THE ECONOMICS OF LABELING CREDENCE GOODS: THEORY AND MEASUREMENT

by

Francisco Albert Scott

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STATEMENT OF COMMITTEE APPROVAL

Dr. Juan Pablo Sesmero, Chair
Department of Agricultural Economics

Dr. Joseph Balagtas
Department of Agricultural Economics

Dr. Steven Wu
Department of Agricultural Economics

Dr. Timothy Cason
Department of Economics

Approved by:
Dr. Nicole J. Olynk Widmar

To my wife

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ABSTRACT

This dissertation expands on the economics of labeling products with credence quality attributes. Specifically, it aims at incorporating recent discussions in the food markets regarding 1) consumers' difficulty of perceiving the exact quality that labels try to communicate and 2) imperfect competition on quality and price between firms providing these labeled products. These items are important because consumers and firms have to navigate a market environment in which there exist many quality labels competing for consumers' preferences (e.g., nonGMO, USDA organic, Bioengineered label, local) with many of these labels offering different grades of quality (e.g., 100% organic, organic, made with organic ingredients). While more quality label may match consumers' heterogeneous preferences, they may cause confusion and misperception among buyers, ultimately impacting efficiency and distribution of surplus in the market. More quality labels also may impact firms' decisions as firms can select themselves into different poles of the quality spectrum and avoid price competition by doing so. Finally, governmental policies that aim at educating consumers or provide them with more options (e.g., informational-based policies, graded USDA organic certification program) can have unintended consequences under an environment in which there exist market failures related to information or competition.

My goal is to evaluate this complex environment in three interconnected studies. The first study is an applied theory paper in which I show how curbing consumers' misperception about quality in a market of labeled credence attributes may decrease welfare if firms imperfectly compete in quality and prices. I show that this is true if consumers' misperception offers incentives for firms to either expand the size of the market or increase the average quality of products offered. The second essay empirically tests these insights in controlled laboratory experiments in which subjects act as sellers that compete along quality and price dimensions. I show that the insights of the theory paper hold particularly when consumers overvalue a high-quality product that holds a large market share. Finally, in the last study of this dissertation, I show that the rank-order of the USDA organic certification program may not hold in all markets, as consumers may not have a high willingness to pay for 100% organic products. In the study, I show that consumers in the market of organic ground coffee

market could be better off if USDA ditched the quality grade **100% organic** of its program. Doing so would also benefit the most profitable firms in the market and increase welfare.

This dissertation shows that label programs and food policies that tackle quality in credence attributes must be designed with two main market characteristics in sight. The first is how well consumers understand the information in labels. The second is what is the degree of competition in the market and how firms can use the certification program to extract further rents from consumers.

1. INTRODUCTION

This dissertation deals with the efficiency and distribution effects of quality food labels when 1) there exists a richer set of grades of food labels in the market, 2) consumers misperceive the true quality of the credence attributes communicated by labels, and 3) competition is imperfect. The discussion is timely because, across markets, consumers' purchase decisions are based on several observable and unobservable product attributes. Unobserved attributes, often called credence attributes, play an important role in determining quality in the market of food goods. Examples range from organic certification programs, meat grades, animal welfare seals, non-GMO seals, local products, to a myriad of ecological friendly products. Particularly for food products, the government has been active in promoting certification for credence attributes, often using grading systems to classify different strands of quality used by firms to compete in the market.

Ultimately, policies that aim to unravel unobservable attributes strive for a better match between what buyers want to consume and the type of product that firms can offer (Roe and Sheldon 2007; Sexton 2013). The quality of information flow determines the extent to which certification policies succeed in creating this match between consumers' tastes and product variety. In markets of credence attributes, this is achieved with the use of third-party certification – in other words, labels. However, not all labels are able to perfectly communicate quality to consumers. Labels with narrow or confusing standards can foster noise in the certification system, which in turn can lead to changes in welfare and suboptimal provision of quality (Albano and Lizzeri 2001; Dranove and Jin 2010). The market of food products does not lack examples: the standards used in USDA's organic certification program are not readily available to consumers, and what truly consists of a genetically modified organism (GMO) is poorly understood (Lee et al. 2013; Lusk 2018).

The government is also involved in the market of food labels, by offering its food label programs. Governmental agencies often promote certification based on a grading system that can foster quality differentiation. In an environment where firms imperfectly compete in quality and prices, competition over product characteristics (e.g. adoption of different label grades) provide a way for firms to avoid intense price competition by selecting into different poles of the characteristic spectrum (e.g. Lehmann Grube 1997; Bonroy and Constantatos 2015) or selecting a product line that contains products with different characteristics (e.g. Eizenberg 2014 and Wollmann 2018). This implies that firms can explore gradation in the certification design to extract rents from consumers.

In practice, labels seem to be a straightforward way to communicate the presence of credence attributes and reach buyers eager to consume better quality, or more ethical (however defined) and healthier products. On one hand, a large part of the economic literature assumes that labels solve the problem of credence attributes by revealing the true quality of goods (Boyan Jovanovic 1982; Lavin, Peck, and Ye 2009; Plastina, Giannakas, and Pick 2011). If this is the case, a richer set of labels corresponds to a richer space of product varieties, and the economic problem becomes matching consumer tastes to product characteristics, a classical problem in industrial organization (Spence 1975; Mussa and Rosen 1978; Ronnen 1991; Motta 1993; Bonroy and Constantatos 2015). On the other hand, the economics literature has devoted large resources to investigate the effects of poor information flow on welfare (Lizzeri 1999; Garella and Petrakis 2008; Milgrom 2009). It is intuitive to think that there exists an intersection between these two problems. Particularly, there exists the possibility that labels can introduce noise in consumers' perception of quality (henceforth we call the phenomenon misperception) when the standards that govern the certification of a quality label are poorly defined and communicated. Yet, a large part of the literature on food labels has studied the problem of quality misperception separately from the problem of imperfect competition.

My first essay, entitled **"Market and welfare effects of quality misperception in food labels"** is an applied theory paper in which we study the efficiency and distributional effects of consumers' misperception of product quality, as well as policies aimed at reducing it, once firms' strategic responses to misperception are accounted for. We consider an oligopoly model where heterogeneous consumers can over- or under-estimate the quality of products, and firms choose quality and prices conditional on consumers' perception of quality. Such environment maps the situation in which consumers misperceive quality of food products that adopted quality labels to communicate a credence attribute.

In this essay, I develop a model in which oligopolist firms producing vertically differentiated products compete in a quality-then-pricing game and find the sub-game perfect Nash equilibrium levels of quality and price. Our model is tractable in that it allows us to generate comparative statics fully characterizing the effect of changes in consumers' perception of quality (presumably due to changes in labeling and information-based policies) on total surplus as well as its distribution across producers and consumer segments. We find that, under empirically prevalent conditions, misperception can increase efficiency in relation to the perfect information case; it does so if 1) it strengthens firms' incentives to provide higher quality, countervailing the chronic underprovision of quality that prevails under perfect information or 2) it galvanizes competition, reversing another deleterious effect of product differentiation, namely high quality-adjusted markups that restrain commerce. Our results imply that information-based policies aimed at curbing misperception (including stricter labeling policies, nudging, changes in labeling format) can have deleterious effects on efficiency and, perhaps more importantly, hurt the consumers they mean to protect.

Empirically testing the conditions under which misperception of quality can increase efficiency in the market is challenging. The challenge lies in the fact that misperception is the difference between a consumer's perceived quality of a product, and the quality the consumer would perceive had they had full understanding of credence attributes in that product. Both of these measures are typically unobservable to the researcher. To circumvent these limitations, I use a laboratory experiment in my essay **"Market and welfare effects of quality misperception: an experimental analysis"** to test the effects of misperception on market surplus.

In the experiment, subjects play the role of sellers facing consumers with heterogeneous preferences for quality (played by the computer). We leverage on the fact that misperception shocks (changes in under- or overvaluation of quality by consumers) translate into specific demand changes to create treatments that depart from a benchmark case in which consumers perfectly understand quality information. I developed 4 treatments that characterize different levels of misperception under over- or undervaluation of high-quality or low-quality by consumers. I incentivize subjects playing sellers in choosing quality and price for their products under different treatments.

Experiment results indicate that overvaluation of high-quality products relative to their lower-quality competitors (e.g., 100% organic relative to organic or made with organic) and undervaluation of low-quality products (e.g., presence of GM inputs relative to GM-free) results in a significant increase in quality and prices at the higher end of the spectrum, increase in profit for the high-quality seller, and increase in total welfare. Misperception produces ambiguous changes in outcomes at the lower end. Efficiency measures show that effective informational-based policies should focus on high-quality products, but distributional measures show that efficiency gain is at the expense of the low-quality segment of the market.

A priori, the effects of additional grades of a quality label on market efficiency and distribution (how rents are distributed between consumers and producers) are ambiguous. On the consumer side, a wider variety spectrum better matches heterogeneous consumer preferences possibly increasing welfare. On the production side, more varieties can increase product differentiation and soften competition possibly resulting in welfare reductions due to market power exertion. Moreover, inefficiency can emerge not only from market power exertion, but also from excessive competition in certain quality segments, and insufficient competition in others. These frictions may emerge because, in the absence of coordination, firms may rush to newly labeled varieties in an attempt to escape competition in existing market segments among firms (Berry, Eizenberg, and Waldfogel 2016). This may reduce the price of the new variety below total average cost, while creating supernormal profits in other segments abandoned by competitors. The interplay between these demand and supply forces makes welfare implications of additional labeling ambiguous.

We deal with this problem in the essay **"Optimal quality gradation in organic labels: evidence from a structural econometric model"** that aims to empirically analyze how government-defined grades for quality labels can impact the size and distribution of surplus in food markets. We use the standards of the USDA's Organic Certification program as a case of study. Products under the Organic Certification program can fall under 2 main grades for organic certification: "100% organic", and "organic". The higher quality organic grade ("100% organic") does not allow for any non-organic input, but products under "organic" are allowed up to 5% non-organic inputs. While both are allowed to carry a USDA organic shield in the front of the package, products certified "100% organic" can additionally use a *100 percent organic* claim. We explore whether the *100 percent organic* claim is salient to consumers and whether firms strategically select into different quality grades to avoid price competition.

To do so, we use scanner data of ground coffee purchases to estimate a structural model of differentiated products that takes into account firms' labeling and price decisions. Demand and supply parameters are estimated via IV-GMM using the traditional BLP framework (Berry and Reiss 2007; Nevo 2001; Berry and Haile 2016). We argue that our model is well-identified under the assumption that producers cannot perfectly predict demand shocks during the labeling decision. We then exploit these structural estimates to generate gradation counterfactuals and examine the market and welfare effects of shrinking or expanding quality gradation. Results indicate that shrinking gradation may result in gains in consumer surplus, and higher profits for some firms. An important qualification of this result is that welfare gains are conditional on firms not exiting the market, something that the coffee market seems to support but need not be true of other markets.

Figure 1.1 shows how the different pieces of the dissertation relate. My objective is to study the effects of labels in an oligopolistic credence goods market, where incentives to differentiate products via certification are strong, but in which signal introduced by labels can be noisy and heterogeneous. I will generate three interconnected studies. This dissertation hopes to inform, theoretically and empirically, the conditions under which labels can be welfare-enhancing in an oligopolistic market of credence goods.

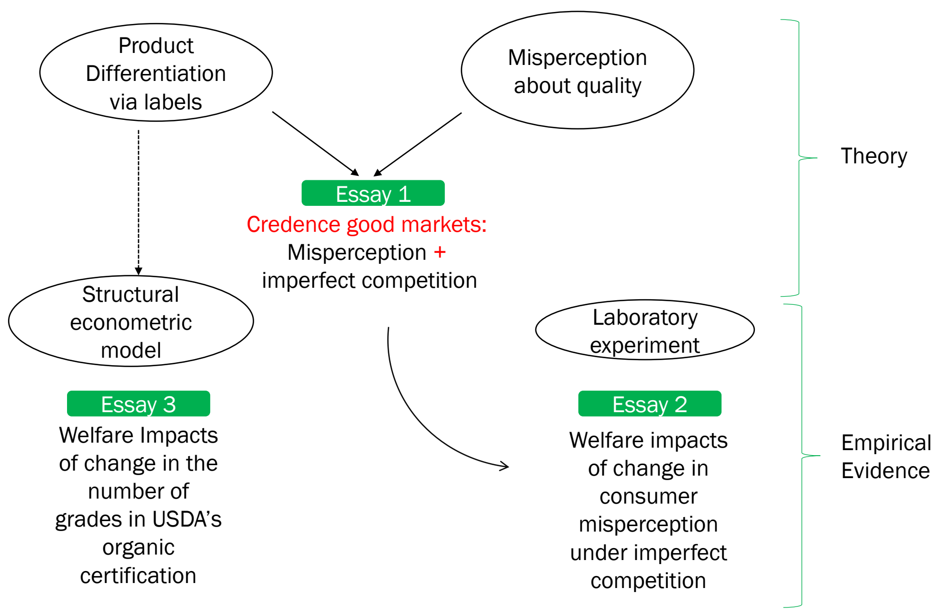

Figure 1.1. The dissertation structure consists of three interconnected essays that use theory and empirical evidence to study labels in markets of credence goods

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2. MARKET AND WELFARE EFFECTS OF QUALITY MISPERCEPTION IN FOOD LABELS

Empirical evidence indicates that consumers routinely misperceive the quality of food products. As a result, they overvalue (overestimate quality) some food products (e.g., Lee et al. 2013; McFadden and Lusk 2018; Bernard, Duke, and Albrecht 2019) and undervalue (underestimate quality) others (e.g. Kiesel and Villas-Boas 2013; Rainie et al. 2015; Liaukonyte, Streletskaya, and Kaiser 2015) relative to their competitors along the quality spectrum. Conventional wisdom dictates that misperception distorts consumers' choices and reduces their welfare. Regulators and the public have favored information-based policies, more prominently labels, to inform consumers and help them make better choices (Roe and Sheldon 2007; USDA 2013; Bonroy and Constantatos 2015; NYTimes 2017; Lusk 2018). Yet, much remains unexamined regarding firms' strategic responses to misperception and, consequently, the effectiveness of information-based policies to protect consumers and enhance overall market efficiency.

We consider a market in which two single-product firms compete on quality and prices. Following Bonroy and Constantatos (2015), we assume quality is determined by credence attributes and these attributes are conveyed by labels, but consumers may misperceive the information in those labels. We show that producers' strategic reactions to consumer misperception can increase welfare of some consumers and even raise market efficiency relative to a situation without misperception. This may seem surprising at first glance. After all, misperception leads consumers to make incorrect choices (Villas-Boas et al. 2020), and it leads firms to extract informational rents from misinformed consumers. However, we find that firms' strategic reactions to misperception lead to higher efficiency if they: 1) raise the average quality offered in the market partly correcting the underprovision of quality that prevails under imperfect competition in the absence of misperception; or 2) expand the size of the market enough to offset reductions in average quality.

Strategic reactions raise the average quality offered in the market when misperception provides incentives for firms to offer higher qualities. In our duopoly model with single-product firms, this takes place when consumers overvalue either labeled product. When consumers overvalue the higher-quality product, the firm offering this product raises its quality (because returns to quality are higher and the firm can also increase markup without a significant loss in market share), to which the follower responds by raising its own quality (because it allows it to increase markup). In other words, the increase in quality of the high-quality product “pulls” the low-quality product up the quality spectrum. Governed by the same forces, when consumers overvalue the low-quality product, the firm offering this product raises its quality and “pushes” the higher-quality product up the quality spectrum in equilibrium.

We also find that misperception can still result in higher efficiency, even if it does not induce a rise in the average quality offered in the market, as long as firms’ strategic reactions to misperception lead to an expansion in the market for labeled products. In our duopoly model with single-product firms, this can happen when consumers undervalue the high-quality labeled product and simultaneously overvalue the low-quality labeled product; in other words, consumers under-estimate product differentiation. As a result, misperception *can* (under conditions we formally identify) push products sufficiently close to each other on the quality spectrum, so that price competition delivers an expansion in the market for labeled products in equilibrium. In this situation, while misperception does not help reverse the underprovision of quality that prevails in its absence, it does galvanize competition intensity which reverses another deleterious effect of product differentiation, namely high quality-adjusted markups that restrain commerce.

A key corollary of our findings is that, under empirically prevalent conditions, information-based policies that seek to curb misperception (e.g. stricter labeling rules, allowing uncertified private labels, changes in the format information is presented, nudging, etc.) may reduce efficiency. But, perhaps more importantly, these interventions may also harm the very consumers they mean to buttress. We find that interventions that reduce misperception invariably hurt at least one consumer segment. In fact, in many cases, the losses in this consumer segment exceed gains in other segments, reducing total consumer surplus. Reduction of misperception harms two consumer segments: consumers that purchase a product that is undervalued before the intervention; or consumers that purchase a product that competes with another that is overvalued before the intervention.

There are many examples of information-based policies that seek to curb misperception and that, based on our findings, seem likely to be detrimental for consumer surplus and efficiency. The Organic Foods Production Act of 1990 and the subsequent rules for organic certification are likely to: decrease the average quality offered in the market due to undervaluation of the organic label in reference to the "made with organic" label (Streletskaya, Liaukonyte, and Kaiser 2019); or weaken price competition due to reduced valuation of the organic label in conjunction with increased valuation of the 100% organic label. FDA's 2003 requirement for labeling the presence of Trans-Fat reduces consumers' valuation of these products relative to other alternatives along the quality spectrum (Kiesel and Villas-Boas 2013), which may erode incentives to reduce Trans-Fat when they are not fully eliminated.

Other prominent examples include California's Proposition 37 of 2012 and Vermont's Act 120 of 2016, as well as the National Bioengineered Food Disclosure Standard of 2016 requiring firms to disclose when products contain GMOs. This is likely to cause undervaluation of these products relative to others without the "contain" label (Liaukonyte, Streletskaya, and Kaiser 2015; Villas-Boas et al. 2020). Finally, examples are not only constrained to enacted policies but also include proposed policies. To simplify information in labels, many have advocated for visual cues that replace rather complicated information; for instance, adding a green-, yellow-, and red-colored stickers to products to reflect their nutritional quality. Strategies that simplify information can result in consumers overestimating the difference in quality across products (Villas-Boas et al. 2020).

Our study contributes to a rather thin literature on market and welfare effects of quality misperception. Studies in this literature model very specific situations both in terms of the nature of misperception, as well as the nature of quality competition. Regarding the nature of misperception, previous studies model misperception as either consumers' inability to distinguish between quality grades (e.g. Brécard 2014; Buehler and Schuett 2014; Brécard 2017) or, specifically motivated by eco-labeling, overvaluation of medium quality products (e.g. Baksi, Bose, and Xiang 2017). Contrarily, empirical evidence suggests that misperception of quality in food products can manifest as under- or over-valuation of goods located anywhere in the quality spectrum. We develop a framework that considers these types of misperception in a systematic way and show that different types of misperception can have drastically different market and welfare implications.

Regarding the nature of competition, the strategic environment in which firms operate can vary widely across food markets. In some markets, firms have the ability to credibly commit to a choice of quality and reveal it to its competitors, effectively turning the quality-competition stage into a sequential game (Aoki and Kurz 2003). A recent example of this is the move by some poultry firms to build capacity to produce cage-free eggs (e.g. EggIndustry 2019) in order to serve retailers and restaurants that took a pledge to demand only cage-free eggs by 2025 (Lusk 2019). In other cases, firms do not have the ability to credibly commit to a choice of quality before others and the quality-competition stage resembles a simultaneous game. An example of this is competition on nutritional content (e.g. non-fat yogurt; no trans-fat) where biochemical processes underlying qualities are well-understood by all firms. A key feature underlying the ability of firms to commit to a quality level is the cost of switching between these levels, influenced by sunk costs and asset specificity; if cost of switching is high (low) firms can (cannot) credibly commit to a choice of quality.

Despite the empirical ubiquity of sequential and simultaneous quality competition and the fact that the nature of quality competition is a crucial factor governing equilibrium in markets without misperception (e.g. Aoki and Prusa 1997, Lehmann Grube 1997), previous studies that incorporate consumer misperception only considered simultaneous quality choice. We differentiate from those studies and examine both simultaneous and sequential quality competition and study their interaction with the nature of misperception.

In sum, we find that quality misperception translates into changes in demand which, in turn, trigger strategic responses by firms. These strategic responses change qualities and prices offered in equilibrium. Consequently, information-based policies seeking to curb consumer misperception shift qualities and prices in equilibrium. We formally characterize these changes in equilibrium and find that the effects of common information-based policies on consumer surplus (total and by consumer segment) and efficiency depend crucially on the nature of misperception as well as the nature of competition. Policies that reduce misperception are likely to be harmful if consumers overestimate the quality of a product, or if the intervention raises (reduces) perceived product differentiation when quality competition is simultaneous (sequential). Thus, our analysis suggests that information-based policies should contemplate not only demand-side forces like the type of misperception likely to prevail in the market, but also supply-side ones like sunk costs and asset specificity associated with production of higher quality levels.

The paper is structured as follows. Section 1 formally introduces the models and our equilibrium concepts. Sections 2 and 3 describe the market and welfare effects of misperception, respectively. Section 4 discusses the implications for information-based policies in the United States and Section 5 concludes.

2.1 Model

2.1.1 The Demand Side: Heterogenous Consumers and Misperception

Consider a market where consumers differ in their taste for quality, denoted by v, and are distributed along a continuum of unit length depicting willingness-to-pay (WTP) for quality, θ. Consumers are distributed along the continuum according to a uniform probability distribution function with unit density. Two single-product firms operate in the market, so consumers can choose between two labeled products and an outside good, and they buy a single unit of the good they choose to consume.

Quality attributes are credence (e.g. effect of consumption on health, the environment, animal and human welfare, etc.) and, hence, unobservable to consumers. However, the quality grade v of each labeled product is certified by a non-profit, credible third-party. This third-party uses a continuous grade program to certify quality. Misperception can arise from imperfect disclosure of information or imperfect understanding of information included in labels (Brécard 2017). We follow many previous studies (Ben Youssef and Abderrazak 2009; Harbaugh et al. 2011; Brécard 2014, 2017) and assume certifiers are honest and do not act strategically. Also, we do not endogeneize the decision of what to label (e.g. Forlin 2020) and instead focus on misperception arising from consumers' inability to fully understand information in labels; a phenomenon widely documented in the literature (see a discussion in Zilberman, Kaplan, and Gordon 2018).

Misperception creates a misalignment between perceived and actual product quality. Because we only have two labeled products in the market, the quality of the product certified with the relatively higher quality grade is represented by v_h, and a relatively lower quality grade is represented by v_l; i.e. $v_h > v_l$. We also formally introduce two misperception parameters, k_h and k_l. We interpret these as wedges between perceived and actual quality; perceived qualities are denoted by $k_h v_h$ and $k_l v_l$ for the high- and low-quality products, respectively. In the absence of misperception regarding quality of product j, we have $k_{\mathrm{j}} = 1$; in the presence of overvaluation $k_{\mathrm{j}} > 1$; and in the presence of undervaluation $k_{\mathrm{j}} < 1$.

As suggested by empirical evidence, misperception can increase or decrease the perceived difference in quality between products, and it can also increase or decrease the perceived average quality of products offered in the market. These are important distinctions because market efficiency is related to the average quality offered in the market but also the intensity of price competition, which is influenced by the perceived difference in quality. Different types of misperception can have disparate effects on these forces, making a systematic analysis of misperception sources crucial.

With these considerations in mind, we study six types of misperception. First, we consider a case in which consumers overvalue the high-quality product only, i.e. $k_h > 1$ and $k_l = 1$; this raises the perceived difference in quality between products while also increasing the perceived average quality of products in the market. Second, we consider a case in which consumers overvalue the low-quality product only, i.e. $k_h = 1$ and $k_l > 1$; this reduces the perceived difference in quality between products while also increasing the perceived average quality of products in the market. Third, we consider a case in which consumers undervalue the high-quality product only, i.e. $k_h < 1$ and $k_l = 1$; this reduces the perceived difference in quality between products while also reducing the perceived average quality of products in the market. Fourth, we consider a case in which consumers undervalue the low-quality product only, i.e. $k_h = 1$ and $k_l < 1$; this raises the perceived difference in quality between products while also reducing the perceived average quality of products in the market. Fifth, we consider a case in which consumers overvalue the high-quality product and undervalue the low quality in the same magnitude; this raises the perceived difference in quality between products but without affecting the perceived average quality of products in the market.

Finally, we consider a case in which consumers undervalue the high-quality product and overvalue the low quality in the same magnitude; this reduces the perceived difference in quality between products but without affecting the perceived average quality of products in the market.

