simple model: while innovation improves observed dimensions of quality, it has ambiguous effects on hidden dimensions. When innovation has negative effects on hidden dimensions, consumers may be willing to pay to ensure they are buying from a noninnovative producer. A common policy response is to mandate disclosure of threatened dimensions of quality, but I show that disclosure policies that neglect dimensions of quality that remain hidden can in some cases lower welfare.

The second, empirical portion is to be completed. I will measure how hidden and observed quality has been affected by innovation in a good of economic importance. I plan to focus on the U.S. food industry, which has four desirable attributes: hidden dimensions of quality are important, the valuation of these dimensions has not drastically changed over time,[2] and there has been substantial innovation in production as well as changes in disclosure.

Over time, regulations have required more dimensions of quality to be disclosed. A key challenge is measuring qualities while they are still hidden. One strategy I will use is to decompose goods into component parts. If changes in hidden quality are primarily due to changes in composition rather than quality changes within components, it is possible to combine historical composition data with modern measurements of components that include more dimensions of quality. For example, say we are interested in how the hidden nutrient content of a type of cracker has changed over time. We can observe how the composition of the product has changed over time by viewing ingredients labels, and may note that butter was replaced with canola oil at some point. If we hold fixed any changes in the nutrient content of components, we can then impute the nutrients of each component from modern tables. This procedure can be replicated at a lower level: first among processed foods, assuming that ingredient quality remains fixed, and then within ingredients themselves. For example, agricultural data suggests that innovation in the varieties of wheat over the past century have resulted in improved yields at the expense of mineral content.[3]

I aim to measure how producers change quality in response to innovations (such as new varieties, additives, irradiation, etc.) and changes in labeling requirements (including minor changes as well as major changes in 1906, 1913, 1966, and 1994).

A grant would provide support for data collection and analysis for the empirical portion of the paper. My hope is that a better understanding of hidden quality can lead to better policies around both disclosure and innovation for sectors where hidden quality is important.

*References*

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[2] For example, vitamins are generally desirable.

[3] See, for example, Garvin, David, Ross Welch, and John Finley. (2006) "Historical Shifts in the Seed Mineral Micronutrient Concentration of US Hard Red Winter Wheat Germplasm." *Journal of the Science of Food and Agriculture*.