Armed with these representations of misperception, we modify the class of indirect utility functions (Bonroy and Constantatos 2015) presented initially by Jean Tirole (1988) and subsequently pursued by Ronnen (1991) and Lehmann Grube (1997) by altering their definition of consumer's utility. We let the indirect utility of consumers that buy labeled quality grade j be $V_{\mathrm{i}}\left(v_{\mathrm{j}}, p_{\mathrm{j}}, k_{\mathrm{j}}\right) = \theta_{\mathrm{i}} k_{\mathrm{j}} v_{\mathrm{j}} - p_{\mathrm{j}}$, where i is an index of the consumer's position in the WTP distribution, θ_{i} is the consumer's valuation of quality, $k_{\mathrm{j}} v_{\mathrm{j}}$ is consumers' perceived quality of product j (j $= l$ for the low-quality labeled product and j $= h$ for the high-quality labeled product), and p_{j} is the price paid for product j. For the treatment in which misperception is on low-quality grades, $k_h = 1$. For treatments in which misperception is on the high-quality grade, $k_l = 1$. We normalize the indirect utility of those consumers consuming the outside good to zero.

The consumer who is indifferent between buying the low-quality product and the outside good, given by θ_{0l}, can be found by setting the indirect utility of these options equal, such that $\theta_{0l} k_l v_l - p_l = 0$. This implies $\theta_{0l} = \frac{p_l}{k_l v_l}$. By the same procedure, the consumer who is indifferent between buying the low-quality and high-quality is $\theta_{lh} = \frac{p_h - p_l}{k_h v_h - k_l v_l}$. These expressions determine the market for low- and high-quality labeled products. Aggregate demands are given by $D_h\left(v_h, v_l, p_h, p_l; k_h, k_l\right) = \int_{\theta_{lh}}^{1} d\theta = 1 - \theta_{lh}$, and $D_l\left(v_h, v_l, p_h, p_l; k_h, k_l\right) = \int_{\theta_{0l}}^{\theta_{lh}} d\theta = \theta_{lh} - \theta_{0l}$ for high- and low-quality products, respectively. It is clear from these expressions that the quality of labeled goods and their price affect their consumption. Both of these emerge endogenously in equilibrium from the interaction between demand and strategic supply responses by firms in this market. We now turn to the supply side of the model.

2.1.2 The Supply Side: Quality and Price Competition

On the supply side, we consider a market with single-product suppliers. Firms have access to the same technology, which consists of constant marginal cost, normalized to zero.

For simplicity let us assume that two firms are active in the market and that they offer products containing one or more credence attributes that are certified through labels. The cost of certification $C(\cdot)$ is independent of the number of units produced but increasing in the quality level. Studies using duopoly models of vertically differentiated products typically assume $C(\cdot)$ is convex and twice continuously differentiable. This assumption guarantees fulfillment of the second order conditions for a maximum and existence of a unique equilibrium in pure strategies (Lehmann Grube 1997). In our study, consideration of a range of misperception types places an additional burden on tractability. We follow a common practice in the literature (e.g. Motta 1993; Aoki and Prusa 1997; Buehler and Schuett 2014 ; Baksi, Bose, and Xiang 2017) and assume a quadratic cost structure of the form $C\left(v_{\mathrm{j}}\right)=\frac{v_{\mathrm{j}}^{2}}{2}$ ($\mathrm{j} \in h,\ l$), which renders our model tractable (i.e., capable of generating unambiguously signed comparative statics) across misperception types.[1]

Conditional on the aggregate demand for each product characterized in the previous sub-section, competition between duopolists proceeds in two stages. First, firms choose quality (quality-competition stage) and then, conditional on quality, they compete in prices (price-competition stage). The solution of the two-stage game is characterized by the Sub-Game Perfect Nash Equilibrium (SPNE), which is computed by backward induction; i.e. we first solve for equilibrium prices of the price-competition stage conditional on qualities (equilibrium best-response prices), and then solve for equilibrium qualities conditional on equilibrium best-response prices.

Profits of duopolist firms in the price-competition stage are:

$$\pi_h = R_h\left(v_h, v_l, p_h, p_l; k_h, k_l\right) - C\left(v_h\right) = p_h D_h\left(v_h, v_l, p_h, p_l; k_h, k_l\right) - C\left(v_h\right) \tag{2.1}$$

$$\pi_l = R_l(v_h, v_l, p_h, p_l; k_h, k_l) - C(v_l) = p_l D_h\left(v_h, v_l, p_h, p_l; k_h, k_l\right) - C(v_l), \tag{2.2}$$

where $R_{\mathrm{j}}(v_h, v_l, p_h, p_l; k_h,\ k_l)$ stands for revenue of the firm offering product j and the rest is as defined before.

1. ↑Our results generalize to other cost structures that are convex, but not of the quadratic form. Numerical simulations that demonstrate this are available from the authors upon request.

The price-competition stage is assumed to be simultaneous because no firm has a credible mechanism to commit to a specific price before the other firm. Therefore, conditional on quality choices, the solution of the price-competition stage is defined by the Nash Equilibrium of the duopoly Bertrand-pricing game, which consists of a system of two first order conditions: $D_h(v_h, v_l, p_h, p_l; k_h, k_l) + p_h \frac{\partial D_h(v_h, v_l, p_h, p_l; k_h, k_l)}{\partial p_h} = 0$ and $D_l(v_h, v_l, p_h, p_l; k_h, k_l) + p_l \frac{\partial D_l(v_h, v_l, p_h, p_l; k_h, k_l)}{\partial p_l} = 0$. With a zero marginal cost of production, the firm raises the price to balance the marginal benefit of a higher markup with the marginal cost of earning that markup on a smaller number of units (due to decreased demand). The solution to this system of equations characterizes optimal prices as functions of qualities (the equilibrium best-response prices):

$$p_h{}^*(v_h, v_l; k_h, k_l) \tag{2.3}$$

$$p_l{}^*(v_h, v_l; k_h, k_l) \tag{2.4}$$

The quality-competition stage is more complex than the price-competition stage. This is because different products are fundamentally different regarding the ability of firms that produce them to switch grades along the quality spectrum. When the cost of switching between different grades is small, firms do not have a credible mechanism to commit to a specific quality before the other firm, given rise to a simultaneous quality-competition game. By contrast, when the cost of switching grades is large, firms can credibly commit to a specific quality giving raise to a sequential quality-competition game. In both cases firms choose quality to maximize profits (2.1) and (2.2) subject to equilibrium pricing strategies (2.3) and (2.4):

$$\max_{v_h} \pi_h = p_h{}^* D_h(v_h, v_l, p_h{}^*, p_l{}^*; k_h, k_l) - C(v_h) \tag{2.5}$$

$$\max_{v_l} \pi_l = p_l{}^* D_l(v_h, v_l, p_h{}^*, p_l{}^*; k_h, k_l) - C(v_l) \tag{2.6}$$

Notice that programs (2.5) and (2.6) are the same as (2.1) and (2.2) but with (2.3) and (2.4) inserted in them. The solution to problems (2.5) and (2.6) varies according to the nature of the game. More fundamentally, the conditions under which there is a solution (a unique equilibrium in pure strategies) also vary according the nature of the game. We now turn to a description of the procedure by which an equilibrium in quality competition is obtained, and the conditions that guarantee such equilibria exist and are unique.

We start by assuming that firms compete sequentially in the quality game. This assumption is in line with markets in which switching across quality grades is very costly and, thus, a firm can commit to a certain quality level preempting the other from choosing that quality. Which firm chooses first is inconsequential in this case because firms are otherwise homogeneous. In this case, the leader (first mover) chooses a quality and then the follower responds by choosing its own. All of these choices are conditional, of course, on optimal pricing strategies (2.3) and (2.4).

The solution to (2.5) and (2.6) is obtained by backward induction. First, the follower chooses quality with knowledge of the quality chosen by the leader. Then the leader chooses its quality with knowledge of the follower's best response to its own quality. The leader may choose a high or a low quality. We restrict ourselves to solutions of the quality game in which there is a unique and stable equilibrium in pure strategies. This condition restricts the domain of misperception and it has come to be known as the "no leapfrogging condition" (Lehmann Grube 1997). It turns out that under the no leapfrogging condition, the leader chooses a high-quality product and obtains higher profits than the follower (Motta 1993; Aoki and Prusa 1997; Lehmann Grube 1997). In the context of our model, we show in Appendix 1 that the no leapfrogging condition holds under the following assumptions:

ASSUMPTION 1.

$$0.75 < k_h < 1.75 \qquad \text{if } k_l = 1,$$

ASSUMPTION 2.

$$0.58 < k_l < 1.33 \text{ if } k_h = 1,$$

Intuitively, assumptions 1 and 2 rule out cases in which misperception is large enough to break the equilibrium that has the leader as the high-quality firm. Conditional on these assumptions, we start by solving problem (2.6) which yields the follower's best response function $v_l\left(v_h; k_h, k_l\right)$. Subsequently, we solve problem (2.5) subject to $v_l\left(v_h; k_h, k_l\right)$, which yields the leader's choice of quality in the SPNE of the sequential game,

$$v_h{}^s\left(k_h, k_l\right) \tag{2.7}$$

Finally, we insert $v_h{}^s\left(k_h, k_l\right)$ into the best response $v_l\left(v_h; k_h, k_l\right)$ to obtain the follower's choice of quality in the SPNE of the sequential game,

$$v_l{}^s\left(k_h, k_l\right) \tag{2.8}$$

We now turn to a situation where firms compete simultaneously in the quality game. This assumption is in line with markets in which switching across quality grades is not very costly and, thus, firms cannot credible commit to a certain quality level. In this case, both firms choose their qualities simultaneously. This implies that both firms choose with knowledge of the other firm's best response function (as opposed to the actual choice as it is the case of the follower in the sequential game), and an equilibrium takes place when both firms are simultaneously playing their best response to the other firm's quality. As in the sequential case, we impose a no leapfrogging condition that guarantees a unique and stable equilibrium in pure strategies; and as in the sequential case the no leapfrogging condition results in one firm choosing a high quality product and the other firm choosing a lower quality. Which firm happens to choose the higher quality is inconsequential for efficiency and market equilibrium as both firms are otherwise homogeneous. We show in Appendix 1 that the no leapfrogging condition holds under the following assumptions:

ASSUMPTION 3.

$$0.75 < k_h < 1.54, \text{ if } k_l = 1,$$

ASSUMPTION 4.

$$0.58 < k_l < 1.33, \text{ if } k_h = 1,$$

Conditional on these assumptions, we use (2.5) to obtain best response function $v_h\left(v_l; k_h, k_l\right)$ and (2.6) to obtain best response function $v_l\left(v_k; k_h, k_l\right)$. We then find the intersection between these to compute the Nash Equilibrium (NE) qualities of the simultaneous game for the high- and low-quality firms:

$$v_h^n(k_h, k_l) \tag{2.9}$$

$$v_l^n(k_h, k_l) \tag{2.10}$$

Note that both quality and prices in the global sub-game perfect Nash equilibrium, for the simultaneous and sequential quality competition cases, depend upon consumers' perception of relative qualities, k_{j}, $\mathrm{j} \in \{h, l\}$. The reaction of firms to misperception of relative qualities can be formally characterized by taking the derivative of the SPNE qualities and prices with respect to k_h or k_l, depending on the treatment we are discussing. We now turn to this issue.

2.2 Market equilibrium effects of quality misperception

2.2.1 Misperception on high-quality grades

Misperception of the high-quality grade (i.e., deviations of k_h away from one) in the absence of misperception of the low-quality one ($k_l = 1$) unleashes multiple forces. A first-order effect is a shift in $D_h(v_h, v_l, p_h, p_l; k_h, k_l)$ which will prompt responses in qualities and subsequently on prices according to (2.5)-(2.8) in the case of sequential quality competition and (2.5), (2.6), (2.9), and (2.10) in the case of simultaneous quality competition. These changes in quality and prices alter the marginal consumers and effectively change the size of the market for low- and high-quality grades. We formally describe these changes in the following proposition:[2]

PROPOSITION 1. Under assumption 1 (in sequential quality competition), or under assumption 3 (in simultaneous quality competition) an increase in perceived quality of the high-quality grade, i.e. an increase in k_h from k_h^0 to k_h^1 where $k_h^0 < k_h^1$,

1. *increases quality of the high- and low-quality products;*

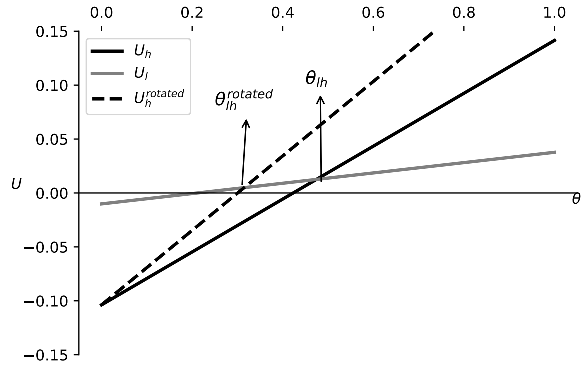
2. *increases prices of the high- and low-quality products;*

2. ↑All proofs can be found in the appendix.

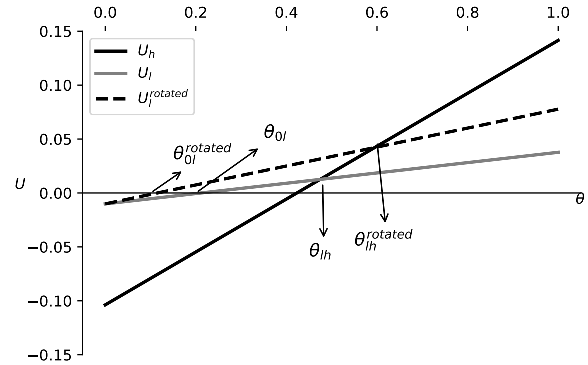
3. *increases quality-adjusted prices of the high- and low-quality products;*

4. *decreases market size of both products.*

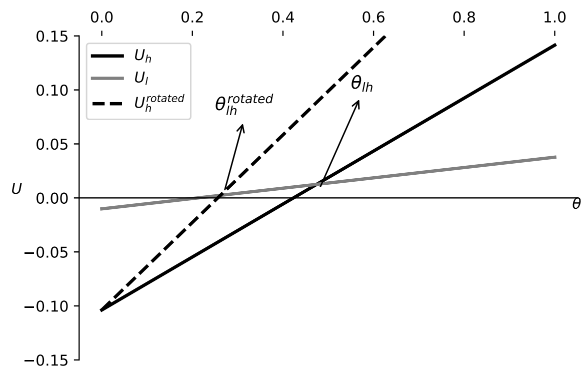
The mechanism underpinning results 1-4 in Proposition 1 is illustrated in Figure 3.1, and it applies to both sequential (under assumption 1) and simultaneous (under assumption 3) quality competition. The figure's horizontal axis represents consumers' WTP, while the vertical axis depicts values of indirect utility. As noted in our demand model, the intercepts of the indirect utility curves are equilibrium prices and the slope of the curves are determined by equilibrium qualities. Notice that the intersection between indirect utility curves marks the marginal consumer θ_{lh}, (i.e., the consumer who is indifferent between low- and high-quality grades), while the intersection between the horizontal axis and the low-quality indirect utility represents the marginal consumer θ_{0l} (i.e., the consumer indifferent between the low-quality grade and an outside option).



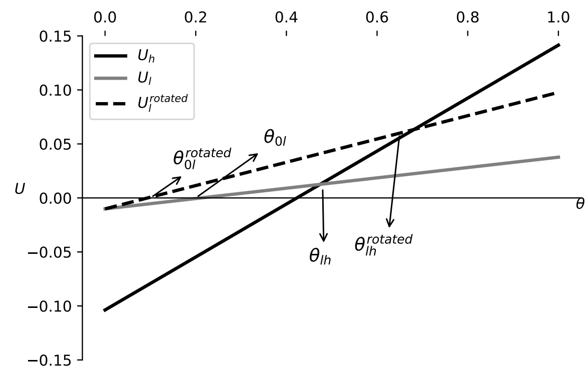
(a) Effect of overvaluation of high-quality product



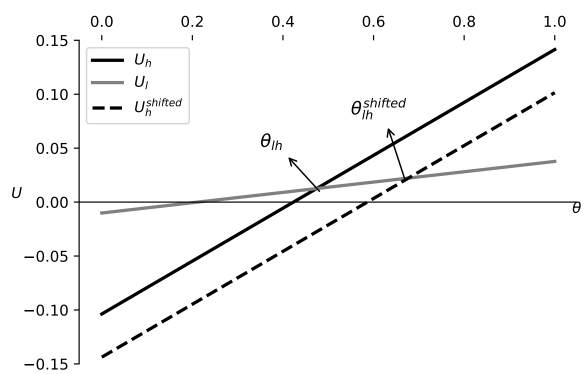
(b) Effect of overvaluation of low-quality product



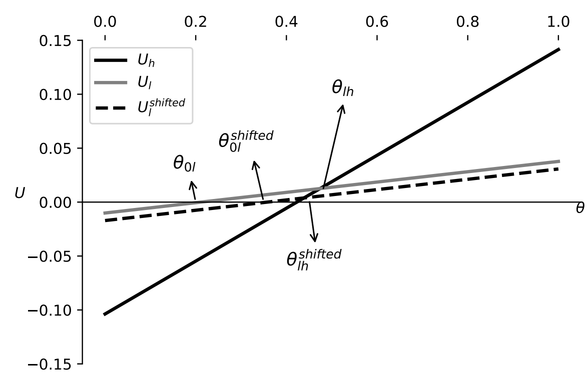
(c) Effect of quality increase in high-quality product



(d) Effect of quality increase in low-quality product



(e) Effect of price increase in high-quality product



(f) Effect of price increase in low-quality product

Figure 2.1. Effects of price and quality increase in the market of food labels. Each panel represents the effect of either prices or quality in marginal consumers, holding all else constant

Consumers' overvaluation of the high-quality grade increases the indirect utility of consumers buying the high-quality grade; and the increase is larger for consumers with a stronger preference for quality. This change is graphically represented in Figure 1a by a counterclockwise rotation of the indirect utility curve. The rotation shifts the marginal consumer θ_{lh} to the left, expanding the market for the high-quality grade. Overvaluation also strengthens the incentives to provide quality by the firm offering the high-quality product because it increases consumers' willingness to pay for higher quality. All else constant, a rise in the high-quality grade further rotates the corresponding indirect utility curve counterclockwise, as seen in panel 1c. As a result, marginal consumer θ_{lh} shifts further to the left and expands the market for the high-quality grade even more.

Following its best response function, the low-quality firm raises the quality of its product to capture market share from the high-quality firm (panel 1d); thus, the raise in quality of the high-quality product "pulls" the low-quality product up the quality spectrum. But, in conjunction with this, the follower also raises the price of its product and its margin which, as depicted in panel 1f, attenuates the gain in market share from increased quality. The low-quality firm will increase quality and price until the benefits and costs from increased margins, increased cost, and reduced market size are balanced out.

The forces depicted in Figures 1a-1f indicate that prices and qualities will raise in equilibrium as consumers increasingly overestimate the high-quality grade relative to the low-quality one (an increase in k_h). But these changes seem to trigger ambiguous effects on the level of quality-adjusted prices (i.e. the ratio of prices to qualities in equilibrium) and, consequently, the overall market size and welfare. Proposition 1 indicates that quality-adjusted prices raise enough to shrink the market for both products, but the market for the low-quality grade shrinks more.

2.2.2 Misperception on low-quality grades

Misperception of the low-quality grade (i.e., deviations of k_l away from one) in the absence of misperception of the high-quality one ($k_h = 1$) also unleashes multiple forces. But they differ in one crucial way from the effects of misperception on the high-quality grade; the overall effect of misperception of the low-quality grade varies according to the nature of quality competition. In sequential quality competition, the high-quality firm preempts the low-quality firm from increasing its own quality to gain market share. Overall, this curbs quality provision by both firms. On the other hand, under simultaneous quality competition, the high-quality firm does not have the ability to preempt the low-quality firm which spurs quality provision. Proposition 2 formally states the effects of misperception of the low-quality grade.

PROPOSITION 2. Under assumption 2 (sequential quality competition), or assumption 4 (simultaneous quality competition), an increase in perceived quality of the low-quality grade, i.e. an increase in k_l from k_l^0 to k_l^1 where $k_l^0 < k_l^1$, under sequential quality competition,

1. *lowers quality of the high-quality product and raises quality of the low-quality product;*
2. *lowers price of the high-quality product and raises price of the low-quality product ;*
3. *lowers quality-adjusted price of the high-quality product and raises quality-adjusted price of low-quality product;*
4. *increases market size for both products.*

Under simultaneous quality competition,

5. *raises quality of the high- and low-quality products;*
6. *lowers price of the high-quality product and raises price of the low-quality product;*
7. *lowers quality-adjusted price of the high-quality product and raises quality-adjusted price of the low-quality product;*
8. *increases market size for both products*

The mechanism underlying results in Proposition 2 is as follows. All else constant, an increase in k_l raises consumers' willingness to pay for the low-quality product (counterclockwise rotation of the consumer's indirect utility in figure 1b), expanding the size of this market (at the expense of markets for the unlabeled and high-quality labeled products). This strengthens the returns from quality provision by the low-quality firm . This firm raises the quality of its product which prompts an additional counterclockwise rotation of the indirect utility curve expanding the market for the low-quality grade, as shown in Figure 1d.

The ripple effects of these changes vary depending on the nature of quality competition. If quality competition is sequential the high-quality firm anticipates these changes and preemptively decreases its quality choice to protect its market share (it also benefits from a reduced cost of providing quality). But by lowering quality the high-quality firm also lowers its price in equilibrium, such that the quality-adjusted price of the high-quality product decreases. If quality competition is simultaneous, the high-quality firm cannot preempt the low-quality one, and both firms raise quality. Therefore, under simultaneous competition the increase in quality of the low-quality product "pushes" the high-quality product up the quality spectrum; this "push effect" does not take place under sequential competition.

While the reaction of the high-quality firm to overestimation of the low-quality product differs according to the nature of quality competition, the qualitative response of the low-quality firm to that reaction does not. In both cases the low-quality firm raises quality, price, and quality-adjusted price . The raise in quality of the low-quality product, in combination with consumers' stronger preference for it, intensifies price competition between products. As a result, the high-quality firm reduces its quality-adjusted price, expanding the size of its market, and possibly crowding out the low-quality product, especially in light of the increase in the quality-adjusted price of the low-quality product. However, the market for the low-quality product expands because the effects of overvaluation (figure 1b) and increased quality (figure 1d) overwhelm the negative effect of the price increase (figure 1f).

2.2.3 Mean-preserving misperception on high- and low-quality grades

Restraining misperception to the case where perceived average quality remains constant at the no-misperception scenario implies that any variation in misperception of the high-quality product is accompanied by a variation in misperception of the low-quality product in the opposite direction. Formally, we are concerned with combinations of k_h and k_l under which $\frac{k_h v_h^0 + k_l v_l^0}{2} = \frac{v_h^0 + v_l^0}{2}$, where v_l^0 and v_h^0 are equilibrium qualities without misperception, which means that $\frac{\partial k_l}{\partial k_h} = -\frac{v_h^0}{v_l^0}$. Such constant rate of variation in misperception implies that the effects of overvaluation (undervaluation) of quality misperception in the high-quality product will be augmented (or counterbalanced) by effects of undervaluation (overvaluation) of the low-quality product. The types of misperception considered so far necessarily alter the perceived average quality in the market which would have direct implications on market and, as we will see later, welfare effects. We now formally examine a type of misperception that does not alter the perceived average quality. Results are presented in proposition 3.

PROPOSITION 3. Under $0.95 < k_h < 1.05$*, a mean-preserving increase in perceived quality of the high-quality product; i.e. change from* k_h^0 *to* $k_h^1 > k_h^0$ *and change in* k_l^0 *by* $-\frac{v_h^0}{v_l^0}(k_h^1 - k_h^0)$*,*

1. *increases quality of the high-quality product, decreases quality of the low-quality product;*
2. *increases price of the high-quality product, decrease prices of the low-quality product;*
3. *increases quality-adjusted price of the high-quality product and decreases quality-adjusted price of the low-quality product;*
4. *decreases quantity consumed of both products in the market*

in both sequential and simultaneous quality competition.

The mechanisms underlying results in Proposition 3 resemble those previously discussed in Figure 1. An increase in k_h implies a counterclockwise rotation of the high-quality utility curve. The high-quality firm responds by raising quality and price (counterclockwise rotation followed by a downward shift of the utility curve), such that the quality-adjusted price increases. This reduces the market size of the high-quality product. In turn, the reduction in k_l implies a clockwise rotation of the low-quality indirect utility curve. The low-quality firm responds to misperception and the reaction of the high-quality firm by lowering price, quality, and quality-adjusted price. The combination of these responses with the demand shift from misperception results in a reduction in the size of the market for the low-quality product.

While our results indicate that changes in quality and the capacity to charge more per unit of quality mediate the distribution of welfare in the market, the direction of the effect of equilibrium displacement on consumers and firms, and thus, on the size of welfare, is unclear. The next section characterizes the effects of changes in misperception on welfare.

2.3 Welfare effects of quality misperception

2.3.1 Efficiency effects of quality misperception

The equilibrium displacement triggered by changes in consumers' quality misperception translates into changes in firms' profits and consumer surplus, altering market efficiency. In this section, we formally characterize the effect of consumers' misperception of quality on efficiency. We define total welfare as the summation of profit of the high-quality firm π_h from equation (2.1), profit of the low-quality firm π_l from equation (2.2), surplus of the segment of consumers purchasing the high-quality product (CS_h), and surplus of the segment of consumers purchasing the low-quality product (CS_l). Since we normalized indirect utility of the outside good to zero, consumer surplus from this segment of the market is zero. Therefore, welfare is defined as $W\left(v_h, v_l, p_h, p_l; k_h, k_l\right) = CS_h + CS_l + \pi_h + \pi_l$.

Changes in profits are straightforward to characterize from equations (2.1) and (2.2). In contrast, characterizing changes in consumer surplus is complicated by the fact that misperception causes a divergence between actual utility, defined as the one the consumer derives from the actual quality of the good, and the perceived utility, defined as the one the consumer derives from the perceived quality of the good. We follow the approach implemented in the literature (e.g., Glaeser and Ujhelyi 2010; Brécard 2014; Baksi, Bose, and Xiang 2017) and evaluate consumer surplus based on the actual levels of quality provided. In other words, we remove the 'veil of ignorance' from consumers when computing their consumer surplus.[3] Formally, instead of computing consumer surplus from buying the high-quality grades as $CS_h = \int_{\theta_{lh}}^{1} \theta k_h v_h - p_h \mathrm{d}\theta$, under misperception of high-quality, we compute it as

3. ↑Computing C.S. with the actual instead of the perceived quality allows for a non-mechanical treatment of C.S. levels. For example, we know that overvaluation of the high-quality product increases consumers' utility and expands the size of the market, all else constant. Expansion of the market increases the mass of C.S. via higher number of consumers buying the high-quality product, but the level of surplus is artificially inflated by wrong consumers' beliefs entering utility. By bringing the utility of consumers to the actual quality offered, we factor out the disproportionate effect of wrong beliefs on surplus and make C.S. values comparable between several levels of misperception. Moreover, if labels refer to health or environmental attributes, then you want to measure welfare based on actual rather than perceived quality in the market.

$CS_h = \int_{\theta_{lh}}^{1} \theta v_h - p_h \mathrm{d}\theta$. For the same reason, we compute consumer surplus of low-quality consumers as $CS_h = \int_{\theta_{0l}}^{\theta_{lh}} \theta v_l - p_l \mathrm{d}\theta$.

Armed with our formal characterization of the equilibrium displacement triggered by misperception, we can compute equilibrium quality and prices under different levels of misperception that affect the perceived average quality in the market (Propositions 1-2). We subsequently insert these qualities and prices into expressions for $\boldsymbol{\pi}_h$, $\boldsymbol{\pi}_l$, CS_h, and CS_l, and add them up to compute welfare W. We formally state our results in Proposition 4.

PROPOSITION 4. Overvaluation (undervaluation) of either the high-quality grade or the low-quality grade; i.e. change from k_h^0 to $k_h^1 > k_h^0$ (from k_h^0 to $k_h^1 < k_h^0$) or from k_l^0 to $k_l^1 > k_l^0$ (from k_l^0 to $k_l^1 < k_l$), increases (decreases) welfare.

We follow the same procedure to compute welfare and surplus of consumer and producer segments in the case where misperception is mean-preserving, i.e. different levels of misperception that do not affect the perceived average quality in the market. The results from this process are formally stated in Proposition 5.

PROPOSITION 5. Under $0.95 < k_h < 1.05$, a mean-preserving increase (decrease) in perceived quality of the high-quality product; i.e. change from k_h^0 to $k_h^1 > k_h^0$ (k_h^0 to $k_h^1 < k_h^0$) and change in k_l^0 by $-\frac{v_h^0}{v_l^0}\left[k_h^1 - k_h^0\right]$ ($\frac{v_h^0}{v_l^0}\left[k_h^1 - k_h^0\right]$),

1. *increases (decreases) welfare under sequential quality competition*

2. *decreases (increases) welfare under simultaneous quality competition.*

A shock (misperception) increases welfare when it pushes the decentralized (market) resource allocation closer to a counterfactual benchmark that a social planner would choose. Understanding more precisely what reallocations push market equilibrium closer to that benchmark clarifies the forces underlying the effect of misperception on efficiency. We shed light on this issue by identifying a benchmark allocation against which the sub-game perfect Nash equilibrium allocation under misperception can be compared. It turns out that the first-best solution is one where only one product is offered in the market which is not directly comparable to our allocation. We constrain our analysis to the allocation of resources that maximizes efficiency but keeping the duopoly structure intact. This is a second-best solution in which the planner chooses quality, but firms compete in prices. Claim 1 compares the decentralized allocation of resources and the allocation under the second-best.

Claim 1. Irrespective of the nature of quality competition and in the absence of misperception, duopolist firms underprovide quality for both products relative to a second-best where the social planner chooses qualities and firms compete on prices conditional on those qualities.

This claim, in combination with our analysis of the market effects of misperception, help uncover the mechanism by which certain combinations of misperception and quality competition increase welfare. Our analysis of market equilibrium effects of misperception (Propositions 1-3) identifies several combinations of misperception and quality competition that result in higher qualities being offered in equilibrium. By Claim 1, this should push the market equilibrium closer to our second-best benchmark and, thus, increase welfare. However, results in Propositions 1-3 also indicate that increases in quality are often accompanied in equilibrium by a rise in quality-adjusted prices. This reduces the size of the market for labeled products and total surplus. The overall welfare effect will, therefore, depend on the relative strengths of these forces which in turn vary with the nature of misperception and quality competition.

Proposition 4 shows that overvaluation of either product keeping all else constant raises welfare, implying that efficiency gains from higher quality provision dominates efficiency losses from a reduced market size. This is because overvaluation of either product not only strengthens incentives for quality provision but also for consumers to purchase labeled products, limiting the reduction in market size associated with an increase in quality-adjusted prices. The same applies to a mean-preserving overvaluation of the high-quality product, as long as quality competition is sequential.

In contrast, Proposition 5 shows there is a situation in which average quality offered in the market drops as a result of misperception, and yet welfare increases with misperception. This happens under a mean-preserving undervaluation of the high-quality product and simultaneous quality competition. The average quality decreases because the reduction in quality of the high-quality product is larger than the rise in quality of the low-quality product. Furthermore, this reduces the perceived degree of differentiation between products which, in turn, galvanizes price competition. The intensified competition expands the size of the market for labeled products, and this expansion is strong enough to offset the reduction in average quality.

We conduct a numerical simulation that confirms our result that misperception can be welfare-enhancing, but reveals it is often local in nature (Figure A.10, Appendix 2). When consumers overvalue the high-quality product only, misperception raises efficiency up to a point and decreases it afterwards. The same is true when consumers overvalue the low-quality product only and quality competition is sequential, and under a mean-preserving overvaluation of the high-quality product and quality competition is sequential. In these cases, efficiency gains from misperception vanish as misperception pushes the market qualities up and the decentralized solution approaches the second-best solution. By contrast, efficiency gains from overestimation of the low-quality product are global if quality competition is simultaneous. This is because qualities rise at a slower pace, approaching the second-best levels only asymptotically.

In sum, there are two channels through which misperception can enhance efficiency. First, it can enhance efficiency if it strengthens firms' incentives to increase quality offered in the market (quality effect). This tends to correct another market failure that takes place in the absence of misperception; the underprovision of quality that prevails under imperfect competition. Second, misperception can also enhance efficiency if it galvanizes competition and expands market size (market size effect). This corrects a different market failure that takes place in the absence of misperception; high markups and small market size that prevail under imperfect competition. Often these channels countervail each other; either firms provide higher quality but also increase quality-adjusted prices, or they provide lower qualities but lower quality-adjusted prices. Misperception raises efficiency when the quality effect is strong enough to dominate an increase in quality-adjusted prices, or when the market size effect is strong enough to dominate a reduction in qualities.

2.3.2 Distributional effects of quality misperception

While many types of misperception have similar qualitative effects on efficiency, they differ considerably on their impacts on profits of high- and low-quality firms, as well as surplus by consumer segment. We start by examining the distributional effects of misperception of the high-quality product. We present our results in the following proposition.

PROPOSITION 6. Under assumption 1 (in sequential quality competition) or assumption 3 (in simultaneous quality competition), overvaluation (undervaluation) of the high-quality product

1. *increases (decreases) profits of both firms*
2. *decreases (increases) surplus of consumers purchasing the high-quality product*
3. *increases (decreases) surplus of consumers purchasing the low-quality product*

under both simultaneous and sequential quality competition.

The market effects characterized in Proposition 1 shed light on these results. Overvaluation of the high-quality product prompts both firms to raise their quality, but also their quality-adjusted prices. An increase in quality-adjusted prices raise markup but at the expense of market size. However, the increase in qualities limits the contraction of the market size. As a result, both firms obtain higher profits. Moreover, both consumer segments are benefited by higher quality but the increase in quality-adjusted prices operates as a countervailing factor. The former effect dominates for consumers of the low-quality product raising their surplus, while the latter dominates for consumers of the high-quality product lowering their surplus. The effects of misperception of the low-quality product on distribution are described next.

PROPOSITION 7. Under assumption 2 (in sequential quality competition) or assumption 4 (in simultaneous quality competition), overvaluation (undervaluation) of the low-quality product

1. *decreases (increases) profit of the high-quality firm and increases (decreases) profit of the low-quality firm*

2. *increases (decreases) surplus of the high-quality consumer*

3. *decreases (increases) surplus of the low-quality consumer*

for simultaneous and sequential quality competition.

The distributional effects of misperception on the low-quality product (Proposition 7) stand in sharp contrast to those of misperception on the high-quality product (Proposition 6), despite the fact that they have similar qualitative effects on efficiency. Results presented in Proposition 2 shed light on this. They indicate that when consumers overvalue the low-quality product, both firms raise quality, but only the firm producing the low-quality product can raise quality-adjusted price. This explains why the low-quality firm obtains higher profits while the high-quality firm does not. It also explains changes in surplus by consumer segment. Consumers of the high-quality product are benefited by a lower quality-adjusted price (and, in the case of simultaneous quality competition, a higher quality as well), while consumers of the low-quality product must pay a higher quality-adjusted price.

Finally, Proposition 8 summarizes the distributional effects of mean-preserving misperception.

PROPOSITION 8. Under $0.95 < k_h < 1.05$*, a mean-preserving increase in perceived quality of the high-quality product*

1. *decreases surplus of the high-quality consumer and increases surplus of the low-quality consumer.*

2. *increases profits of the high-quality firm and decreases profits of the low-quality firm under both simultaneous and sequential quality competition.*

The mechanism behind these results is similar to that in Propositions 6 and 7. The high-quality firm has the ability to increase its price more than proportionally to the quality supplied. This increases the high-quality firm's profit even though its market shrinks. Naturally, this also reduces surplus of consumers of the high-quality product. This is because there are less consumers purchasing the high-quality grade and those who still purchase it, pay a higher price per unit of quality. On the other hand, the low-quality firm lowers the quality-adjusted price of its product, but its market shrinks, nonetheless, due to consumers undervaluation of the low-quality grade. This reduces the low-quality firm's profit but also benefits those who purchase its product because they pay a lower price per unit of quality.

2.4 Implications for information-based policies

We discuss in this section how our insights can help refine policies aimed at curbing misperception. Propositions 4 and 5 identify conditions under which misperception raises or lowers efficiency. These conditions are expressed in terms of the nature of misperception and the nature of competition. The nature of misperception for certain product categories is routinely measured by empirical studies. These studies use experimental and observational data to determine whether consumers understand the information contained in labels and, as a result, whether they under- or over-estimate the quality of products offered in the market (e.g. McFadden and Lusk 2018; Streletskaya, Liaukonyte, and Kaiser 2019; Villas-Boas et al. 2020). In turn, the nature of competition can be assessed based on observables, most prominently the size of sunk costs of providing higher quality relative to the marginal cost of production.

We found that policies that reduce misperception and, in doing so, lower consumers' valuation of certain grades relative to their competitors along the quality spectrum, reduce efficiency. At first glance, it seems counterintuitive that a policy-induced reduction in misperception can harm certain consumer segments and, more generally, efficiency. Our analysis shows that consumers that purchase the product whose quality is misperceived do benefit from more information. But they also show that the benefits of informing one consumer segment are dominated by the losses associated with weaker incentives to provide quality by both producers in the market. Previous studies indicate that the USDA's organic certification program is an example of such policies, because present rules are likely to induce consumers to undervalue non-organic relative to organic grades (e.g. Streletskaya, Liaukonyte, and Kaiser 2019). In this case, it may be advisable to explicitly certify gradations of organic below 95%, instead of opting for a more binary approach (the USDA organic seal is only granted to above 95%). Other prominent examples are mandates to disclose in labels the presence of attributes that reduce consumers' valuation of products. These include mandates to disclose the presence of genetically modified organisms (California Proposition 37, Vermont Act 120, and the National Bioengineered Food Disclosure Standard). In these instances, it may be advisable to certify the presence of a positive attribute (non-GMO or no Trans Fat) instead of requiring disclosure of a negative attribute (contains GMOs or contains Trans Fat).

We also found that a policy in which a reduction in misperception implies raising consumers' valuation of the high-quality product and lowering consumers' valuation of the low-quality product may also hamper efficiency in markets where sunk costs of providing quality are relatively small. In this type of market, the benefits of informing both consumer segments (and reducing their misperception) are dominated by losses associated with weaker price competition, conditional on equilibrium qualities. This is because the policy prompts firms to increase product differentiation, softening competition. Statutory rules regulating information on nutritional contents fit this case. First, sunk costs of providing quality are relatively low which makes this market resemble one with a simultaneous quality competition. Moreover, FDA rules require disclosing the presence of trans-fat which induces undervaluation of these products (Villas-Boas et al. 2020), and allow for label stacking such as organic and non-GMO which induces overvaluation of these products (McFadden and Lusk 2018). In this case, our analysis indicates that the government could potentially raise efficiency by not disallowing redundant labels and eliminating mandates to disclose a negative attribute. Interestingly, not informing consumers of a negative attribute would protect them by providing the low-quality firm to raise quality.

2.5 Conclusions

Governments around the world have and continue to implement rules that regulate the information that can, cannot, and must be included in food labels. The main goal of these policies is to curb consumers' misperception (a pervasive phenomenon according to empirical evidence) thereby, so the argument goes, helping them make better choices and raising welfare. Therefore, information-based policies are based on the premise that misperception harms consumers and, perhaps, efficiency. We examine the validity of this premise by studying the market and welfare effects of quality misperception by consumers.

We find that the premise underpinning information-based policies is often erroneous, and that misperception can in fact benefit consumers and enhance efficiency due to firms' strategic reactions to it. However, the relationship between misperception and welfare hinges upon the direction of misperception, where misperception occurs along the quality spectrum, and the nature of quality competition among firms. This underscores the usefulness of the framework we develop in this study. In contrast to previous contributions to this literature, our framework is general enough to consider a range of misperception types that seem supported by empirical evidence, as well as different types of quality competition depending on firms' ability to commit to a quality grade, preempting competitors to enter that market segment. On the other hand, our framework is also parsimonious enough to formally characterize combinations of misperception and quality competition under which misperception enhances efficiency.

It is important to emphasize that these results are conditional on the existence of labels. The conclusions of this study do not imply that labels themselves are harmful, but merely that misguided information-based policies can decrease efficiency in the market with labeled products. However, desirable credence attributes would not be provided in the absence of labels.

One notable limitation of our analysis is that we do not consider potential entry of more firms along the quality spectrum, nor do we consider multi-product firms. Such extensions could fundamentally change our insights, though predicting the nature of those changes requires more than simple intuition. A closely related limitation is that we do not consider horizontal differentiation along with vertical differentiation. This could also change the nature of our results as it may induce strategies like fighting brands and product line pruning, strategies that have been studied in markets without misperception (Shen, Yang, and Ye 2016). We believe a promising extension of this research is to develop a framework to consider these, more complicated trading environments.

Moreover, we do not offer in this study a fully-fledged strategy to make our theoretical analysis empirically operational as such an endeavor exceeds the boundaries of this study.

This seems like a useful extension of our analysis. A significant challenge to this task is to empirically measure misperception, as well as the plausible effects of new regulations on misperception. This is challenging because misperception is the difference between consumer's perceived quality of a product, and the quality the consumer would perceive had they had full information and understanding of credence attributes in that product. Both of these measures are typically unobservable to regulators, though maybe obtainable through randomized controlled experiments. Yet, in this study we are able to provide what we believe are useful guiding principles in the section titled "Implications for information-based policies".

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3. MARKET AND WELFARE EFFECTS OF QUALITY MISPERCEPTION IN FOOD LABELS: AN EXPERIMENTAL ANALYSIS

3.1 Introduction

Information-based mechanisms identifying unobserved credence attributes (e.g., labels) have proliferated in the markets of food products. Their increasing popularity is based on the assumption that they help consumers making better choices by eliminating informational asymmetries (Roe and Sheldon 2007; Bonroy and Constantatos 2015; Lusk et al. 2018). However, evidence provided by choice experiments reveals that consumers often fail to understand the information conceived in labels (Kiesel and Villas-Boas 2013; Lee et al. 2013; Liaukonyte, Streletskaya, and Kaiser 2015; McFadden and Lusk 2018), which implies that consumers can miss-perceive (over- or undervalue) the true quality of labeled products. Economic intuition suggests that misperception can distort consumers' choices and change sellers' strategic responses (e.g. quality choice, price charged), impacting the size and distribution of welfare in the market. Despite this intuition, empirical studies examining sellers' strategic reactions to consumers' misperception are seldomly undertaken. This is partly explained by the unobserved nature of consumers' misperception and the difficulty of finding data with observational variation to misperception (Dranove and Jin 2010).

To circumvent these limitations, I report a laboratory experiment that analyzes the degree to which the intensity of consumers' misperception alters sellers' strategic responses. In this paper, I manipulate the intensity of consumer misperception in a laboratory experiment to test the direction and magnitude of the effects of misperception of quality on market outcomes (qualities and prices), and welfare outcomes (consumer surplus, profits, and total welfare). My experimental design is based on the comparative statics from Scott and Sesmero (2020) which modifies the canonical model of competition by vertical differentiation to include the effects of consumers' misperception of quality. They consider a market where two single-product sellers— one serving the high-quality segment of the market and the other the low-quality segment— imperfectly compete on quality and prices. The authors assume quality is determined by credence attributes that can be conveyed by some costly informational mechanism to be adopted by sellers (e.g., labels), but consumers may misperceive the information in those mechanisms.

This framework is relevant for several reasons. A few markets, such as food markets, use third-party certification in the form of labels to correct asymmetric information in credence products (Roe and Sheldon 2007; Bonroy and Constantatos 2015). The assumption is that consumers use labels to verify the quality of products and adjust premiums accordingly, avoiding rent-seeking behavior from sellers (Dulleck and Kerschbamer 2006). Under these conditions, labels would increase market efficiency, conditional on competition and market structure remaining constant. However, consumers' misperception of a label's quality alters the marginal benefit of sellers to adopt such a label. This, in turn, allows firms to strategically adopt higher or lower quality labels to capture some extra market surplus. Such changes in quality adoption are important because standard economic theory suggests that markets where sellers vertically differentiate suffer from chronic underprovision of quality (Buehler and Schuett 2014; Scott and Sesmero 2020). If firms are responsive to misperception, this implies that the intensity of misperception can be high (low) enough to incentivize firms to increase (decrease) quality provision and overcome (deepen) the underprovision of quality, increasing (decreasing) welfare as a result. Empirical results in this paper aim to show the conditions in which misperception leads to quality choices that increase (decrease) total welfare and how this welfare is distributed.

My experimental framework is closely related to experiments examining quality commitment in markets of imperfect information. The experimental design of most of these studies either (1) exogenously varies the informational mechanism or (2) exogenously varies the quality signal that firms send to consumers. Cason and Gangadharan (2002) is an example of (1). Motivated by the introduction of green-labels in the market, the authors compare a green label certification scheme with other informational mechanisms (such as cheap talk and firm reputation). They find that, despite being costly, certification is a necessary condition to increase the number of green-labeled products in a market. Differently from my setting, the authors assumed complete adherence between the information given by the certification and consumer perception of quality.

Henze, Schuett, and Sluijs (2015) is an example of (2). Using the primitives of a model of vertical differentiation, they vary the proportion of consumers informed about the quality of products— from full information to no information. Their full information treatment corresponds to the environment that I use as my benchmark, where misperception about the quality of a product is absent. However, their interest lies in the proportion of consumers that understand a quality signal, rather than the effects of the intensity of quality misperception, as in my study. The intensity of misperception is particularly important to food markets because the food industry uses several complex information mechanisms (e.g. labels and certification of credence attributes) that may magnify consumers' misperception and alter demand significantly (e.g., Villas-Boas et al. 2020).

Scott and Sesmero (2020) provides the ideal environment to test the strategic response of sellers to different intensities of misperception. While their study only considers a duopoly market, they are able to generate unambiguous comparative statics results from different intensities of consumers' misperception. Their comparative statics refers to market outcomes (equilibrium qualities, prices, and market share), as well as welfare outcomes (profits, consumer surplus, and total welfare) and how they relate. They find that firms' strategic reactions to misperception lead to higher efficiency under one of two conditions: (1) misperception incentivizes sellers to increase the average quality offered in the market which partly corrects the underprovision of quality that prevails in the absence of misperception (due to imperfect competition in quality and prices); or (2) misperception leads to a large enough expansion of the size of the market capable of offsetting reductions in average quality. The intuition behind these results is explained in the theoretical part of this paper.

The experiment reported in this paper compares the outcomes between a market where misperception is absent to the outcomes of four types of consumers' misperception: 1) overvaluation of the high-quality product; 2) undervaluation of the high-quality product; 3) overvaluation of the low-quality product; 4) undervaluation of the low-quality product. From a policy perspective, this is interesting because it informs the outcomes of informational-based policies that try to curb consumers' misperception, i.e. policies that bring consumers' perception close to the product's true quality. The experiment shows that the firm supplying for the high-quality segment of the market is highly responsive to misperception of quality (i.e., significantly changes its quality and prices when misperception changes), while the firm supplying for the low-quality segment remains largely unresponsive. This result is important because it shows that informational policies observes changes in market outcomes coming from the high-quality segment of the market only.

Efficiency and distribution are also impacted by changes in misperception. The experiment shows that, on average, sellers benefit from different types of misperception. The high-quality seller captures a large part of surplus when consumers overvalue the high-quality product or when they undervalue low-quality products; the low-quality seller captures surplus when consumers undervalue high-quality products or overvalue low-quality products. Consumer surplus from the high-quality segment is largely unresponsive to misperception of quality, while consumer surplus from the low-quality segment of the market largely moves in the same direction as the low-quality seller's profit. These results are explained by the magnitude of changes in quality and market size resulting from misperception. The distributional results are important because they reveal the winners and losers of different informational-based policies. Finally, decomposition of total welfare shows that changes in efficiency largely depend on the high-quality segment of the market (changes in high-quality profits and consumer surplus).

These results contribute to a body of economic experiments examining markets of credence goods. The existent research have investigated how liability and verifiability alter the incentives to overcharge or mislead consumers about their necessities (e.g., Dulleck, Kerschbamer, and Sutter 2011); how competition and incentives can alter the incentives to overcharge (e.g., Mimra, Rasch, and Waibel 2016); and other incentive problems related to the market of credence goods, as described in Kerschbamer and Sutter (2017). My study expands the literature on such market experiments, particularly focused on the intensity of consumers' misperception of quality. From a policy perspective, it reveals that in an environment where consumers misperceive quality and competition is imperfect, correcting overvaluation of high-quality products or undervaluation of low-quality has a deleterious effect on efficiency, but can benefit sellers and consumers of the low-quality segment of the market, without an impact on consumers of the high-quality product.

The paper is divided as follows. Section 1 describes the theory and experimental hypotheses. Section 2 describes the experimental design. Section 3 describes the results, and section 4 concludes.

3.2 Theory and hypotheses

3.2.1 Equilibrium and comparative statics

We heavily rely on the theoretical predictions of Scott and Sesmero (2020). We reproduce most of their model and intuition here. The model considers a market where consumers differ in their taste for quality and are distributed uniformly along a continuum of willingness-to-pay (given by θ) for quality (given by v). The parameters of the uniform distribution are $[\underline{\theta}, \bar{\theta}]$. Quality is a credence attribute and, hence, unobservable to consumers. Consumers rely on a credible, non-profit, third-party to certify quality grade v. The third-party uses a continuous grade program to certify quality. The model also considers a single-product duopoly in which firms have access to the same technology, which consists of a constant marginal cost, normalized to zero, for simplicity. The firms offer products with credence attributes that are certified through labels. Certification is costly, and I let cost be represented by $C(\cdot)$. For this study, I resort to a quadratic cost structure, following previous papers (e.g. Motta 1993; Aoki and Prusa 1997; Buehler and Schuett 2014).

The model assumes an honest and non-strategic third-party, but allows for misperception of certified grade quality v by consumers. For example, misperception can arise from imperfect disclosure or imperfect understanding of information of certified products, such that misperception creates a wedge between the actual quality offered by firms and the perceived quality by consumers. Since the model considers only two labeled products in the market, the quality of the product certified with the relatively higher quality grade is represented by v_h, and a relatively lower quality grade is represented by v_l, such that $v_h > v_l$. The model describes the two misperception parameters, k_h (misperception of the high-quality grade) and k_l (misperception of the low-quality grade). Perceived qualities are denoted by $k_h v_h$ and $k_l v_l$ for the high- and low-quality products, respectively. In the presence of overvaluation, the authors let $k_{\mathrm{j}} > 1$ for product $\mathrm{j} \in \{h, l\}$; in the presence of undervaluation $k_{\mathrm{j}} < 1$; and in the absence of misperception, $k_{\mathrm{j}} = 1$.

As in Scott and Sesmero (2020), I consider relative misperception of qualities and its implications. For example, consider a case in which consumers only overvalue the high-quality product, i.e. $k_h > 1$ and $k_l = 1$. This increases the perceived difference in quality between products while also increasing the perceived average quality of products in the market. Similarly, overvaluation of the low-quality product only, i.e. $k_h = 1$ and $k_l > 1$, reduces the perceived difference in quality between products while increasing the perceived average quality of products in the market. Undervaluation of the high-quality product, i.e. $k_h < 1$ and $k_l = 1$, reduces the perceived difference in quality between products while reducing the perceived average quality of products in the market. Undervaluation of the low-quality product, i.e. $k_h = 1$ and $k_l < 1$, raises the perceived difference in quality between products while also reducing the perceived average quality of products in the market.[1]

The model defines indirect utility of consumers that buy labeled quality grade j as $V_{\mathrm{i}}(v_{\mathrm{j}}, p_{\mathrm{j}}, k_{\mathrm{j}}) = \theta_{\mathrm{i}} k_{\mathrm{j}} v_{\mathrm{j}} - p_{\mathrm{j}}$, such that i index the consumer's position in the WTP distribution, θ_{i} is the consumer's valuation of quality, $k_{\mathrm{j}} v_{\mathrm{j}}$ is consumers' perceived quality of product $\mathrm{j} \in \{h, l\}$, and p_{j} is the price of product j. The indirect utility of those consumers consuming the outside good is zero. This class of indirect utility is a modification of indirect utilities commonly found in the literature (e.g., Jean Tirole 1988; Lehmann Grube 1997; Bonroy and Constantatos 2015). Marginal consumers θ_{lh} (indifferent between low- and high quality), θ_{0l} (indifferet between outside good and low-quality), and aggregate demand functions (D_h, D_l) are derived as in the traditional vertical differentiate model (see Jean Tirole 1988).

Conditional on the aggregate demands, firms compete in two stages. First, a quality-competition stage, in which firms choose quality. Then, a price-competition stage in which, conditional on quality, they compete in prices. The solution of the two-stage game is computed by backward induction in the usual way (Ronnen 1991; Aoki and Prusa 1997; Lehmann Grube 1997).

1. ↑Scott and Sesmero (2020) also discusses the special case in which over-(under-)valuation of a product is offset by an under-(over-)valuation of the other product, such that average perceived quality is unaltered from a perfect information case. We do not discuss this case here, as it is not implemented as part of the experiment.

Firms' profits are given by equations 3.1 and 3.2:

$$\pi_h = R_h\left(v_h, v_l, p_h, p_l; k_h, k_l\right) - C\left(v_h\right) = p_h D_h\left(v_h, v_l, p_h, p_l; k_h, k_l\right) - C\left(v_h\right) \tag{3.1}$$

$$\pi_l = R_l(v_h, v_l, p_h, p_l; k_h, k_l) - C(v_l) = p_l D_h\left(v_h, v_l, p_h, p_l; k_h, k_l\right) - C(v_l), \tag{3.2}$$

where $R_{\mathrm{j}}(v_h, v_l, p_h, p_l; k_h,\ k_l)$ is revenue of the firm offering product j.

In this paper, price-competition is simultaneous, while quality-competition is sequential. The timing of the game reflects empirical situations in which a firm can commit to a specific quality before the other, but it cannot do the same with prices. Such timing is associated with large switching costs between quality investments (Aoki and Kurz 2003). In food markets, this reflects the empirical realities of industries in which producing technologies are asset-specific, as the cage-free egg industry (e.g., EggIndustry 2019). In food markets, many of these industries also rely on labels to communicate credence attributes.

Scott and Sesmero (2020) shows that a sufficient condition for a global solution of the sequential programming described above consists in restricting misperpcetion k_h to $[0.75, 1.75]$ when $k_l = 1$, and k_l to $[0.5, 1.3]$ when $k_h = 1$. Under these parameters, the leader always assume the high-quality spectrum of quality, while the follower becomes the low-quality firm. The optimal quality solution of the game is represented by $\{v_h^*, v_l^*(v_h)\}$, which consists of the equilibrium quality chosen by the high-quality firm and the follower's best-response to the high-quality grade. Optimal prices are represented by $\{p_h^*(v_h^*, v_l^*), p_l^*(v_h^*, v_l^*)\}$. Total welfare is the summation of profit of the high-quality firm (π_h), profit of the low-quality firm (π_l), surplus of the segment of consumers purchasing the high-quality product (CS_h), and surplus of the segment of consumers purchasing the low-quality product (CS_l). Therefore, I define welfare as $W\left(v_h, v_l, p_h, p_l; k_h, k_l\right) = CS_h + CS_l + \pi_h + \pi_l$.

Notice that under misperception there is a divergence between the actual utility, defined as the one the consumer derives from the actual quality of the good, and the perceived utility, defined as the one the consumer derives from the perceived quality of the good. The authors follow the approach implemented in the literature (e.g. Glaeser and Ujhelyi 2010; Brécard 2014; Baksi, Bose, and Xiang 2017) and evaluate consumer surplus based on the actual levels of quality provided, v_j, instead of the augmented perceived quality, $k_j v_j$. Formally, consumer surplus is defined as in equations 3.3 and 3.4.

$$CS_h = \int_{\theta_{lh}}^{\bar{\theta}} \frac{\theta v_h - p_h}{\bar{\theta} - \underline{\theta}} d\theta. \tag{3.3}$$

$$CS_l = \int_{\theta_{0l}}^{\theta_{lh}} \frac{\theta v_l - p_l}{\bar{\theta} - \underline{\theta}} d\theta. \tag{3.4}$$

Armed with these definitions, we can explore the effects of shocks in misperception to market outcomes (qualities, prices, demanded quantity) and welfare (profits, consumer surplus). I now turn the attention to these comparative statics which are later tested in my experimental setting. Table 3.1 summarizes the direction of change for increases in misperception parameters (see Scott and Sesmero 2020 for a full derivation).

Table 3.1.

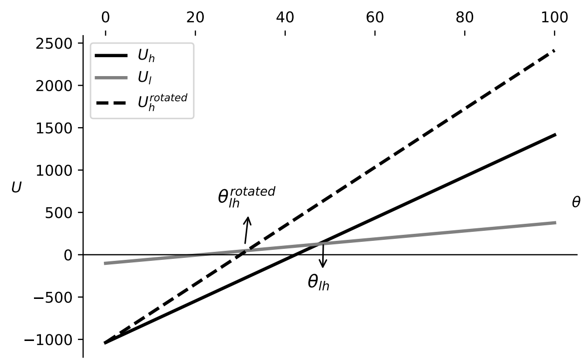
Sign of the comparative statics under misperception shock $dk_{\mathrm{j}} > 0$, $\mathrm{j} \in \{h, l\}$

Effect	Overvaluation of high-quality	Overvaluation of low-quality
Quality		
High	+	-
Low	+	+
Price		
High	+	-
Low	+	+
Price per quality		
High	+	-
Low	+	+
Market-Share		
High	-	-
Low	-	-
Profit		
High	+	-
Low	+	+
Consumer Surplus		
High	-	+
Low	+	-
Total Welfare	+	+

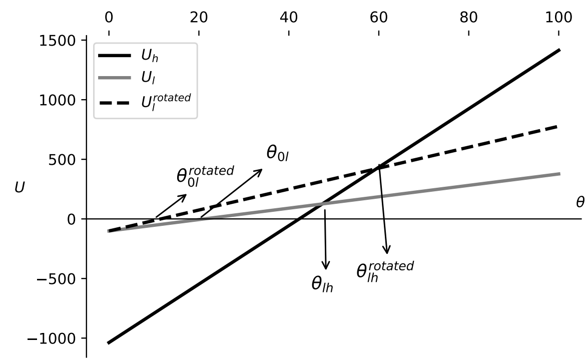
The reverse signs are found under misperception shocks leading to $dk_{\mathrm{j}} < 0$

I discuss the intuition of the comparative statics now. Understanding the intuition behind the model's comparative statics will help later when I discuss the experimental results. I start with Figure 3.1. The horizontal axis represents the consumer's WTP index, θ_{i}, and the vertical axis represents utility as previously defined. The intercept of the utility curve represents equilibrium prices, and the curves' slope represents equilibrium quality. Relative to the case where misperception is absent, the model predicts that consumer's overvaluation (an increase in k_h, holding $k_l = 1$) increases the perceived utility of high-quality consumers, as indicated by the counterclockwise rotation of its utility curve (figure 3.1a). Also, overvaluation of the high-quality grade strengthens the incentives for the high-quality firm to offer more quality. Thus, the high-quality consumer's utility further rotates left, expanding the market for the high-quality product, all else constant. This can be seen by the left shift of the marginal consumer θ_{lh} (figure 3.1c).

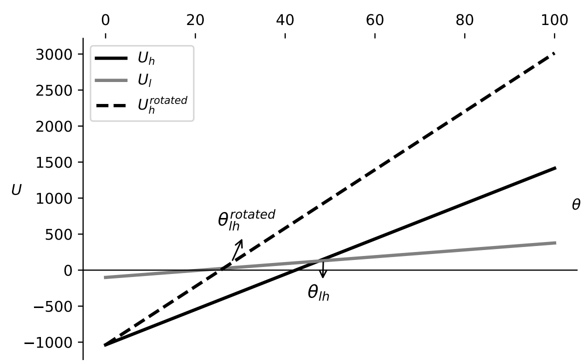
The increase in high-quality grade allows the follower to capture part of the consumers with higher WTP by increasing the quality of the low-quality product. This implies a counterclockwise rotation of the low-quality consumers, as indicated by figure 3.1d. With higher quality, both firms increase their prices (Figures 3.1e and 3.1f). This is done to increase margins until the marginal benefits (i.e., increase in markups) equates marginal costs (loss of market share). At equilibrium, firms are able to increase price more than they increase quality, which implies that quality-adjusted prices increase, and so do profits for both firms.



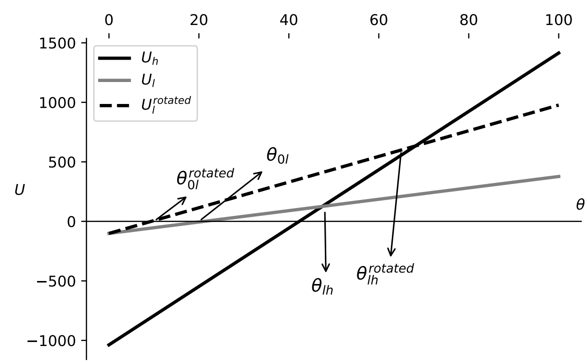
(a) Effect of overvaluation of high-quality product



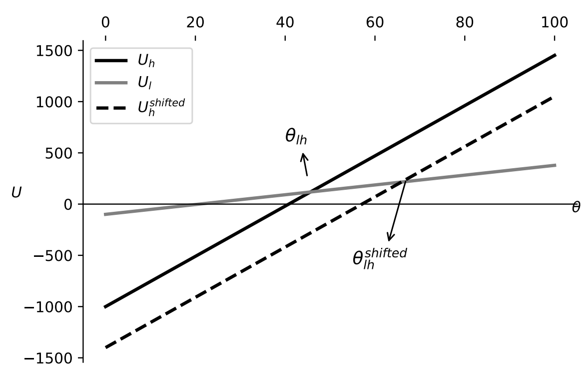
(b) Effect of overvaluation of low-quality product



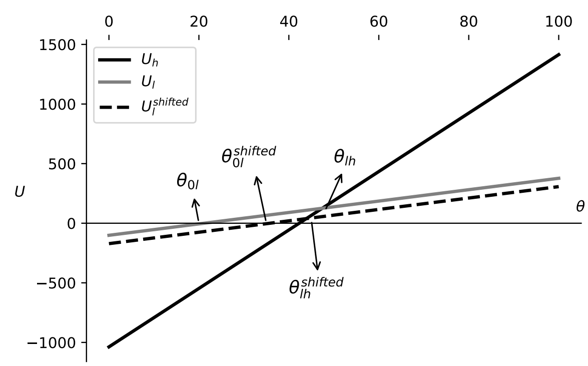
(c) Effect of quality increase in high-quality product



(d) Effect of quality increase in low-quality product



(e) Effect of price increase in high-quality product



(f) Effect of price increase in low-quality product

Figure 3.1. Effects of price and quality increase in the market of food labels. Each panel represents the effect of either prices or quality in marginal consumers, holding all else constant. Reproduced from Scott and Sesmero (2020) under different parameters.

Overvaluation of the low-quality grade (an increase in k_l, holding $k_h = 1$) rotates the low-quality consumer's utility counterclockwise (Figure 3.1b), which strengthens the return to quality for the low-quality firm. By offering higher quality, the low-quality firm expands the market for its product, all else constant. However, to prevent losses in market share, the leader pre-emptively decreases its quality and prices in order to retain market share. Additionally, the leader is able to decrease its fixed costs, as it only depends on the quality offered by the firm. In equilibrium, the model predicts that overvaluation of low-quality grade allows the low-quality firm to increase quality, price, and quality-adjusted price. This allows for higher profits for the low-quality firm. The high-quality firm decreases its quality and prices, in such magnitude that its quality-adjusted price decreases. As a result, its profits decrease.

The model predicts that consumer surplus decreases for the consumer segments incurring misperception. For example, high-(low-)quality consumers will overpay for quality in markets where there exists overvaluation of high-(low-)quality labels. This implies a decrease in consumer surplus for this segment, according to equations 3.3 and 3.4. Putting all together, misperception is predicted to produce multiple forces impacting total welfare. While overvaluation (undervaluation) of high-quality increases (decreases) surplus for firms and low-quality consumers, it decreases (increases) surplus of the high-quality consumer segment. Scott and Sesmero (2020) show that these movements are related to two main variables: average quality supplied by sellers and total size of the market. The authors show that information-based policies that decrease average quality decrease welfare; but lacking increases in average quality, they also show that welfare can still increase if the size of the market expands enough to offset the deleterious effects of lower qualities to welfare. Next, I summarize these effects in testable hypotheses.

3.2.2 Hypotheses

Based on the results of these comparative statics, I construct 6 hypotheses to be tested in an experiment. Hypotheses 1-3 refer to market outcomes: quality levels, and prices charged under different treatments of misperception of quality. Hypotheses 4-6 refer to welfare outcomes under the same treatments: firms' profits and consumer surplus of the high- and low-quality segments.

Hypothesis 1: Quality offered. In relation to the benchmark case in which misperception is absent (i.e., $k_h, k_l = 1$),

1. high- and low-quality increase (decrease) under overvaluation (undervaluation) of the high-quality product.

2. high-quality decreases (increases) and low-quality increases (decreases) under overvaluation of the low-quality product.

Hypothesis 2: Prices. In relation to the benchmark case in which misperception is absent (i.e., $k_h, k_l = 1$),

1. high- and low-quality prices increase (decrease) under overvaluation (undervaluation) of the high-quality product.

2. the price of the high-quality product decreases (increases) and the price of the low-quality product increases (decreases) under overvaluation (undervaluation) of the low-quality product.

Hypothesis 3: Quality-adjusted prices. In relation to the benchmark case in which misperception is absent (i.e., $k_h, k_l = 1$),

1. high- and low-quality quality-adjusted prices increase (decrease) under overvaluation (undervaluation) of the high-quality product.

2. quality-adjusted price of the high-quality product decreases (increases) and the quality-adjusted price of the low-quality product increases (decreases) under overvaluation (undervaluation) of the low-quality product.

Hypothesis 4: Profits. In relation to the benchmark case in which misperception is absent (i.e., $k_h, k_l = 1$),

1. profits of the high- and low-quality firms increase (decrease) under overvaluation (undervaluation) of the high-quality product.

2. the profit of the high-quality firm decreases (increases) and the profit of the low-quality firm increases (decreases) under overvaluation (undervaluation) of the low-quality product.

Hypothesis 5: Consumer Surplus. In relation to the benchmark case in which misperception is absent (i.e., $k_h, k_l = 1$),

1. under overvaluation (undervaluation) of the high-quality product, the consumer surplus for the high- quality segment of the market decreases (increases), while consumer surplus of the low-quality segment of the market increases (decreases).

2. under overvaluation (undervaluation) of the low-quality product, the consumer surplus for the high- quality segment of the market increases (decreases), while consumer surplus of the low-quality segment of the market increases (decreases).

Hypothesis 6: Total Welfare. In relation to the benchmark case in which misperception is absent (i.e., $k_h, k_l = 1$), total welfare increases (decreases) under overvaluation (undervaluation) of high- and low-quality products.

These 6 hypotheses are tested in a laboratory experiment. The next section describes the experimental design, the parameters used, and the theoretical equilibria of the treatments.

3.3 Experimental Design

We start by describing the experimental setting. I conduct a between-subjects experiment to investigate the role of consumers' misperception on market and welfare outcomes. I compare the results of 4 treatments under different intensities of consumers' misperception to a benchmark case under the absence of misperception. Subjects take the role of firms, while the role of consumers is automated. Automated consumers allow for better causal identification of market and welfare outcomes because we eliminate possible behavioral confoundings that may arise from the demand side of the market. It also allows for better traction between theory and the experimental setting, as both theory and experiment have demand curves arising from atomistic consumers distributed uniformly according to their willingness to pay for quality.

The treatments take the form of (1) overvaluation of high-quality grade, (2) undervaluation of high-quality grade, (3) overvaluation of low-quality grade, and (4) undervaluation of low-quality grade. The misperception parameters are summarized in table 3.2. The choice of parameters is discussed next. Notice that the misperception (k_{j}, $\mathrm{j} \in \{h, l\}$) is a continuous variable. This implies that the experimenter can set the treatment level k_{j} anywhere in the interval where a global solution exists. To test the effects of undervaluation of the high-quality grade, k_h can be set anywhere in the interval $(0.75, 1]$. Likewise, the experimenter can choose any k_h between $(1, 1.75)$ to test outcomes under overvaluation of high-quality. To test undervaluation of low-quality, k_l can be set to any value in $[0.5, 1)$; overvaluation of low-quality needs k_l to be anywhere $(1, 1.3]$. To decide the appropriate levels of k_{j}, I follow List, Sadoff, and Wagner (2011). The authors argue that, under continuous linear treatment effects, the experimenter should set the treatment variable to extreme values, such that it maximizes the difference between treatment outcomes. Therefore, I set $k_h = 1.5$, $k_h = 0.8$, $k_l = 1.3$, and $k_l = 0.65$ for treatments (1), (2), (3), and (4), respectively.

Table 3.2.
Parameters and equilibrium solutions

	Parameter	Equilibrium	Surplus
Benchmark (BE)			
k_h	1	$v_h = 24.51$, $v_l = 4.78$	$\pi_h = 244.70$, $\pi_l = 15.15$
k_l	1	$p_h = 1037$, $p_l = 101$	$CS_h = 404.64$, $CS_l = 16.54$
		$p_h/v_h = 42.30$, $p_l/v_l = 21.12$	$TW = 681.01$
Overvaluation k_h (OH)			
k_h	1.5	$v_h = 37$, $v_l = 5.56$	$\pi_h = 628.66$, $\pi_l = 18.15$
k_l	1	$p_h = 2589$, $p_l = 128$	$CS_h = 80.57$, $CS_l = 19.16$
		$p_h/v_h = 69.67$, $p_l/v_l = 23.02$	$TW = 753.53$
Undervaluation k_h (UH)			
k_h	0.8	$v_h = 19$, $v_l = 4$	$\pi_h = 140.92$, $\pi_l = 13$
k_l	1	$p_h = 598$, $p_l = 80$	$CS_h = 425.62$, $CS_l = 13.78$
		$p_h/v_h = 31.47$, $p_l/v_l = 20$	$TW = 593.07$
Overvaluation k_l (OL)			
k_h	1	$v_h = 23.64$, $v_l = 5.12$	$\pi_h = 211.97$, $\pi_l = 21.47$
k_l	1.3	$p_h = 913$, $p_l = 128$	$CS_h = 438.29$, $CS_l = 10.49$
		$p_h/v_h = 38.63$, $p_l/v_l = 25.14$	$TW = 682.23$
Undervaluation k_l (UL)			
k_h	1	$v_h = 24.92$, $v_l = 3.64$	$\pi_h = 280.67$, $\pi_l = 7.41$
k_l	0.65	$p_h = 1155$, $p_l = 54$	$CS_h = 357.90$, $CS_l = 19.85$
		$p_h/v_h = 48.81$, $p_l/v_l = 22.82$	$TW = 665.83$
Common parameters to treatments			
$\bar{\theta}$	100		
$\underline{\theta}$	0		

v stands for quality, p stands for price, p/v stands for quality-adjusted prices, π stands for profit, $C.S.$ stands for consumer surplus and TW stands for total welfare. Subscript h refers to high-quality, and l to low-quality.

The decision space for high quality was set to $[16, 50]$, while the decision space for the low quality was set to $[2, 15]$. This decision is informed by the conditions by which the comparative statics were derived, which requires $v_h > v_l$. The decision space for price is set to $[590, 2700]$ for the high-quality product, and $[50, 150]$ for the low-quality product. Again, we restrict the decision space for values $p_h > p_l$. The decision spaces track the theoretical results and are chosen to minimize out-of-the-path equilibria that may arise from behavioral aspects of the game. Next, I turn to the exact procedures of the experiment.

3.3.1 Procedures

I conducted experimental sessions during September 2020 using oTree (Chen, Schonger, and Wickens 2016). Subjects are mainly undergraduates from a large university located in the United States. Student recruitment was managed via ORSEE (Greiner 2015). I conducted 16 sessions, with 8 students per session.[2] A session consisted of the following steps. First, the experimenter handled printed copies of the experimental instructions to subjects. The experimental instructions were read out loud. Second, subjects responded to a post-instruction quiz to check for their understanding of the rules of the game. Subjects were paid per every right question answered during the quiz. The experiment started after the post-instruction quiz. The experiment consisted of 2 phases: a training phase in which subjects played 4 rounds of the game (2 as leaders and 2 as followers) and an effective experiment that consisted of 10 rounds. Each round is described according to figure 3.2. Each round consists of 3 periods: a period in which the leader makes its quality choice, a period in which the follower makes its quality choice, and a period in which leader and follower choose prices simultaneously. For each treatment, subjects face different incentives to provide quality and charge prices that are consistent with over- or undervaluation of high- or low-quality grades, as described in the treatments in Table 3.2.

In practice, two subjects are randomly paired to play a round of the game. One of the players is randomly selected to play the leader (the high-quality seller), while the other plays the follower (the low-quality seller). The leader must select its own quality first; to facilitate

2. ↑A session under benchmark had 10 students, and 5 others (under different treatments) had 6 students due to last minute cancellations.

the quality choice, the leader has access to a calculator that shows the revenue, costs, payoff, and the follower's payoff based on the qualities selected. To perform computations, the calculator requires the leader to guess the follower's quality and price choices, as well as a guess of its own price choices during the price period. Thus, the leader has 4 choices to make during its quality round: its quality, a guess for its own prices during the price period, and a guess for the follower's price and quality choices. After the leader choices, the follower sees the leader's quality and chooses its own quality level. Again, a calculator with information about the follower's revenue, cost, payoff, and leader's payoff is available to facilitate the player's quality choice. The calculator uses the quality previously chosen by the leader to make its computations. To use the calculator, the follower has to choose its own quality, make a guess for its own price, as well as a guess the leader's price during the price period. Finally, during the price period, both players observe their quality choices and must choose prices for their product. Similarly to previous periods, a calculator is available. Players must choose their price and make a guess for the other player's price during the price period to use the calculator. After the price period, players observe their payoff and a new round starts. To make choices, subjects move a handle or type the quality/price values they wish to choose.

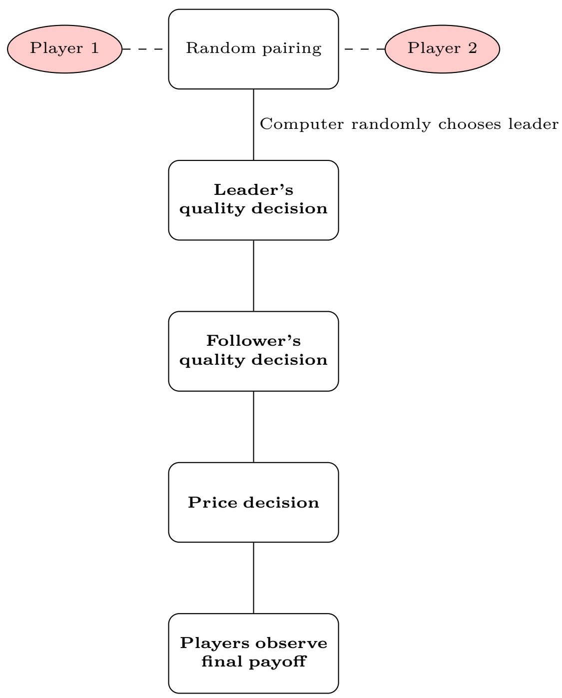


Figure 3.2. Description of a round

Finally, I use a payment schedule based on a random selection of rounds to be paid within a session. Out of the 10 effective rounds of each experimental session, the experiment randomly selects 4 to be paid. During the experiment, payoff values are named points, such that points are converted to U.S. dollars by a conversion rate. Subjects' average payment during the sessions, including the $5 show-up fee, was $16.92 for a 1-hour session. The observed outcomes of the experiment are discussed next.

3.4 Results

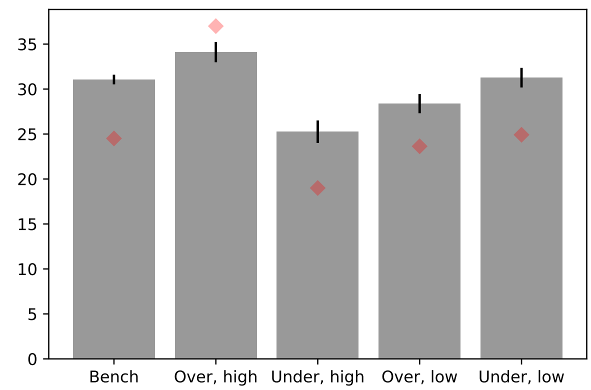
3.4.1 Market outcomes

I discuss market outcomes first. Figure 3.3 summarizes the experimental results by looking at the means of different market outcomes.[3] Hypothesis 1 predicts that quality levels offered by sellers increase under overvaluation of the high-quality product; Hypothesis 2 predicts the same for prices. Undervaluation of high-quality has the opposite effects.

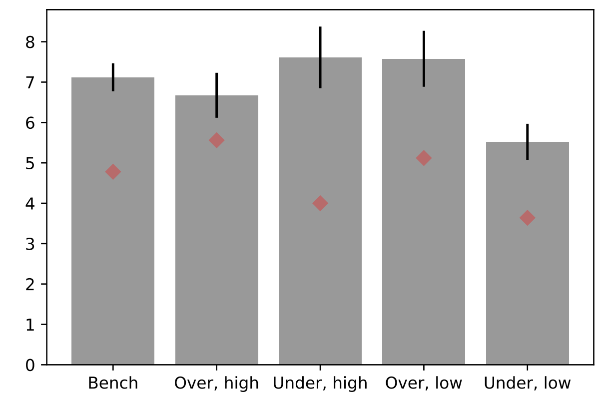
Notice that both the quality offered and the price charged by high-quality sellers under the benchmark experiment are higher than what the theory predicts (Figure 3.3a and 3.3b). This was observed previously in the literature in experiments that discussed quality competition (e.g., Henze, Schuett, and Sluijs 2015). The data confirms that the high-quality seller substantially increases quality and prices under overvaluation of the high-quality product relative to the benchmark case. However, on average, these choices fell below theoretical predictions (Figure 3.3a and 3.3b). The opposite is true under most of the other treatments; qualities and prices for the high-quality seller tend to be higher than the theory predicts. Interestingly, observed quality-adjusted prices (prices over quality) for the high-quality seller were much closer to the theoretical predictions (Figure 3.3e) than quality or prices taken separately. This is important because quality-adjusted prices largely drive the size of profits.

3. ↑While the figures in this paper show means and confidence intervals, I also computed significance levels for the difference in means between benchmark and treatment, for all treatments. During these calculations, I corrected p-values for family-wise error rate (FWER) as described in List, Shaikh, and Xu (2019). Qualitatively, results are largely the same as presented here and, thus, not reported. However, such calculations are available upon request.

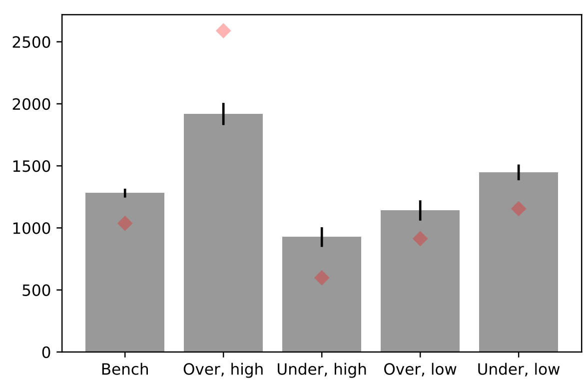
Recall that profits are determined by the markup (price over marginal costs), but also by the seller's market share, which is positively affected by qualities and negatively affected by prices. Quality-adjusted prices show how well sellers were able to balance the opposing forces enacted by changes in markup and market share. The closer quality-adjusted prices are to the theoretical predictions, the closer to the optimal profit sellers become, even if quality and prices are individually away from predictions.



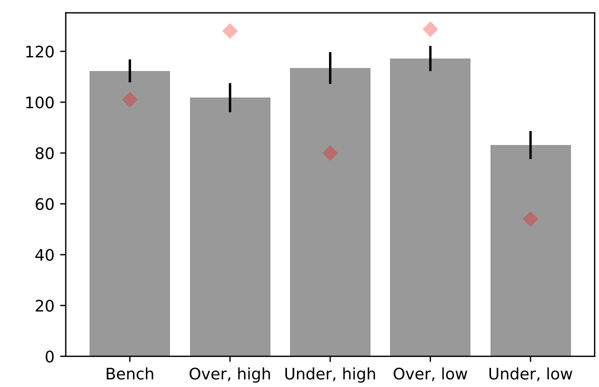
(a) Quality of high-quality product



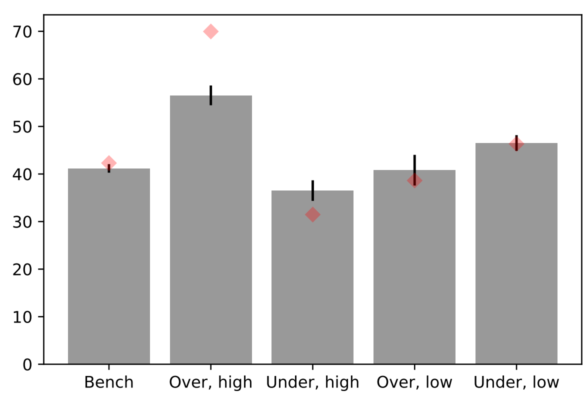
(b) Quality of low-quality product



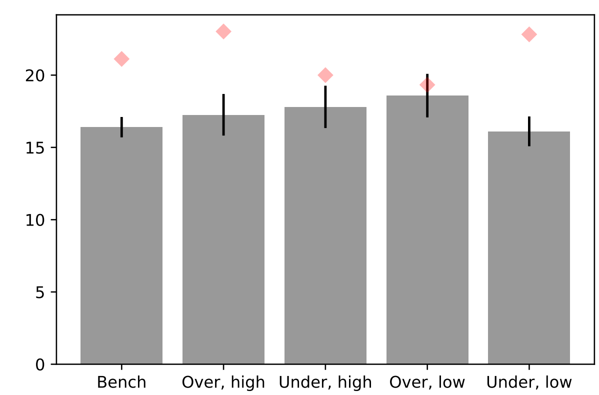
(c) Price of high-quality product



(d) Price of low-quality product



(e) Quality-adjusted prices of the high-quality product



(f) Quality-adjusted prices of the low-quality product

Figure 3.3. Market outcomes under different treatments. The height of the columns represent average observed outcomes, the red marks represent theoretical equilibria, and the bars are the 95% C.I.

While high-quality sellers' quality-adjusted prices are close to the theoretical predictions, low-quality sellers' quality-adjusted prices are consistently below (Figure 3.3f). Particularly, low-quality sellers tend to offer qualities above what theory predicts (Figure 3.3b).[4] Prices charged by the low-quality seller are below what theory predicts for overvaluation of both products and above what theory predicts for undervaluation of both high- and low-quality products (Figure 3.3d).

According to the 95% confidence intervals, the means for low-quality seller's quality, prices, and quality-adjusted prices are not different from the benchmark means, except for prices under low-quality undervaluation. I explore two possible explanations. From Table 3.2, we notice that the difference between equilibria for low quality is small. The small difference in equilibria increases the likelihood of finding a null effect if the variability of quality choices during the experiment is large. This is true even with enough ex-ante statistical power to detect differences in means. This explanation could be valid for qualities of the low-quality seller, but less likely for prices and quality-adjusted prices because of larger differences in equilibria between treatments for these outcomes.

A second explanation is behavioral. Higher-than-expected low quality reveals a failure of backward induction because low-quality sellers were adamant about decreasing quality significantly, as it could impact their market share (as explained in Figure 3.1). This resulted in qualities around 7 for all treatments.

Tables 3.3 and 3.4 present regression results that further confirm the difference in means discussed above. Different regression models use the observed level of high quality, low quality, high-quality price, and low-quality price as the dependent variable. These models compare the different treatments with the observed qualities and prices obtained in the benchmark (no misperception of qualities). The independent variables include a dummy taking the value of one if the observation belongs to treatment and zero otherwise, a conditional mean (intercept), and a time trend indicating the round during which subjects were making the choice. Subjects' demographic characteristics were added to balance the

4. ↑The observed low-quality choices are also above the best response to the observed quality choices of the high-quality seller. Low-quality sellers are consistently providing a level of quality above their best response, which magnifies the discrepancy between predicted and observed quality choices.

samples, but suppressed from the table as they offer no particular insight. The sign of the treatment dummy indicates the direction of the misperception treatment over the dependent variable, and the magnitude indicates the impact of quality supply or price charged under each treatment.

Table 3.3.
Treatment effects under misperception of the high-quality product

	Overvaluation of high-quality			
	Quality, high	Price, high	Quality, low	Price, low
Const	29.59***	1393.6***	6.180***	123.0***
	(2.82)	(143.9)	(1.51)	(28.61)
Treat	3.003***	603.4***	-0.312	-10.99
	(0.75)	(23.96)	(0.35)	(6.27)
Round	0.106	17.82*	-0.0479	0.235
	(0.08)	(8.62)	(0.04)	(0.56)
N	240	240	240	240
	Undervaluation of high-quality			
Const	35.45***	1637.4***	8.281***	139.0***
	(3.37)	(158.50)	(1.29)	(24.62)
Treat	-5.830***	-372.0***	0.402	-0.325
	(1.50)	(58.62)	(0.60)	(5.90)
Round	-0.00380	0.0278	-0.0647	0.0420
	(0.11)	(5.78)	(0.12)	(0.53)
N	230	230	230	230

Notes: *** prob. < 0.01, ** prob. < 0.05. Models estimated using hierarchical random effects (at the session level). Standard errors clustered at the session level. Subjects' demographic characteristics included in all specifications.

I start discussing the treatment effects of overvaluation of the high-quality product. The sign of the treatment effect on quality and price of the high-quality seller is as expected by theory, but the magnitude is lower. This is most likely due to the higher-than-expected quality offered under the benchmark case. Sign and magnitude of the treatment effect on high-quality prices have the expected sign and magnitude. Overvaluation of the higher quality has no significant impact on either quality offered or price charged by the low-quality seller. Similarly, undervaluation of the high-quality product produces the expected sign and magnitude of the treatment effect on quality and price of the high-quality seller, but no significant effect on the low-quality seller's choices.

Table 3.4.
Treatment effects under misperception of the low-quality product

	Overvaluation of low-quality			
	Quality, high	Price, high	Quality, low	Price, low
Const	33.57***	1408.0***	5.336***	108.4***
	(2.67)	(182.10)	(1.51)	(23.35)
Treat	-3.124**	-137.2***	0.690	7.311**
	(0.99)	(29.23)	(0.99)	(3.47)
Round	0.0422	4.756	-0.0145	0.0647
	(0.14)	(5.81)	(0.04)	(0.14)
N	250	250	250	250

	Undervaluation of low-quality			
Const	33.21***	1576.3***	5.386***	105.9***
	(1.87)	(171.20)	(1.02)	(24.51)
Treat	0.0517	152.3***	-1.522***	-28.82***
	(0.60)	(26.74)	(0.26)	(4.28)
Round	-0.0745	-10.02	0.0196	0.0360
	(0.08)	(7.20)	(0.03)	(0.24)
N	230	230	230	230

Notes: *** prob. < 0.01, ** prob. < 0.05. Models estimated using hierarchical random effects (at the session level). Standard errors clustered at the session level. Subjects' demographic characteristics included in all specifications.

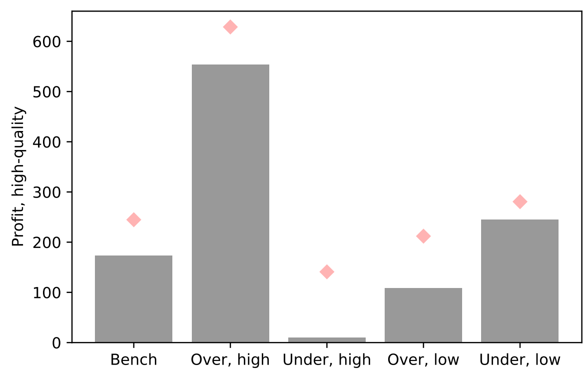
Misperception of the low-quality product produces multiple forces. When consumers overvalue the low-quality product, the high-quality seller lower quality supplied (as expected), but at a higher magnitude than predicted by the theory. While no effect was detected on supply of the lower quality (which is already higher than theory would predict, as discussed), overvaluation of the low-quality product allowed low-quality sellers to increase prices charged, with expected magnitude, as shown by the significantly positive treatment effect coefficient. Finally, the treatment effect of undervaluation of low-quality has no effect on the higher quality, but it increases the high-quality price in the expected magnitude; it also decreases the lower quality at the expected magnitude and sign. Finally, the treatment effect on low-quality prices is not as negative as expected by theory.

In sum, these results suggest that treatment effects (misperception of the high- or low-quality product) on low-quality choices (quality and price) are only strong enough when misperception direct affects the low-quality product. But misperception of both high- and low-quality products produce strong enough incentives to alter the high-quality seller's choices. Expected treatment effects for high-quality sellers aligned with unexpected magnitudes of treatment effects for low-quality sellers are likely to produce unexpected welfare results. We turn our attention to welfare outcomes next.

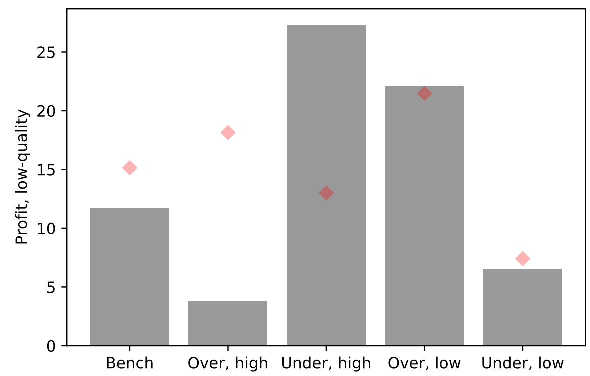
3.4.2 Welfare outcomes

Hypothesis 4 predicts that overvaluation of either product increases the profits of firms. Undervaluation is predicted to have the opposite effect on profitability. Hypothesis 5 predicts decreases in the surplus of the consumer segment that suffers from overvaluation of quality. For example, high-quality consumers are predicted to be worse off as they overvalue the high-quality product because they would be mistakenly overpaying for each unit of quality acquired. Hypothesis 6 states that overvaluation increases total welfare in the market, as overvaluation provides enough incentives to overcome underprovision of quality in the market.

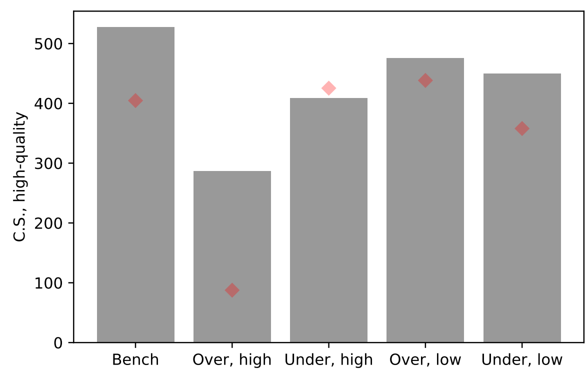
The previous sections showed that most market outcomes under one of the treatments are, on average, different from the benchmark in the expected direction. However, welfare outcomes are a result not only of the direction of the treatment effect, but also of its magnitude. I start by showing welfare outcomes calculated via a central tendency of the choices made during the experimental sessions. Specifically, I plug the averages of the qualities and prices of the high- and low-quality products on equations 3.1, 3.2, 3.3, and 3.4 to evaluate surplus measures before discussing treatment effects. Figure 3.4 shows the results.



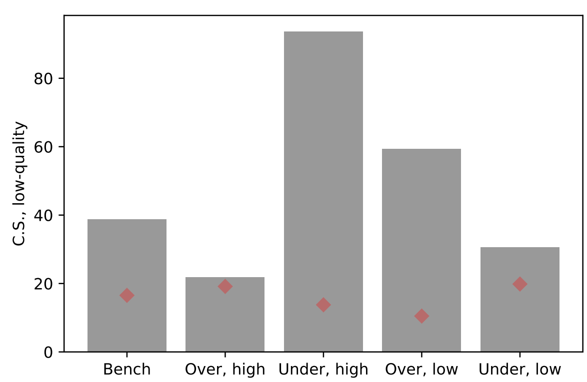
(a) Profit of high-quality seller



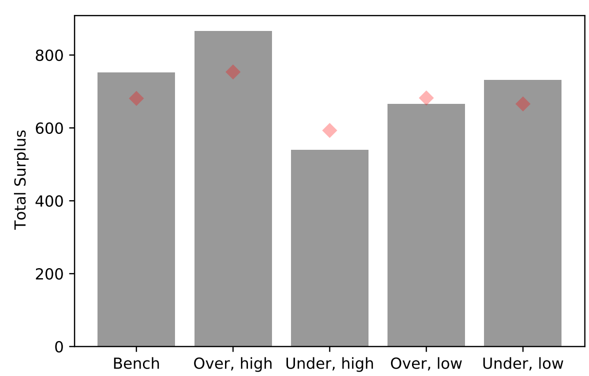
(b) Profit of of low-quality seller



(c) Consumer Surplus of high-quality product segment



(d) Consumer Surplus of low-quality product segment



(e) Total Welfare

Figure 3.4. Welfare outcomes under different treatments. The height of the columns represent observed outcomes under average qualities and prices for each treatment, and the red marks represent theoretical equilibria

Holding prices and qualities on their observed averages produces total welfare outcomes close to the theoretical predictions, as shown by Figure 3.4e. But the distribution of surplus follows predictions only under some treatments. First, notice that high-quality profits and surplus of the high-quality segment are close to theoretical predictions (Figures 3.4a and 3.4c). Under overvaluation of high-quality, the profit of the low-quality seller is way below the predicted value; for undervaluation of high-quality, the profit of the low-quality seller is substantially above the prediction (Figures 3.4b). Surplus of the low-quality consumer is way above prediction, as shown in Figure 3.4d.

The average treatment effects are discussed next. Tables 3.5 and 3.6 show regression models much like those described in Tables 3.3 and 3.4, but in which the dependent variable is (1) the profit for high-quality seller, (2) profit for the low-quality sellers, (3) the consumer surplus for the high-quality seller segment, (4) the consumer surplus for the low-quality segment, and (5) total welfare. These welfare measures are obtained during a given round of the experiment, i.e. they use the observed qualities and prices of a given round during the experiment and not a central tendency measured as in Figure 3.4. The variable “Treat” captures the sign and magnitude of the treatment effect.

The treatment effect for high-quality profits has the expected sign for all treatments. Compared to theoretical results, it underestimates the magnitude of the effect under overvaluation of high-quality, and it overestimates the magnitude under the other treatments. On the other hand, treatment effects for the low-quality profits have the expected sign for over- and undervaluation of the low-quality product, but the wrong sign for over- and undervaluation of the high-quality product. These results are a direct outcome of (1) the lower-than-expected low-quality prices charged under overvaluation of high-quality, and (2) higher-than-expected low-quality prices for undervaluation of high-quality associated with higher-than-expected observed qualities under all treatments. The failure to adjust for incentives provided by misperception often led some low-quality sellers to obtain negative payoffs during rounds.

I find no significant treatment effect for consumer surplus for the high-quality segment, except for undervaluation of the high-quality product. These results, which are contrary to

Table 3.5.
Treatment effects of welfare measures under misperception of the high-quality product

	Overvaluation of high-quality				
	Profit, high	C.S., high	Profit, low	C.S., low	Welfare
Const	162.6***	417.5***	9.277	31.12	679.2***
	(17.94)	(62.05)	(7.69)	(28.57)	(44.94)
Treat	252.8***	6.069	-19.68***	-47.23***	189.3***
	(7.48)	(12.93)	(1.60)	(6.04)	(5.05)
Round	-0.882	-2.017	0.174	3.070	0.258
	(1.18)	(3.75)	(0.37)	(3.56)	(1.31)
N	240	240	240	240	240

	Undervaluation of high-quality				
Const	118.6***	411.7***	5.843	42.09	655.2***
	(30.27)	(65.06)	(4.83)	(30.58)	(48.61)
Treat	-218.6***	-87.77***	17.29***	55.37***	-237.0***
	(8.34)	(15.34)	(1.55)	(8.30)	(8.21)
Round	-0.671	-1.395	0.143	2.653	0.758
	(1.23)	(4.24)	(0.36)	(3.60)	(1.89)
N	230	230	230	230	230

Notes: *** prob. < 0.01, ** prob. < 0.05. Models estimated using hierarchical random effects (at the session level). Standard errors clustered at the session level. Subjects' demographic characteristics included in all specifications.

Table 3.6.
Treatment effects of welfare measures under misperception of the low-quality product

	Overvaluation of low-quality				
	Profit, high	C.S., high	Profit, low	C.S., low	Welfare
Const	184.3***	471.3***	5.250	14.61	778.7***
	(31.97)	(78.61)	(6.36)	(37.43)	(28.25)
Treat	-66.83***	-7.427	8.938***	7.045	-58.14***
	(11.08)	(11.40)	(1.34)	(7.75)	(7.96)
Round	-0.923	-4.247	0.460	3.745	-1.111
	(1.32)	(3.81)	(0.25)	(3.46)	(2.03)
N	250	250	250	250	250

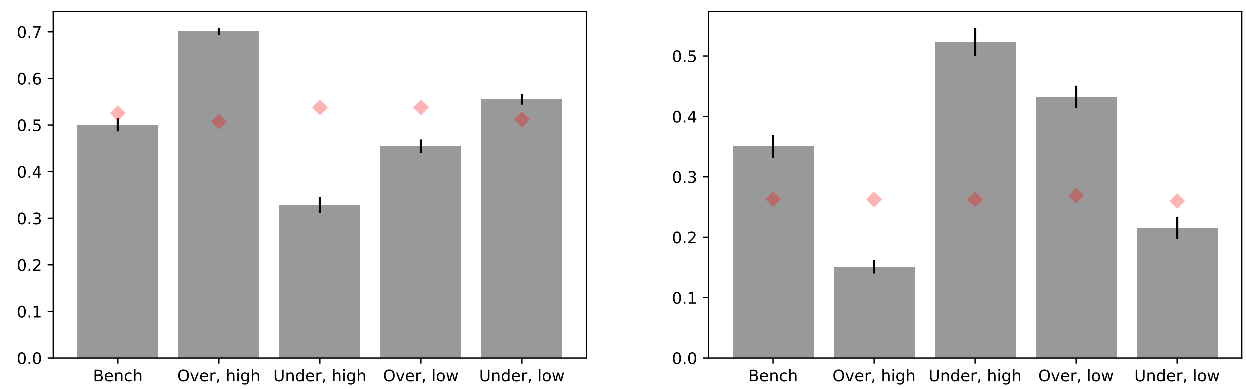
	Undervaluation of low-quality				
Const	149.4***	458.9***	6.964	30.21	765.5***
	(16.80)	(60.38)	(6.84)	(28.82)	(23.15)
Treat	61.35***	23.43	-14.76***	-28.13**	45.31***
	(14.17)	(1.74)	(1.681)	(9.67)	(5.16)
Round	-0.206	-1.398	0.0238	2.789	0.989
	(1.10)	(3.94)	(0.38)	(3.61)	(1.65)
N	230	230	230	230	230

Notes: *** prob. < 0.01, ** prob. < 0.05. Models estimated using hierarchical random effects (at the session level). Standard errors clustered at the session level. Subjects' demographic characteristics included in all specifications.

the signs predicted by theory, arises from the much lower-than-expected prices charged by the high-quality seller. As a result, consumers were able to enjoy higher quality (Figure 3.3a), at a relative lower price (Figure 3.3c). The combination of qualities and prices for undervaluation of high-quality grade left the share of the market consuming the low-quality product far below what was predicted (Figure 3.5b). In combination with a higher-than-expected surplus under the benchmark, this explains the negative treatment effect on consumer surplus of the low-quality segment. A low market share for the low-quality product was also observed for the treatment effect under low-quality undervaluation, such that the treatment effect was significantly lower than the benchmark. The opposite happens under undervaluation of high-quality. Under this treatment, the share of consumers buying the low-quality product was above what theory predicts, resulting in a significant and positive treatment effect, as seen in Table 3.6.

Finally, total welfare is significantly higher when consumer overvalues high-quality, and significantly lower when consumers undervalue high-quality products. This is in line with the theory. However, contrary to predictions, welfare decreases under overvaluation of low-quality, driven by the large decrease in high-quality profits. This large drop in profits is not compensated by any significant increase in high-quality consumer surplus, as predicted, leading to an overall drop in total welfare. The exact opposite happens under undervaluation of low-quality: the sharp increase in high-quality profits is large enough to offset the decrease in low-quality profit and consumer surplus.

In sum, much like the market outcomes, the welfare outcomes for the high-quality seller support the theoretical predictions. Low-quality profits had the expected sign of the treatment effects only under over- and undervaluation of low-quality. Measures of consumer surplus, which are a function of market shares and, because of that, much sensitive to the magnitude of quality and price choices, do not track theoretical predictions well. Surplus outcomes are direct corollaries of quality and price choices by the sellers. The heterogeneity of the choices of sellers during each round of the experiment translates into significant



(a) Market share of high-quality product

(b) Market share of of low-quality product

Figure 3.5. Market share under different treatments. The height of the columns represent average observed outcomes, the red marks represent theoretical equilibria, and the bars are the 95% C.I.

heterogeneity in welfare outcomes. However, if one takes a central measure of those choices under each treatment (average high- and low-quality, and average high and low prices) to calculate welfare measures, total welfare outcomes during the experimental setting track well to what theory predicts (Figure 3.4). The treatment effects of total welfare follow the sign of high-quality profits because of the magnitude of the impact of high-quality profits in total welfare.

3.5 Conclusion and policy implications

There is little empirical evidence about how sellers' decisions vary when consumers misperceive quality, particularly in food markets. As a consequence, researchers still do not fully grasp the efficiency and distributional effects of misperception. This makes policy that tries to curb misperception unpredictable from an efficiency and distributional point of view. The challenge for empirical studies lies in the fact that misperception is the difference between a consumer's perceived quality of a product, and the quality the consumer would perceive had they had full understanding of the product's credence attributes. This measure is not readily observable by the researcher, which limits identification strategies. To circumvent this limitation, I report results from a laboratory experiment that leverages on predictions about consumers' misperception on welfare and distribution under an empirical prevalent market structure, i.e. oligopoly markets in which sellers commit to quality of a product (via certification and labels, for example) and compete in prices.

Using different misperception intensities for different products (high- or low-quality), I tested the theoretical predictions of Scott and Sesmero (2020). I summarized these predictions under 6 hypotheses that describe how market and welfare outcomes under different intensities of misperception vary in comparison to when misperception is absent. I summarize the treatment effects obtained from the experiment below in Table 3.7. All market and welfare effects for the high-quality seller are aligned with the theory, which implies that the high-quality seller tends to offer more (less) quality and charge higher (lower) prices under overvaluation (undervaluation) of high-quality products. Also, the high-quality seller tends to decrease (increase) quality and price to preserve (expand) market share under overvaluation (undervaluation) of the low-quality product. The experiment found no significant effects on market outcomes for the low-quality seller in most of the treatments. This impacts distributional outcomes such that most of the theoretical predictions for the low-quality seller are either null (lack of significant treatment effect), or with the reversed signed as predicted by theory.

Table 3.7.

Theoretical prediction vs. observed outcomes of market and welfare results. The sign to the left of the dash shows the theoretical predictions while the the sign to the right of the dash shows estimated treatment effect during the experiment

Effect	**Overvaluation of high-quality**	**Undervaluation of high-quality**	**Overvaluation of low-quality**	**Undervaluation of low-quality**
Quality				
High	+/ +	-/-	-/-	+/Null
Low	+/Null	-/Null	+/Null	-/-
Price				
High	+/ +	-/-	-/-	+/+
Low	+/Null	-/Null	+/+	-/-
Profit				
High	+/ +	-/-	-/-	+/+
Low	+/-	-/+	+/+	-/-
Consumer Surplus				
High	-/Null	+/-	+/Null	-/Null
Low	+/-	-/+	-/Null	+/-
Welfare	+/+	-/-	+/-	-/+

This paper shows that welfare outcomes under different misperception treatments can substantially differ from theoretical predictions even if the majority of market outcomes (qualities and prices) agrees with the sign of theoretical comparative statics. The magnitudes of the changes in quality and price under different misperception intensities directly impact the distribution of surplus, rendering most of the theoretical predictions on consumer surplus either null or with treatment effects with the reversed sign. These unexpected effects on distribution show that policies that try to curb misperception need to be explicit about which segment of the market the policy is targeting, so that different parts of society can evaluate the policy.

Additionally, and for the same reasons, policymakers need to be attentive of the magnitude of the changes in sellers' choices after a policy to curb misperception is implemented. For example, overvaluation of the high-quality product seems to affect supply of quality of the high-quality only, with no serious consequences for surplus of the high-quality consumer segment, as was initially suggested by theory. Most of the interventions to curb misperception would lead to a combination of qualities and prices that would produce a null effect on high-quality consumer surplus. Undervaluation of either product does not seem to impact the surplus of the low-quality segment in the direction suggested by theory. However, the experiment suggests that high-quality seller benefits from overvaluation of high-quality product or undervaluation of the low-quality product, as predicted by theory.

The most deleterious effect for efficiency would be a correction of overvaluation of the high-quality product. However, correcting undervaluation of high-quality products would be advised, as high-quality profits and consumer surplus are lower under this condition, impacting total welfare negatively. More generally, if policymakers are interested in the total size of welfare, focusing on policies that target high-quality sellers and the segment of high-quality consumers would be best, as the size of those market segments is way above the size of surplus from low-quality segment of the market.

Finally, it is important to emphasize that external validity of laboratory experiments is limited. Limited external validity arises from experimental results being conditional on a set of parametric choices for misperception of quality and functional forms of demand. However, I believe that this paper sheds important light on features that can be explored by further field experiments and observational studies. First, the higher capacity of high-quality sellers to influence the size of total surplus in markets under consumer's misperception of quality; second, the necessity to consider a wide range of misperception treatments to assess distributional effects; and third, the necessity to focus on size and magnitude of the effects of a policy that tries to curb misperception.

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4. OPTIMAL QUALITY GRADATION IN ORGANIC LABELS: EVIDENCE FROM A STRUCTURAL ECONOMETRIC MODEL

4.1 Introduction

The food industry has seen a proliferation of labels identifying otherwise unobservable (credence) quality attributes (McFadden and Lusk 2018; Lusk et al. 2018). The proliferation of such labels has been promoted not only by the private sector (e.g. Non-GMO project, Fair Trade) but also by the public sector (e.g. USDA's organic certification, USDA's meat shields, EPA green labels). Regulators have embraced food labels because they are assumed to help the public make better choices by increasing the availability of information during shopping (Roe and Sheldon 2007; Bonroy and Constantatos 2015). Regulators also have promoted labels with a higher number of grades that represent different qualities of the product (vertical differentiation) under the justification that more quality differentiation provides information to consumers and the addition of value to producers.[1]

There are several reasons to question the rationale that more vertical differentiation in the form of a higher number of quality grades will improve efficiency in the market. For example, consumers often fail to understand information contained in these labels and their grades, either because of cognitive bias (e.g. Lee et al. 2013), health halo effects (e.g. Kiesel and Villas-Boas 2013 and Liaukonyte, Streletskaya, and Kaiser 2015), or overload of information (e.g. McFadden and Lusk 2018 and Bernard, Duke, and Albrecht 2019). Also, in an environment where firms imperfectly compete in quality and prices, a higher number of grades provide a way for firms to differentiate their products thereby softening competition (e.g., Lehmann Grube 1997; Eizenberg 2014; Bonroy and Constantatos 2015; Wollmann 2018). Taking these arguments together, it is not clear whether a higher number of grades increase market efficiency and who, if anyone, benefits from them. In this paper, we aim to estimate the efficiency and distributional effects of a higher number of grades in the food industry.

1. ↑See https://www.ams.usda.gov/sites/default/files/media/AMSProductLabelFactsheet.pdf

We do so by estimating a structural model of a market with 2 levels of vertical grades. We then use this model to generate a counterfactual scenario in which one grade is eliminated and compare the counterfactual scenario with the baseline scenario on the basis of their efficiency and distribution using data for organic certified ground coffee. We use USDA's organic certification to study graded labels as it contains several categories of certification. USDA's organic certification program establishes two possible grades for organic certification that carry the USDA organic seal: **100% organic**, and **organic** (allows for no less than 95% organic ingredients, by weight, as long as all agricultural ingredients are organic), and two grades that do not carry the seal: **made with organic** and **contains organic ingredients**. We focus this work on the grades that have the salient feature that identifies organic products, the USDA organic seal. To differentiate between **organic** and **100% organic**, products certified as **100% organic** can claim anywhere on the package that it contains 100% organic ingredients.

Our structural model consists of multi-product firms that select the characteristics of their product line (including which grade of organic certification) to then compete in prices. Consumers with heterogeneous preferences make purchase decisions based on product characteristics and prices. The model obtains a parametric solution for consumers' indirect utility and firms' marginal cost and we use the estimated structural parameters to explore a counterfactual scenario in which the highest-quality category, the **100% organic grade**, is eliminated. We choose this counterfactual scenario because we can preserve all the products in the market since **100% organic** products satisfy the standards of the **organic** grade, but the converse is not true. By eliminating the **100% organic grade**, firms have to find a new equilibrium in product characteristics under a narrower product characteristic space. Under this narrower space, producers must choose from closer quality categories, which, in equilibrium, alters price competition.

The counterfactual simulation reveals that, on average, weekly welfare (summation between profits and consumer surplus in a week) would increase from US$ 10,973 to US$ 12,738 (an increase of 16.08%) due to the elimination of the **100% organic** grade. Results indicate that shrinking gradation may result in an increase in mean consumer surplus of 2.56% (from US$ 6,010 to US$ 6,139 per week). This is mostly because we calculate higher WTP for **organic** label which allows for expansion in the market for organic coffee products under the counterfactual. Despite some heterogeneity in the counterfactual price distribution, mean prices increase by 0.9% under the counterfactual. The mass of profits increases for more profitable firms under the counterfactual; particularly, mean profits are estimated to increase from US$ 509 to US$677. This reveals that consumers demand more products from high-profit firms. The counterfactual reveals that efficiency tends to increase under a lower number of grades, but while firms at the right tail of the profit distribution increase profits, competition intensity decreases the profitability of firms at the middle and left tail of the profit distribution.

Finally, this work is important because USDA's organic certification program is not a product differentiation mechanism that was endogenously created by the market. It is a government-sponsored *graded* certification scheme exogenously created under the pretext of making consumers more informed and therefore better off (Golan, Kuchler, and Mitchell 2001). Our results show that this pretext needs not to be true, as consumers can be better off with a simpler gradation system. Our paper relates to two strands of literature. The first is related to demand for quality in food products, particularly via labels (e.g., Lusk 2018, 2019; Streletskaya, Liaukonyte, and Kaiser 2019; Villas-Boas et al. 2020). We expand this literature by measuring the demand and consumers' willingness to pay for a different number of grades of organic certified products. The second relates to the literature that deals with imperfect competition in the supply of attributes and the effects that this imperfect competition has on markets (e.g. Nevo 2001; Eizenberg 2014; Wang and Çakır 2020). We advance this literature by computing the extent to which firms can take advantage of mechanisms of vertical differentiation (i.e., a higher number of quality grades) available in the market of food products.

The next session discusses the USDA organic certification program and the data used in this paper. A section dedicated to the formal model is presented after that. This is followed by a section on identification and estimation, a section on results, and then the counterfactual exercise.

4.2 Industry and Data

4.2.1 Organic certification

USDA's organic certification program started to take shape at the beginning of the 1990s, under the Organic Foods Production Act. The standards of the national organic food standard certification were developed in 1997 and, in response to an initial negative reaction, revised in 2000 (Golan, Kuchler, and Mitchell 2001). The National Organic Program (NOP) provides regulatory oversight under the Organic Foods Production Act. The NOP regulates the entire organic supply chain, from the agronomic standards of organic production (soil health, farm biodiversity, pasture) to inputs allowed (e.g., the prohibition of genetically modified organisms, antibiotics, hormones, and a list of synthetic agrichemicals).

There are four grades in the organic certification program: **100% organic**, **organic**, **made with organic**, and **specific organic ingredients**. The **100% organic** category must have all ingredients certified organic, as well as any processing aids. The **organic** certification must have all *agricultural* products certified organic except those that are in an exempt list named National List.[2] Also, non-organic ingredients allowed by the National List may be used, but should not add up to more than 5% of the content of the product. The grade **made with organic** is less restrictive, as it mandates at least 70% of the product content (by weight) must be certified organic. The non-organic ingredients still face restrictions (e.g., cannot be GMO), while the non-agricultural products must be allowed by the National List. Finally, products with less than 70% organic ingredients can list the name and percentage of organic ingredients. These products fall under the **specific organic ingredients**. Only **100% organic** and **organic** get the USDA organic certification seal and the **100% organic** can add the claim that the product uses 100% organic ingredients (although this is not mandatory).

All producers except those selling less than $5,000 in organic products must be certified by a USDA-accredited certifier such that private certifiers and the USDA-AMS enforce the organic standards. Operations that violate standards can suffer civil penalties of $11,000 per

2. ↑Examples of nonagricultural nonorganic substances allowed in **organic** are lactic and citric acids, and a wide arrange of enzymes and flavors (as long as nonsynthetic) when organic flavors are not available. See more at https://www.ams.usda.gov/rules-regulations/organic/national-list

violation (Kuchler et al. 2017) and USDA mandates that an annual inspection of products (or crops and animal production) be conducted by USDA accredited certifiers. In this paper, we use organic coffee as a case study. Our data is discussed next.

4.2.2 Data: shares, prices, products, and input prices

We use the market of organic ground coffee as a case of study in this paper. The choice for organic coffee makes sense because 1) it has faced a fast growth over the years,[3] 2) it is a single-ingredient product which increases the likelihood of observing products that claim the 100% organic certification.[4] We use data from several sources. Most importantly, we obtain data for unit sales and prices of organic coffee from the Kilts Nielsen Scanner Dataset in the year 2016. The data is organized by UPC, store level, and week. Our geographical unit of analysis is Designed Market Area (DMA) which consists of a group of counties where local television stations hold dominance of total watched hours.[5]

Nielsen Scanner Dataset provides information about organic coffee that contains the USDA organic seal, and information about products that claim to be 100% organic.[6] Kilts Nielsen Scanner Dataset also includes characteristics of products. Relevant for the organic coffee are flavor (constructed as a binary variable that indicates whether a product is flavored or not), type (caffeinated or not), brand, style (the type of blend, which is constructed as traditional blend or other), and organic certification (organic or 100% organic). Brand, flavor, type, style, and organic are defined as products' characteristics. We consolidate the UPC-week-store data by DMA, and the product characteristics to obtain total sales of organic coffee. For example, a popular product among consumers is Newman's Organic (brand), traditional (style), caffeinated (type), non-flavored (flavor) organic (label) coffee. In

3. ↑Some estimates predict the growth of 8.2% in market size from 2019 to 2026 according to the Allied Market Research

4. ↑Other markets were explored as well, particularly the market of organic ready-to-eat cereal and grape juice. But the number of products that claim 100% organic in these markets is limited and unlikely to yield good estimates.

5. ↑A DMA is defined to capture local markets based on local advertisements. More information in https://tinyurl.com/y3rp8o5k

6. ↑This information is found on "product extra file", under "USDA organic seal code" and "Organic Claim Description". We classify **100% organic** certified coffee the products that claim to be 100% organic in the claim description.

total, we have 95 unique products. We convert packages of coffee to weight (ounces) values. This implies that the unit of quantity of coffee sold in a week is given in ounces (OZ.), and the average price per ounce is computed by dividing total sales value by total quantity of coffee; thus, we report values for quantity and prices in a per ounce-basis.

We compute market size by multiplying the total population of DMA by the per capita organic coffee consumption in that area. We use Census population estimates to obtain the yearly total population per county and aggregate it up to the DMA level. We assume that population is constant in DMA over the weeks in 2016 and divide the yearly DMA population by the number of weeks in 2016 to obtain weekly population. Given the size of DMAs (which are a union of contiguous counties) and patterns of commuting (mostly around contiguous counties), this assumption seems innocuous. We calculate per capita organic coffee consumption using Nielsen's Consumer Panel Data.

We define the size of the "relevant market" for organic coffee faced by a firm next. A "relevant market" consists of the total quantity offered (or total sales) of all competitors in a specific market for effects of defining the market share of a product. Different studies approached the size of the "relevant market" in different ways.[7] Some studies use a group of products with a high degree of substitution to define relevant markets, while others assume that there only is a high degree of substitution between brands within the boundaries of a single product. For example, Villas-Boas et al. (2020) define the relevant market for microwave popcorn not only as the sales of popcorn itself but also the sales of potato chips and other chips (taken as the outside option for consumers). On the other hand, Nevo (2001) uses only the total ready-to-eat cereal to estimate demand in his studies. We take the approach of Nevo and followed extensively in the literature (e.g., Berry, Levinsohn, and Pakes 1995, Nevo 2000, Villas-Boas 2007, and Matthew Backus, Conlon, and Sinkinson 2020), and define the relevant market as only the market of a single product (in our case, coffee) as a relevant market.

7. ↑Brown Shoe Co. *vs* United States is commonly used as a criterion for defining the relevant market for monopoly cases in the United States. The case states "The outer boundaries of a product market are determined by the reasonable interchangeability of use or the cross-elasticity of demand between the product itself and substitutes for it". For a discussion on the possibilities of this definition for applied research see Kovo and Eizenberg (2019).

However, we narrow the relevant market even further in our study. We consider only the organic coffee market for our demand analysis. This is because organic coffee represents less than 5% of total coffee volume in the Nielsen Scanner Dataset and brands with organic seals have a low share of the total market over the more popular non-organic brands (e.g., Folgers, Maxwell, etc.). Extremely low shares of some products are outliers and tend to cause numerical and econometric problems in our analysis (Conlon and Gortmaker 2020). While there may be some degree of substitution between organic and non-organic coffee products, there is anecdotal evidence that this substitution is weak. For example, special coffees and common coffees tend to be placed on different shelves in the supermarket; also, packaging of these products is different with common coffees being sold in larger containers, and special coffees being sold in smaller and shinier packages. This is consistent with different market niches being targeted for organic and non-organic labeled coffees (i.e., limited cross-price elasticities between these products). So, while the choice of market scope is not without loss of generality, the possible low cross-price elasticity between special and common coffee is unlikely to affect the answer to the main question posed in the paper: the welfare and distribution consequences of the organic graded certification scheme.

While some organic coffee brands only enjoy a small market presence, there are a few that retain high sales and volume share over the years. To illustrate concentration over the 191 DMAs where organic coffee is sold over the 53 weeks of 2016, we show the distribution of CR4 in figure 4.1. While there is a big mass of markets that are not concentrated, we can see that some markets have products having a large market share. Also, the number of brands that carry the **100% organic** label product is smaller. In total, there are 7 brands that carry **100% organic** and 39 brands that carry **organic** seal. Some DMAs do not carry products **100% organic** in our database. Table 4.1 shows that, nationally, there is only 1 brand that claims to be **100% organic** among the top 10 most consumed organic coffee products.

We compute average prices to be $1.19/OZ. The average price for products labeled **100% organic** ($0/90/OZ.) is significantly lower than the average price for products labeled **organic** ($1.20/OZ.). This would indicate that the willingness to pay for **100%** grade is lower than the **organic** grade. But because coffee products have several attributes, the price

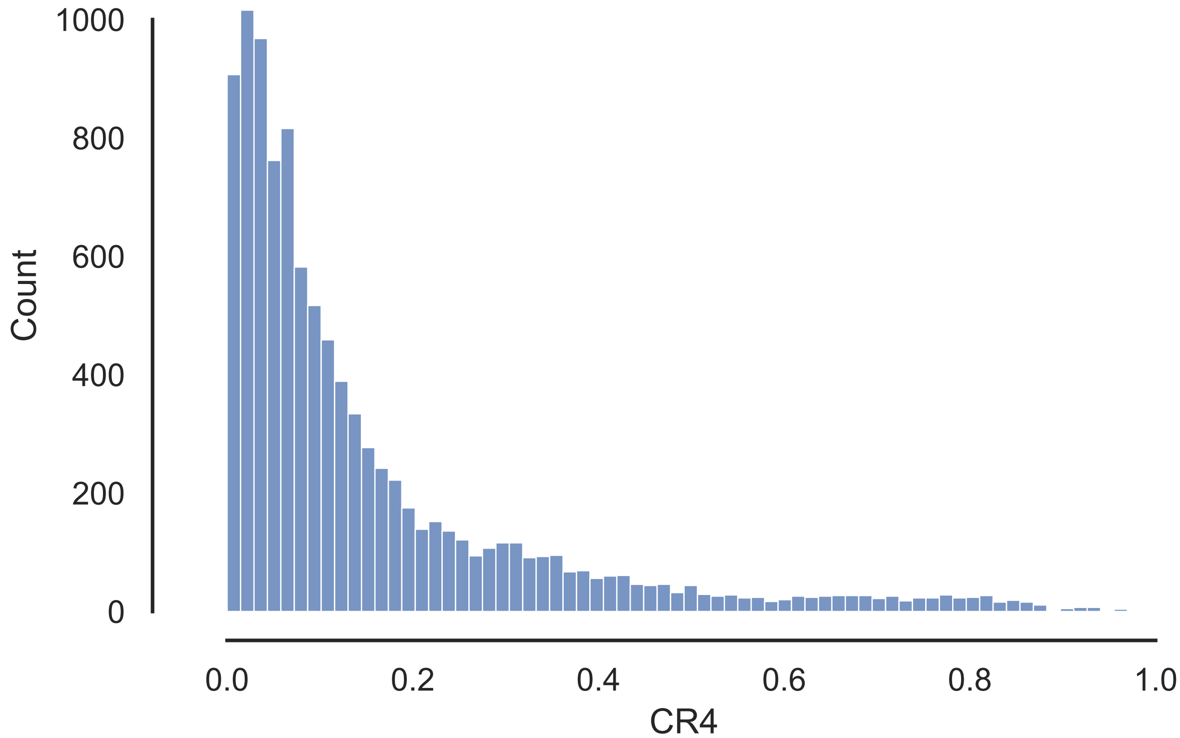


Figure 4.1. Distribution of CR4 across DMA-weeks

Table 4.1.
Top 10 brands in organic coffee by volume in the United States, 2016

Brand	100% org	org	Volume (OZ.)	Sales ($)
Newman's Own Organics Heurg HT	No	Yes	11,084,856.88	13,578,478.8
Seattle's Best Coffee	No	Yes	10,648,212.00	4,797,706.0
Newman's Own Organics Keurig	No	Yes	9,922,741.64	15,284,415.8
Green Mountain Coffee Keurg HT	No	Yes	4,018,913.82	6,486,307.1
Wicked Joe	No	Yes	3,274,344.00	2,474,079.6
Vermont Coffee Company	Yes	No	2,982,920.00	2,027,477.6
Green Mountain Coffee Keurig	No	Yes	1,883,485.20	2,719,744.3
Marley Coffee	No	Yes	1,823,085.06	2,615,334.5
Newman's Own Organics	No	Yes	1,377,456.00	1,139,772.8
Puroast	No	Yes	1,363,574.16	1,061,793.7

Source: author's calculations based on Nielsen Retail Scanner Dataset differential may be due to these other attributes correlated with **organic**. We then run a battery of linear regressions of prices on coffee product attributes: we include a dummy variable ”organic” that takes the value of one if the product has the **organic** label and zero if the product is labeled **100% organic**; a dummy ”flavor” that takes the value of one if the product is flavored (any flavor) and zero otherwise; a dummy ”caffeinated” that takes the value of one if the product has caffeine and zero if the product is decaf; a dummy ”traditional blend” if the blend is traditional and 0 otherwise, and finally a dummy ”bag” that takes the value of 0 if the product is capsule and 1 if the product is packaged in a bag. We also include a time trend, and brand and DMA fixed effects in some specifications. The results are presented in table 4.2.

We can see that the model that includes all fixed effects shows that the **organic** label is associated with higher prices; specifically, conditional on other coffee attributes, **organic** products are associated with $0.047/OZ. higher price, which suggests consumers value more **organic** than **100% organic**. These regressions are not without limitations. Since we only observe equilibrium prices, the idea that we can causally compute price premiums based on selection on observables, as in table 4.2, is not strong in our case.[8] However, the regressions on table 4.2 show that coffee attributes are strongly correlated with prices, and should be included in a model of supply and demand.

Next, we present a demand and supply model to formally compute consumers' WTP for different grades and also establish the impact of the different grades on firms' costs. These models are later used to compute our counterfactual exercise.

4.3 Model

4.3.1 Consumer demand

We present a model of demand for differentiated products next. A product j is offered in a DMA in a given week, which implies that each market, t, consists of a DMA-week combination. As in most discrete choice models, we assume consumers buy one unit of a

8. ↑We also performed the same analysis with a matched sample over observables (the coffee attributes); results are qualitatively identical.

Table 4.2.
Linear panel regression on prices of organic products

	(1)	(2)	(3)	(4)
Constant	0.9071***	1.5090***		
	(0.0031)	(0.0046)		
Organic	0.3021***	0.1018***	0.0969***	0.0475***
	(0.0034)	(0.0021)	(0.0110)	(0.0052)
Flavored		0.0705***	0.0742***	0.0058
		(0.0038)	(0.0130)	(0.0113)
Traditional Blend		0.0772***	0.0411***	−0.0934***
		(0.0036)	(0.0120)	(0.0148)
Caffeinated		−0.0568***	−0.0489***	−0.0657***
		(0.0022)	(0.0063)	(0.0067)
Bag		−0.8470***	−0.8473***	−0.8370***
		(0.0015)	(0.0076)	(0.0132)
Time trend			−0.0020***	−0.0017***
			(0.0001)	(0.0001)
DMA F.E.	No	No	Yes	Yes
Brand F.E.	No	No	No	Yes
Observations	134,080	134,080	134,080	134,080
Adjusted R^2	0.0303	0.7328	0.7350	0.8114

Notes: *p<0.1; **p<0.05 ***p<0.01. Heteroskedasticity-robust standard errors in parenthesis.

product j offered in market t or choose an outside option. The outside option in our case consists of organic brands not included in our database, a common feature in this literature (e.g., Nevo 2001). An individual i's indirect utility is given by equation 4.1:

$$U_{\text{ij}t} = \underbrace{x_{\text{j}t}\theta + \xi_{\text{j}t}}_{\delta_{\text{j}t}} + \underbrace{\sum_{k}^{K} \sigma^k x_{\text{j}t}^k v_{\text{i}t}^k + \boldsymbol{\pi}^p x_{\text{j}t}^p y_{\text{i}t}^p}_{\mu_{\text{ij}t}} + \epsilon_{\text{ij}t}, \tag{4.1}$$

where $x_{\text{j}t}$ is a vector of product attributes (including prices) that impact the utility of consumer i. We also introduce a dummies that combines all the horizontal coffee characteristics: caffeinated, flavored, blend, and type of packaging, which is part of the structural error $\xi_{\text{j}t}$. We let θ be the parameters that enter linearly in the utility function. We allow for random coefficients over consumers' characteristics, such that consumers unobserved tastes (v_{i}, assumed to be normally distributed) for those characteristics shift around their mean for a constant and prices according to some parameter σ^k, where $k \in \{\text{constant, prices}\}$. Notice that σ^k is the diagonal of Σ, a block diagonal matrix of covariance around the mean (therefore, non-negative σ). Finally, the let income (y) be a shift around the mean for prices $x_{\text{j}t}^p$ according to parameter $\boldsymbol{\pi}^p$.

We introduce brand and DMA-fixed effects, such that the demand shock $\xi_{\text{j}t}$ can be decomposed in a time-invariant brand fixed-effect, ξ_{j}^b, and a DMA fixed-effect, ξ_{j}^{DMA}, as well as the fixed effects related to the combination of horizontal characteristics discussed before. The demand unaccounted error term is represented by $\Delta\xi_{\text{j}t}$.

The mean utility from the outside good is normalized to zero and given by equation 4.2:

$$U_{\text{i}0t} = \epsilon_{\text{i}0t} \tag{4.2}$$

Assuming $\epsilon_{\text{ij}t}$ follows a extreme value type-I distribution, the predicted market-share of product j in market-time t is given by:

$$s_{\text{j}t} = \int \frac{\exp[\delta_{\text{j}t} + \mu_{\text{ij}t}(x_{\text{j}t}, v_{\text{i}}, y_{\text{i}}; \sigma_k, \boldsymbol{\pi})]}{1 + \sum_k \exp[\delta_{\text{j}t} + \mu_{\text{i}kt}(x_{kt}, v_{\text{i}}, y_{\text{i}}; \sigma_k, \boldsymbol{\pi})]} f(\mu_{\text{i}t}|\boldsymbol{\pi}, \sigma) d\mu_{\text{i}t}, \tag{4.3}$$

where $f(\mu_{\text{i}t}|\boldsymbol{\pi}, \sigma)$ is the distribution of consumers' taste shifter. We turn to the supply next.

4.3.2 Supply

Within a year, for each week, we assume that each company (processor) chooses to offer a brand of organic coffee containing certain characteristics. Recall that we let the brand-characteristics combination be a product j offered at market t. Companies can offer or withdrawn products from a certain market weekly; thus, in each week, vendors[9] (e.g. Newman's Own Organic) must decide which brand, with which characteristics (e.g. non-flavored traditional blend 100% organic) would be offered in a market. Firms already have their brands well established, so the endowment of brands is assumed constant in the year, even though a firm may choose not to offer it in a given market. We let profits for each firm be determined by equation 4.4.

$$\boldsymbol{\pi}_t^d = \left[\sum_{\mathrm{j} \in J} (p_{\mathrm{j}t} - mc_{\mathrm{j}t})\, s_{\mathrm{j}t}(\mathbf{p_t}) M_t \right], \tag{4.4}$$

where p is price, $\mathbf{p_t}$ is a vector of prices for all products, mc is constant marginal cost, s is product shares (as defined in equation 4.3), M is market size, and J is the set of all products. We assume that firms compete in prices (conditional on J) and we use a Nash-Bertrand equilibrium concept (see Berry and Haile (2016) for an extensive list of studies that use the same competition assumption). We identify mc by jointly solving the necessary conditions for equilibrium for a multi-product firm in a market, as in equation 4.5 and subtracting observed prices from the estimated markup.

$$s_{\mathrm{j}t}(\mathbf{p_t}) + \sum_{k \in J} \frac{\partial s_{kt}}{\partial p_{\mathrm{j}t}}(\mathbf{p_t}) \cdot (p_{kt} - c_{kt}) = 0 \tag{4.5}$$

One can conveniently stack the necessary conditions for equilibrium and as in equation 4.6, and represent the problem in matrix form.

$$\mathbf{p} - \mathbf{mc} = \left(-\Omega \odot \frac{\partial \mathbf{s_t}}{\partial \mathbf{p_t}}(\mathbf{p_t}) \right)^{-1} \mathbf{s_t}(\mathbf{p_t}), \tag{4.6}$$

9. ↑Prices are at the retail level, but we do not explicitly model retail competition in this paper. Implicitly, part of the markup in models of differentiated products are being accrued to retailers

where Ω is a $J \times J$ ownership matrix with entry (j, k) equals 1 if a firm products products j and k. Finally, we assume that marginal cost depends linearly on the observed characteristics chosen by firms ($x_{h\mathrm{j}t}$), following equation 4.7.

$$mc_{\mathrm{j}t} = \sum_h \gamma_v x_{h\mathrm{j}t} + \omega_{\mathrm{j}t}, \tag{4.7}$$

where ω_{j} is the structural error. The subgame perfect Nash equilibrium (SPNE) consists of the set of observed products in the market (and their characteristics), and the prices by which they sell. This supply estimation is for the year 2016, so we consider this a short-run estimation. Having outlined all concepts, we turn now to the estimation of parameters and how to identify them.

4.4 Estimation and Identification

The set of demand parameters to be estimated consists of those entering linearly in the demand system, (θ), and those entering nonlinearly, jointly represented by the matrix $\mathbf{\Sigma}$ and Π. We discuss the requisites for their point-identification next. We will go over the two arguments: the first consists of the identification of random coefficient models that use Berry, Levinsohn, and Pakes (1995) (henceforth BLP) algorithm. The second goes over the plausibility of the assumptions outlined in BLP.

Demand estimation that uses the BLP algorithm consists of a fixed-point iteration nested within an IV-GMM estimator. The main intuition is that consumers buy a product that gives them the highest indirect utility, as given in equation 4.1. Thus, market-level demand is fully characterized by the distribution of random utilities, as shown in Berry and Haile 2016. From equation 4.1, we observe product's characteristics $\mathbf{x_j}$, prices, $\mathbf{p_t}$, and observed market-shares $\mathbf{s_j}$, and we impose the distribution of random coefficients. But to fully identify demand, one would need to observe the stochastic shocks ξ_{j}. This implies that the endogenous variables for each product (quantities and prices, s_{j} and p_{j}) depend on the entire vector ξ and that a battery of controls and instruments are necessary to identify demand parameters (Berry and Haile 2016).

For our case, Berry, Gandhi, and Haile (2013) shows that standard instrumental variable estimation can be used to identify demand parameters under two conditions: 1) higher values of the index δ_{j} raise utility for good j, but not for utilities of good $k \neq \mathrm{j}$ (this implies a sufficient condition for weak gross substitution between products, see Berry, Gandhi, and Haile (2013) for details); 2) there exists a chain of substitution leading to the outside good the paper argues that (1) is directly attained in discrete choice models because of weak monotonicity, and as long there does not exist a subset of products that are only substitutes among themselves, (2) is satisfied.[10]

What is left is to discuss the variables that we use as instruments for the vectors $\mathbf{s_j}$ and $\mathbf{p_j}$. Cost shifters excluded from demand and proxies for marginal cost are generally used to identify prices (Berry, Levinsohn, and Pakes 1995; Nevo 2001; Villas-Boas 2007; Berry and Haile 2016; Eizenberg 2014; Conlon and Gortmaker 2020). In our case, we control for brand fixed-effects and a time trend, as well as DMA fixed-effects. This implies that $\Delta\xi_{jt}$ represents the unaccounted weekly-DMA specific deviations (conditional on a product's horizontal characteristics) from product's j valuation. Given our control variables, prices of the brand between DMAs are independent of weekly-DMA specific shocks but share a correlated marginal cost due to specific production characteristics. This implies that prices of the same brand in other DMAs a proxy for marginal cost and they are sufficient to identify the price parameter.

To circumvent the possibility of price instruments being weak, we augment the set of instruments with input prices that impact retail prices in a region. These are average (over counties that compose a DMA) quarterly electricity costs and cost of labor in 2016, which are own-cost-shifters. These instruments provide spatial and time variation in costs. One worry is that these instruments may correlate with DMA-fixed effects because they are measured quarterly but first-stage regressions show that these measures are not excessively correlated.

10. ↑Formally speaking, the argument is more complicated than that, in the sense that conditions (1) and (2) outlined in the text imply that the market-share can be inverted in such a way that there is an unique utility index of product j associated with product's j stochastic error ξ_{j} (instead of the entire vector ξ) that rationalize the vectors $\mathbf{s_j}$ and $\mathbf{p_t}$, rendering IV estimations possible under completeness and exclusion conditions, see Berry and Haile (2016) for a discussion.

Additionally, Berry and Haile (2016) argue that traditional cost shifters cannot be instruments for the vector $\mathbf{s_t}$, as they only shift shares via prices. However, they show that exogenous product characteristics shift shares via mean utility, such that exogenous product characteristics can be used as instruments. To qualify this argument and further circumvent the possibility of weak IVs, we use Gandhi and Houde (2015) differentiation IVs. The authors develop this IV for shares based on the fact identification of demand under IV is relevant if it can approximate the conditional inverse demand. While the full argument of Gandhi and Houde (2015) is outside the scope of this paper, the intuition of their approach is that relevance of an IV in the context of RCLM is attained when one can describe the empirical distribution of characteristics differences for product j in a market. In other words, a strong instrument reveals the degree of differentiation between products. Formally, following Gandhi and Houde (2015), we construct IV in their local variant where the instrument is given by $d_{\mathrm{i},k} = |x_{kt} - x_{\mathrm{j}t}|$, in which the distance between characteristics is summed for every pair of product (k, j).

Armed with these instruments we fit a linear model over the battery of instruments (first-stage regression) that shows that, together, these instruments can explain prices ($F-\text{value}:$ 26450, and adj. $R^2 = 0.719$). Then, conditional on characteristics choices by firms, we argue that we have a well-identified demand side. However, notice that consumers only observe product characteristics after firms decided the product line offered in market t and incurred fixed and sunk costs related to this product line (cost of certification, stock management, packaging and design, etc.). As stated by Eizenberg (2014), the decision of firms to offer a product line that is only a subset of all the possible products renders a non-random sample of product characteristics. An additional assumption is required to claim identification of parameters on the demand side: the error term $\xi_{\mathrm{j}t}$ is only observed after the firm makes its product choices. This implies that the firms select characteristics of the product lines taking the price competition stage into consideration, but not the exact value of the stochastic demand shocks. This mean conditional independence is not testable, but we argue that the likelihood of firms knowing the mean realization of the entire vector ξ is small. The results of the estimation are discussed next.

4.5 Estimation Results

We start by presenting the results for demand estimation. Table 4.3 shows the result from an IV-logit model and the random coefficient Logit model. The parameters that enter utility linearly are similar in both models, as expected. The mean price effect on utility has the expected negative sign; we also estimate a small downward time trend for organic coffee in the year 2016.

The random coefficient Logit estimates include the interaction between income and prices (Π). The positive coefficient reveals that higher-income households are less price-sensitive, but the effect of the estimate has a higher degree of uncertainty (parameter value is 0.079 and its std. error is 1.369). The unobserved (assumed to be bivariate normally distributed) heterogeneity parameters (Σ) were also included in the random coefficient estimation. Both parameters hit the lower bound of the estimation.[11] This implies that we do not observe consumer heterogeneity due to unobserved characteristics, once income is included. The mean (across all products in all markets) own-price elasticity for organic coffee products is estimated to be -2.1.

One important characteristic that can be computed from these estimates is the average (over the all markets) willingness to pay (averaged over all simulated consumers in the market) for **organic** label over the **100% organic** label.[12] On average, consumers are willing to pay up to 0.19/OZ more to substitute **100% organic** product with its **organic** labeled version. In other words, the WTP for **organic** labels is higher than **100% organic**, holding everything else constant. This suggests that organic coffees labeled as **100% organic** are not perceived by consumers as having superior quality than those labeled **organic**. This result is rationalized by the fact that consumers often fail to understand the information labels and their different gradations are trying to communicate. This failure can happen because of cognitive bias (e.g., Lee et al. 2013), health halo effects (e.g. Kiesel and Villas-Boas 2013 and Liaukonyte, Streletskaya, and Kaiser 2015), or overload of information (e.g., McFadden and Lusk 2018 and Bernard, Duke, and Albrecht 2019). The most likely explanation for

11. ↑The result is robust to a battery of different starting values.

12. ↑This is computed as $\frac{1}{T}\sum_1^T \left(\frac{1}{I}\sum_1^I WTP_{\mathrm{i}}\right)$, where $WTP_{\mathrm{i}} = -\frac{\partial U_{\mathrm{i}}}{\partial x_{org}} \Big/ \frac{\partial U_{\mathrm{i}}}{\partial p} = \frac{\theta_{org}}{\theta_{price}+\sigma_p v_{\mathrm{i}}^p+\pi_p y_{\mathrm{i}}}$

Table 4.3.
Demand estimation under Random Coefficient Logit Model and Logit

Parameters Demand	Variable	RCLM		Logit - 2SLS
β	Prices	-2.542		-1.850
		(1.457)		(0.053)
	Organic	0.0854		0.0845
		(0.021)		(0.016)
	Trend	-0.003		-0.003
		(0.000)		(0.000)
Σ		Const	Prices	
	Const	0.000		
		(5.651)		
	Prices		0.000	
			(3.291)	
Π		Income		
	Prices	0.079		
		(1.369)		
Observations		134080		134080
DMA FE		191		191
Brand FE		40		40
H. Charac. FE		11		11

Notes: Heteroskedasticity-robust standard errors in parenthesis.

higher WTP for **organic** is the high consumers' search costs for the different gradations of the organic label, as described in Streletskaya, Liaukonyte, and Kaiser (2019).

Despite the lower WTP for **100% organic**, firms' decision to label their coffee products **100% organic** make economic sense if the markup associated with this labeling is higher. Table 4.4 reveals that the marginal costs of products associated with **organic** label are higher than those associated with **100% organic**, even after controlling for firms fixed effects. This implies that, conditional on constant mc and additive and linear cost-shifter, coffees labeled **organic** are more expensive at the margin. This can be rationalized by a diverse set of reasons that are discussed next.

Table 4.4.
Marginal cost and additional information from supply side

Parameters Supply	Variable	
γ	Constant	0.994
		(0.006)
	Flavor	0.007
		(0.003)
	Traditional Blend	-0.087
		(0.004)
	Caffeinated	-0.063
		(0.002)
	Bag	-0.755
		(0.002)
	Organic	0.037
		(0.002)
Observations		134080
Firm FE		35

Markups and additional information	
Median markup (US$)	0.54
Median markup org. (US$)	0.55
Median markup 100% (US$)	0.53

Notes: Heteroskedasticity-robust standard errors in parenthesis. A Mood's median test rejects the null hypothesis that the medians of the markup for **organic** and **100% organic** are equal.

First, we make the distinction between the effects of the certification in sunk and marginal cost in our context. As of 2020, there were nearly 80 agents authorized to certify businesses to the USDA organic regulations. A combination of different pricing charged by certification services by these agents and regional constraints (including cost-share programs) can change the size of sunk costs of adopting different organic gradations. This explains adopting different organic gradations from the firms' perspective (as the size of the fixed/sunk cost influence the entry/exit of *products* in the firms' product line). Conditional on the adoption of **organic** (which is determined by the possibility of non-negative profits), firms search for inputs (blends of coffee beans from different countries) that satisfy the firms desired characteristics for their products. Our cost regression suggests that the mix of inputs (e.g., origin of coffee beans) for **organic** products tends to be more expensive than the search for inputs for **100% organic coffee** according to our estimates. In other words, the coefficient "organic" in the cost function does not reveal the direct costs of labeling **organic** (as this would be part of the sunk cost), but rather we interpret this coefficient as changes in search costs for specific blends of coffee that are labeled **organic**. In other words, our results suggest that **organic** coffees are more complex products to produce than **100% organic** products and the "organic" coefficient captures this fact.

Median estimated markup is 0.54/OZ for the entire sample, but 0.53/OZ for the **100% organic** coffee and 0.55/OZ for the **organic** coffee, as shown in table 4.4. Thus, our estimates show that **organic** coffees producers obtain higher markup; this higher markup is possible because producers charge higher prices than **100% organic**, even though it seems that cost per OZ of **organic** is slightly higher. This is corroborated by the higher estimated WTP for **organic** products.

There are two reasons for these estimated markups. The first relates to firms being able to offer a differentiated product that consumers want (organic coffee). These markups are likely justified by a supply response that arises as a response from consumers' needs (Miller and Weinberg 2017) rather than to firm conduct that derives from a non-competitive behavior, like tacit collusion. The second possible reason for high markups arises from the strategic choice of some firms to select their products into different organic grades. Next, we examine what happens to markup, prices, and market shares of firms when we eliminate the **100% organic** grade.

4.6 Counterfactual analysis

The previous session discussed a model that finds a parametric solution for consumers' indirect utility and firms' marginal cost. In this section, we use the estimated structural parameters to explore a counterfactual scenario in which the category **100% organic** grade is eliminated. We assume that all products previously labeled **100% organic** are labeled with the **organic** gradation under the counterfactual. We choose this counterfactual scenario because we can preserve the number of products in the market since **100% organic** products satisfy the standards of the **organic** grade, but the converse is not true, as discussed in the Industry and Data section.

This implies that the first assumption for the counterfactual exercise is that the market structure remains the same (i.e., no observation is discarded in the counterfactual; rather products labeled as **100% organic** change the vertical characteristics from **100% organic** to **organic**). This assumption is important because preserving the number of products and changing the labeling on them isolates the effects of a different number of organic grades in the market. The second assumption is that the observed horizontal characteristics for each product (flavor, caffeine content, package, traditional blend) remain constant and are not impacted by the change in availability of the **100% organic** label. In other words, firms choose observed horizontal characteristics and the type of label independently from each other. By computing equilibrium prices, marginal costs, consumer surplus, profits, and total welfare from this counterfactual exercise, we are able to estimate the efficiency and distributional effects of a higher number of organic grades in the organic coffee market.

By eliminating the **100% organic grade**, we assume that firms find a new equilibrium in product characteristics under a narrower vertical characteristic space. Under this narrower quality space, products that were positioned in different parts of the quality spectrum are not anymore; in equilibrium, this alters price competition. Thus, the counterfactual analysis assumes an equilibrium selection (firms choose products to have **organic** label instead of dropping out of the market). Under this assumption, the change in sunk costs due to labeling products as **organic** instead of **100% organic** is not big enough to make this equilibrium unfeasible. This seems to be an innocuous assumption as there is no evidence that labeling products as **100% organic** entail much higher sunk cost to processors than **organic**, as the process of certification for both follows the same set of standards by the USDA. Also, cost-sharing programs used to offset sunk costs are widespread for small producers (Kuchler et al. 2017). While the literature has developed the tools to (partially) identify sunk costs (see Eizenberg 2014 and Wollmann 2018), the exercise is likely to have limited use and poor descriptive properties in our case given the institutional characteristics of organic labeling.

We find the new vector of marginal costs mc^* under the counterfactual by assigning the **organic** label to all products. New prices under the counterfactual are found recursively via the FOC equilibrium condition as in equation 4.6. Letting p_t^* be the new vector of prices, we iterate equation 4.8 until convergence.

$$\mathbf{p_t^*} - \mathbf{mc_t^*} = \left(-\Omega \odot \frac{\partial \mathbf{s_t}}{\partial \mathbf{p_t^*}}(\mathbf{p_t}) \right)^{-1} \mathbf{s_t}(\mathbf{p_t^*}), \tag{4.8}$$

Since equation 4.8 is not a contraction, we use the fixed-point algorithm developed by Morrow and Skerlos (2011), which is shown to converge more reliably (Conlon and Gortmaker 2020). However, 27,635 products are in a market that observes no **100% organic** which implies that these products are not included in the counterfactual. Also, we find that a market with 39 products did not converge in our counterfactual exercise. For markets in which equation 4.8 converged, counterfactual prices are then used to compute counterfactual shares and markups. Table 4.5 shows these results.

Median prices (over all products and all markets) decreased, but mean prices increased. Together these central tendencies hide heterogeneity. For example, table 4.5 shows that the 1st quartile of the price distribution (all products, all markets) increased by 2.29%, and the 3rd quartile decreased by 0.17%. Mean prices of products that have more than 5% of any market increased 7.7% in the counterfactual scenario (from 0.93 to 1.00), with the largest single product price increase being \$0.59/OZ. and the largest negative price increase being -\$0.36/OZ.

Table 4.5.

Distribution of prices and counterfactual prices (left) and markups and counterfatual markups (right). All values in US$

	Prices	Count.	Diff
mean	1.1491	1.1593	0.88%
25%	0.7810	0.7988	2.29%
50%	0.9863	0.9852	-0.11%
75%	1.5567	1.5540	-0.17%

	Markup	Count.	Diff
mean	0.557392	0.563234	1.05%
25%	0.522568	0.524721	0.41%
50%	0.548101	0.548811	0.13%
75%	0.579601	0.579414	-0.03%

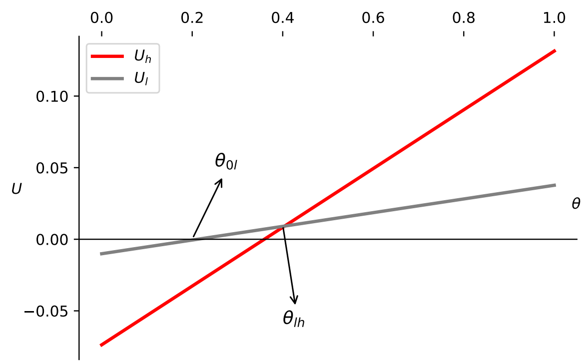
The table shows the mean and the quartiles of prices and markups at the product level under the factual and counterfactual scenario, for all markets that contain **100% organic** products at the factual scenario ($n = 106,407$). The percentage difference is calculated at the mean and quartiles of the distribution.

Median and mean markup increased under the counterfactual scenario. We calculate a high coefficient between counterfactual prices and markups (Pearson's correlation of 0.97) which implies products facing higher prices under the counterfactual increase their markup. Notice that, all else constant, higher competition in the quality spectrum (ie., more products under the **organic** label) would pressure prices down, but we calculate an increase in prices for about half of the products (over all markets) under the counterfactual. We discuss the plausibility of this increase in prices next.

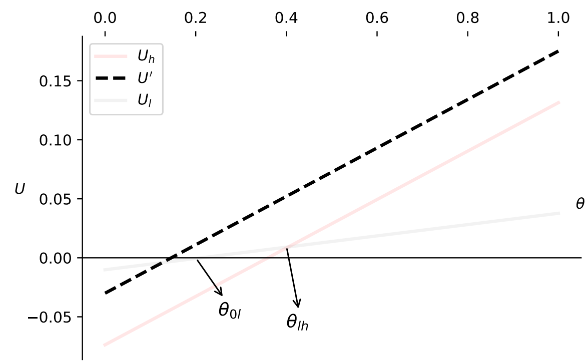
An exogenous shock that makes products previously labeled **100%** to be labeled **organic** shifts demand of these products to the right (see model results on table 4.3). This implies that, all else constant, products labeled **organic** should see an increase in their market share. However, the higher WTP for **organic** also implies that firms could increase prices (up to what is allowed by their best response functions). This increase in prices triggers responses from the demand side that may increase or decrease products' market share (according to own- and cross-price elasticities).

Strictly from the supply side, the counterfactual scenario implies that firms face less differentiation, and price competition becomes stronger. This would correspond to a decrease in prices, but potentially an increase in shares depending on how large these prices decrease. The net result of these multiple forces determines how much more market share products have, and what prices are they charging. From the supply side, one could expect a vector with lower average prices under the counterfactual, but from the demand side, a vector with higher average prices is plausible.

Our results show that mean prices, mean markups, and mean shares have increased. This suggests that demand-side effects are stronger than supply-side effects. Specifically, mean shares have increased from 1.3% of the market to 1.6%, with most of the share increased concentrated in firms with an already larger share. Next, we explain how these results are theoretically sound using a vertical differentiation model for a market with 2 products presented in figure 4.2 (see Jean Tirole 1988 for a formal derivation). The simplified 2 product market allows for a visual cue of the mechanism behind these counterfactual results. Since our counterfactual exercise holds horizontal characteristics constant, the vertical differentiation model is useful at explaining the intuition behind the counterfactual because it abstracts away from horizontal characteristics.



(a) Equilibrium in a 2 product vertical differentiation model



(b) Equilibrium after elimination of the low-quality product; fading curves are the same as the figure in the left panel

Figure 4.2. Effects of eliminating the low-quality product in a market of vertical differentiation with 2 products. The left panel shows quality and prices for low- and high-quality products. The right panel shows the effects of transforming all products into high-quality.

The left panel of the figure 4.2 represents a simplified version of our factual results. It shows consumers' indirect utility curve U_h for a product perceived as higher quality (according to our demand estimates this would be **organic**) and the consumers' indirect utility of a product perceived as lower quality (**100% organic** according to our demand estimation), U_l. These are utilities for consumers with heterogeneous WTP for quality (which are represented in the x-axis).[13] The slope of the utility curves are average qualities of products in equilibrium (steeper slope means higher quality), and the intercept of the curves are average prices in equilibrium (lower the intercept, the higher the price). The size of the market is given by the segment of line to the right of the consumer indifferent between the low-quality product and the outside good, θ_{0l}. The outside good's utility is zero in the figure, as it is in our empirical model. The consumer indifferent between high- and low-quality products is given by θ_{lh}.

13. ↑For sake of exposition, we use utilities of the linear form, market size is unit-sized, and assume consumers are uniformly distributed along the WTP line, as in most of the two product vertical differentiation models, see Bonroy and Constantatos 2015.

A simplified version of the counterfactual is represented in the right panel of figure 4.2. In the counterfactual, we eliminate the **100% organic** label (perceived as low-quality in our estimation) and set all products to be labeled as **organic** (perceived as high-quality). This is represented by the new utility curve U'; the faded curves represent the factual scenario and are included for comparison.

Under the counterfactual, the quality that consumers face (slope of U') is the same as the U_h curve (notice the same slope for both curves), which implies a counterclockwise rotation in the utility from consumers previously consuming low-quality; under the counterfactual scenario, prices increase over the low-quality prices charged in the factual scenario because firms can now charge a higher price for higher quality products (hence the downward shift of U' in relation to U_l). In equilibrium, average prices in U' are higher than average prices in the factual (averaged over high- and low-quality prices), and equilibrium quality is the same as the high-quality product in the factual. The curve U' crosses the x-axis to the left of the curve θ_{0l}, which implies that the market size in the counterfactual increases over the factual scenario. This is possible because the impact of higher average quality (which increases market size via consumers' preferences for quality) is higher than the decrease in market size due to increase in average price. As a result, under fewer grades we have higher average market size, higher average prices, and higher average quality than in the factual scenario, as seen in figure 4.2. This is the same results we obtain in our empirical counterfactual exercise. In other words, the empirical counterfactual equilibria that we obtain are fully consistent with a theoretical model of vertical differentiation in which the low-quality product is eliminated.

The general intuition that demand-side forces guide our counterfactual exercise is also confirmed by the increase in average consumer surplus in our empirical model[14] (over all markets) under the counterfactual, as shown in table 4.6.[15] Mean C.S. increases by 2.11%

14. ↑Consumer surplus is computed as $\frac{1}{I}\sum_{\mathrm{i}} CS_{\mathrm{i}}$, where $CS_{\mathrm{i}} = \ln(1+\sum_{\mathrm{j}} \exp(U_{\mathrm{ij}t}))/\left(-\frac{\partial U_{\mathrm{i}1t}}{\partial p_{1t}}\right)$. The denominator is the marginal utility of price of the first product in our database. Subtracting the factual consumer surplus from the counterfactual consumer surplus gives us a measure of compensating variation for the mean consumer in the market, for each OZ. of organic coffee. Multiplying this by the size of the market of organic coffee gives us a total consumer surplus measure.

15. ↑These results are robust to the selection of products that have a higher share in the market. We can show an increase for mean and median prices, shares, and markups under the counterfactual for products with more than 5% of the market prior to the counterfactual.

Table 4.6.
Distribution of consumer surplus and its counterfactual (left) and profits and its counterfactual (right). All values in US$

	CS	Count.	Diff
mean	6010	6139	2.11%
25%	566	579	2.15%
50%	1524	1564	2.55%
75%	5089	5229	3.90%

	Profit	Count.	Diff
mean	509.252	677.1092	32.96%
25%	19.10086	13.3722	-29.99%
50%	66.48925	63.19101	-4.96%
75%	239.7793	263.5399	9.91%

The table shows the mean and the quartiles of the consumer surplus (at the market level for all markets containing **100% organic** at the factual scenario, $n = 6,460$) and profits (at the firm-market level for all markets that contain **100% organic** at the factual scenario, $n = 62,960$) under the factual and counterfactual scenario. The percentage difference is calculated at the mean and quartiles of the distribution.

from US$ 6,010 per week in each DMA to US$ 6,139. This results from both higher market size under the counterfactual and higher consumers' utility values under fewer grades.

We briefly discuss changes in profit for firms. We consider firms' profits as in equation 4.4. Mean, prices, mean markups, and shares (over products) increase in our counterfactual, but mean profits (over firms' profit per market) decrease. Looking at the distribution of counterfactual profits, we see that firms at the high end of the distribution increase profit, while profits for those at the middle and lower end of the distribution decrease.

Armed with these values, we compute total changes in welfare. We define total welfare as the summation of total profits and consumer surplus at the market level and the results are presented in table 4.7. We see that under the counterfactual, efficiency in the market increase for all quartiles and also for the mean, supporting the thesis that fewer grades are better for the market of organic coffee.

The counterfactual shows that a possible simplification of gradation standards of the organic certification program benefits consumers, at the same time that it can also benefit more profitable firms. On average, efficiency tends to increase.

Table 4.7.

Distribution of total welfare and counterfactual welfare. All values in US$

	Welfare	Count.	Diff.
mean	10,973	12,738	16.08%
25%	1,066	1,345	26.20%
50%	2,880	3,560	23.60%
75%	9,660	12,120	25.48%

Mean and quartiles of total welfare (consumer surplus plus total profits) over all markets ($n = 6,460$) under the factual and counterfactual scenario. The percentage difference is calculated at the mean and quartiles of the distribution

4.7 Conclusion

Government-sponsored label certification programs are created under the justification that labels will help consumers make better choices. Label grades take this notion further by assuming that more vertical grades can match consumers' heterogeneous preferences and improve welfare. This paper challenges this notion by showing that fewer grades in the USDA's organic certification program can increase efficiency, consumer surplus and increase the profits of some firms.

Consumer surplus under the counterfactual (i.e., **100% organic** is eliminated and products are labeled as **organic** instead) increases because consumers are more willing to pay for **organic** products than **100% organic** products. This expands the market size, despite higher prices for some products. Under the counterfactual scenario, markups increase for products offered by firms that are in the right tail of the profit distribution. In general, we show that welfare can increase under a less graded label organic program. This welfare increase is followed by higher mean prices, higher mean markups, and higher mean shares. One important qualification is that we assume that no product exit the market under the counterfactual scenario, something with which the organic certification program seems to agree (due to similar fixed costs between **100% organic** and **organic**), but needs not to be true for other certification programs.

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A. PROOFS ESSAY 1

A.1 No leapfrogging conditions

We use equations A.1- A.6 throughout appendix 1 and 2. Equations A.1 and A.2 are derived by substituting equilibrium prices $p_{\mathrm{i}}^{*}(v_h, v_l; k_h, k_l)$, i $\in \{h, l\}$ in the revenue functions. For misperception on high-quality, we set $k_l = 1$ in the equations below; whereas for misperception on low-quality, we set $k_h = 1$ in the equations below.

$$R_h = \frac{4k_h^2 v_h^2 (k_h v_h - k_l v_l)}{(4k_h v_h - k_l v_l)^2}. \tag{A.1}$$

$$R_l = \frac{k_h k_l v_h v_l (k_h v_h - k_l v_l)}{(4k_h v_h - k_l v_l)^2}. \tag{A.2}$$

$$\frac{\partial R_h}{\partial v_h} = \frac{4k_h^2 v_h (4k_h^2 v_h^2 - 3k_h k_l v_h v_l + 2k_l^2 v_l^2)}{(4k_h v_h - k_l v_l)^3} > 0 \text{ if } \frac{v_l}{v_h} < \frac{4k_h}{7k_l}. \tag{A.3}$$

$$\frac{\partial R_h}{\partial v_l} = -\frac{4k_h^2 k_l v_h^2 (2k_h v_h + k_l v_l)}{(4k_h v_h - k_l v_l)^3} < 0, \text{ if } \frac{v_l}{v_h} < \frac{4k_h}{7k_l}. \tag{A.4}$$

$$\frac{\partial R_l}{\partial v_l} = \frac{k_h^2 k_l v_h^2 (4k_h v_h - 7k_l v_l)}{(4k_h v_h - k_l v_l)^3} > 0 \text{ if } \frac{v_l}{v_h} < \frac{4k_h}{7k_l}. \tag{A.5}$$

$$\frac{\partial R_l}{\partial v_h} = \frac{k_l k_h v_h^2 (2k_h v_h + k_l v_l)}{(4k_h v_h - k_l v_l)^3} > 0, \text{ if } \frac{v_l}{v_h} < \frac{4k_h}{7k_l}. \tag{A.6}$$

Armed with these definitions, we start by showing conditions under which the no leapfrogging condition holds for different treatments.

Sequential competition under misperpcetion of high-qualty grade

First, we explain the notation used in this appendix. Let v represent quality, let the superscript $\{L, F\}$ stand for leader and follower firm, respectively, and let the subscript $\{l, h\}$ refers to low and high quality, respectively. We will use the following convention: a given function $K(x, y)$ depends on the high-quality and low-quality level chosen by firms, such that x is always the lower level of quality and y is the higher level of quality. For example, the function $K_h^L(x, y)$ refers to the high-quality (subscript h) leader's (superscript L) $K(\cdot)$ function, under high-quality choice y and low-quality choice x. Similarly, the notation for the low-quality follower in this example would be $K_l^F(x, y)$, where it chooses quality level x, and y is the leader's quality choice.

We show that there exists a unique equilibrium in pure strategies for the sequential game over a range of misperception parameters, such that the leader's quality in equilibrium is higher than the follower's quality in equilibrium. The set of conditions that guarantee such equilibrium in pure strategies are known as the no-leapfrogging conditions (Motta 1993; Lehmann Grube 1997).

To understand the no leapfrogging conditions, we first discuss the leader's possible decisions, following Lehmann Grube 1997. The leader has three options: i) it can choose a low-quality level v_l^L that forces the follower to best-respond with a higher-quality level $v_h^F = b(v_l^L)$; ii) the leader can choose the high quality level v_h^L that guarantees that the follower best-responds with a lower-quality level $v_l^F = h(v_h^L)$; iii) leader can choose a level of quality $\hat{v}$ such that the follower is indifferent between choosing a higher $\hat{v}_h$ or lower $\hat{v}_l$ quality level than $\hat{v}$. To show no leapfrogging conditions in sequential games, we must show that, over a range of misperception parameters, (1) the leader makes higher profits by positioning as high-quality firms rather than lower-quality firm and (2) the high-quality leader makes higher profits than lower-quality follower in equilibrium. This is formally defined in equations A.7 and A.8:

$$\pi_l^L = R_l^L(v_l^L, v_h^F; k_h) - C(v_l^L) < R_h^L(v_l^F, v_h^L; k_h) - C(v_h^L) = \pi_h^L \tag{A.7}$$

$$\pi_l^F = R_l^F(v_l^s, v_h^s; k_h) - C(v_l^s) < \pi_h^L = R_h^L(v_l^s, v_h^s; k_h) - C(v_h^s) \tag{A.8}$$

where v_h^s is the maximum between $\hat{v}$ and v_h^L. Equation A.7 guarantees that the leader's profit under its best high-quality choice, conditional of follower best responding with a low-quality choice, strictly dominates the leader's profit under its best low-quality choice, conditional on the follower best responding with a high-quality choice. Equation A.8 guarantees that the high-quality leader has no incentive to deviate from its best high-quality choice, say choosing a quality that is closer to the follower's low-quality choice, because the leader can always make higher profits than the follower. Together, condition (1) states that the leader will force the follower to best-respond with lower-quality and once the leader chooses high-quality, condition (2) guarantees that the leader's choice yields the highest profit among the firms, which implies that there is no incentive to deviate from it. These are the no-leapfrogging conditions.

LEMMA A1. Conditional on a misperception parameter, (1) the best low-quality choice by the leader in sequential games, v_l^L, is higher than the optimal low-quality choice in simultaneous games, v_l^n; (2) the follower's high-quality best-response to (1), $v_h^F(v_l^L) = b(v_l^L)$, is higher than the optimal high-quality choice in simultaneous games, v_h^n.

Proof: Suppose the leader chooses low quality. The necessary condition for optimality must satisfy the leader's first-order conditions of the sequential game:

$$d\pi_l^L/dv_l^L = 0, \tag{A.9}$$

which can be written $\partial R_l^L/\partial v_l^L + (\partial R_l^L/\partial v_h^F)b'\left(v_l^L\right) = dC(v_l^L)/dv_l^L$. Notice that the first-order condition of the sequential and simultaneous game for the follower is $\partial R_h^F/\partial v_h^F - dC^L(v_h^F)/dv_h^F = 0$. We can totally differentiate the follower's first-order condition with respect to v_l^L and rearrange the terms to obtain:

$$b^{'}(v_l^L) = \underbrace{\frac{\partial \frac{\partial R_h^F}{\partial v_h^F}}{\partial v_l^L}}_{>0} \Bigg/ \left(\underbrace{\frac{\partial \frac{\partial C_h}{\partial v_h^F}}{\partial v_h^F}}_{>0} - \underbrace{\frac{\partial \frac{\partial R_h^F}{\partial v_h^F}}{\partial v_h^F}}_{<0} \right) > 0, \tag{A.10}$$

which implies $b'(v_l^L) > 0$. Notice that $\partial R_l^L/\partial v_h^F > 0$. Also, notice that the necessary conditions for a solution for a simultaneous quality game would imply $\partial R_l^L/\partial v_l^L = dC^L(v_l^L)/dv_l^L$. Thus, by comparing first-order conditions of the sequential and simultaneous games, we know that $v_l^L > v_l^n$, where v_l^n is the solution for a simultaneous game. Since best responses are monotonic, we know that the follower chooses $v_h^F > v_h^n$ at the optimal values.

LEMMA A2. Conditional on a misperception parameter, (1) the best high-quality choice by the leader in a sequential game, v_h^L, is lower than the optimal high-quality choice in simultaneous games, v_h^n; (2) the follower's low-quality best response (1), $v_l^F(v_h^L) = h(v_h^L)$, is lower than the optimal high-quality choice in simultaneous games, v_l^n.

Proof: Assume that the leader acts as the high-quality firm by choosing quality level v_h^L. Under these circumstances, the follower would best respond with $v_l^F = h\left(v_h^L\right)$. Now, the necessary condition for optimality must satisfy the first-order conditions of the sequential game, such that:

$$\frac{\partial \pi_h^L}{\partial v_h^L} = \frac{\partial R_h^L}{\partial v_h^L} + \frac{\partial R_h^L}{\partial v_l^F} h'(v_h^L) = \frac{dC^L(v_h^L)}{dv_h^L}. \tag{A.11}$$

Notice that $\partial R_h^L / \partial v_l^F < 0$. One can check that $h'(v_h^F) > 0$ using the same procedure used in Lemma A1. Comparing first-order conditions for the sequential and simultaneous games, we can check that $v_h^L < v_h^n$, where v_h^n is the solution of the simultaneous quality game. Since the best response function is monotonic, we know that the follower chooses $v_l^F < v_l^n$.

LEMMA A3. Conditional on a misperception parameter, we can state $v_h^F > v_l^L > \tilde{v}_l$, where $\tilde{v}_l$ is the best response of the follower in case the leader chooses v_h^F.

Proof: Assume that the leader acts as the high-quality follower and chooses v_h^F. The follower would respond with $\tilde{v}_l = h(v_h^F)$. The necessary condition of the sequential game are:

$$\frac{\partial \pi_h^L}{\partial v_h^F} = \frac{\partial R_h^L}{\partial v_h^F} + \frac{\partial R_h^L}{\partial \tilde{v}_l} h'(v_h^F) = \frac{dC^L(v_h^F)}{dv_h^F}. \tag{A.12}$$

Again, we get that $\tilde{v}_l < v_l^n$. Then, using the results from Lemma A1 and Lemma A2, and the necessary conditions for the sequential game when the leader acts as the higher-quality follower, we can state the following relationship: Let $v_h^F = z$, where $z \in \{R\}_{++}$. Then, $v_h^F = z > v_l^L = az > \tilde{v}_l = \hat{a}z$, for $1 > a > \hat{a} > 0$.

LEMMA A4. High-quality leader's profit is bounded below by the quality choice of v_h^F.

Proof: Assume that, all else constant, the leader's profit level can increase by choosing a v_h, such that $v_h < v_h^F$. Notice that the leader's profit is decreasing in v_l. Since the follower's quality best response is monotonic, i.e., $v_l(vh) > 0$, a deviation from v_h^F to v_h can only increase the leader's profit. Notice that by Lemma A1 and A2, a deviation from the leader's quality choice cannot be higher than v_h^F without violation of the FOCs. Thus, the high-quality leader's profit is bounded below by v_h^F.

Next, we will show a set of misperception parameter that is sufficient for condition (1) to hold. Again, we are not deriving necessary conditions on an interval of misperpcetion such that condition (1) holds; rather, we are finding a sufficiently large interval of misperception by which we can discuss the effects of misperception on market outcomes, welfare, and distribution.[1]

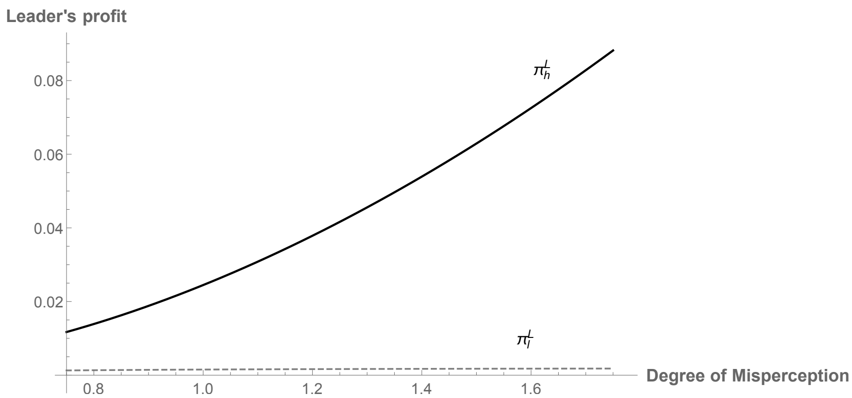
Suppose the leader chooses low quality v_l^L (best low-quality for leader), and follower best respond with v_h^F, then $\pi_l^L(v_l^L, v_h^F; k_h)$ is the low-quality leader's profit. By Lemma A4, we know that the profit of the high-quality leader is bounded below when the leader chooses v_h^F and the follower best respond with the low-quality level $\tilde{v}_l^F$, which implies that the leader's profit is given by $\pi_h^L(\tilde{v}_l^F, v_h^F; k_h)$. Lehmann Grube 1997 shows that under no misperception, the leader always chooses high-quality. We will check that there exists a interval of misperception parameters around the no misperception case for which a leader prefers to choose high-quality. To do that, it is sufficient to find the set interval of misperception parameters that guarantee that the lower bound profit level of the high-quality leader is above the profit level associated with the best low-quality choice by the leader. Formally, we want a range of misperception parameters that guarantees:

$$\pi_h^L\left(\tilde{v}_l^F,\ v_h^F; k_h\right) = R_h^L\left(\tilde{v}_l^F,\ v_h^F; k_h\right) - C\left(v_h^F\right) > R_l^L\left(v_l^L,\ v_h^F; k_h\right) - C\left(v_l^L\right) = \pi_l^L(v_l^L,\ v_h^F; k_h) \tag{A.13}$$

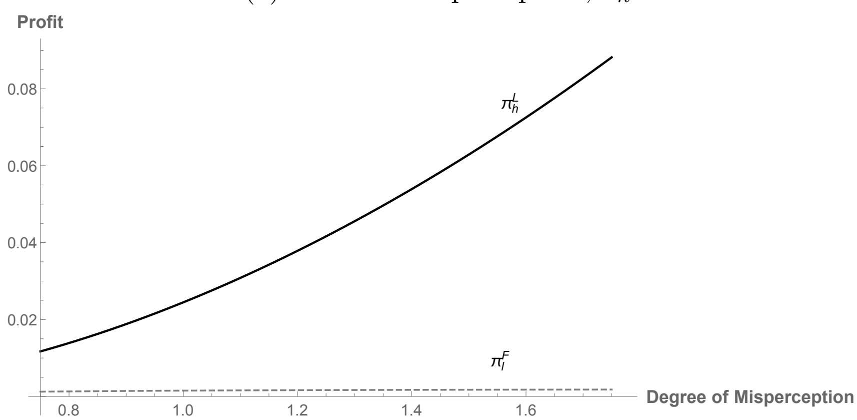
We can show that inequality A.13 holds for $0.75 < k_h < 1.75$ – we call it Assumption 1 – by substituting the revenue functions A.1 and A.2 in equation A.13 and assuming quadratic costs. Under Assumption 1, equation A.7 holds, as shown in Figure A.1a Within the range $0.75 < k_h < 1.75$, one can check numerically that equation A.8 (leader's profit is higher than follower's profit) also holds for quadratic costs, as depicted in Figure A.1b. However, more

1. ↑One can find the largest possible interval of k_h by which the no leapfrogging holds by numerically checking whether equations A.7 and A.8 hold for incremental values of k_h. The implementation of such algorithm is tedious and likely not to yield any interesting additional insight from the implementation discussed in the appendix. While we eventually resort to solutions under quadratic costs in this appendix, the reader can check that other convex cost structures can be used to the same qualitative conclusions.

generally, one can also notice that condition (2) is always satisfied for a k_h range in which a high-quality firm makes higher profits than the lower quality firm for the optimal solution of the simultaneous quality game. That is because (i) by Lemma A2, $v_h^L < v_h^n$, (ii) profit level of the low-quality firm is increasing in high- and low-quality levels, and (iii) the best response of the follower is monotonically increasing in the levels of leader's quality choice. Thus, if the follower's profit is smaller than the leader's profit under $\{v_h^n,\ v_l^n\}$, then (i)-(iii) guarantee that the leader still earns higher profit than the follower under $\{v_h^L, v_l^F\}$. Lastly, under quadratic costs, the leader's quality level that leaves the follower indifferent to best respond with higher or lower quality, $\hat{v}$, is below v_h^L. All together, these conditions implies that v_h^L is enough to prevent leapfrogging.



(a) Effect of misperception, k_h



(b) Effect of misperception, k_h

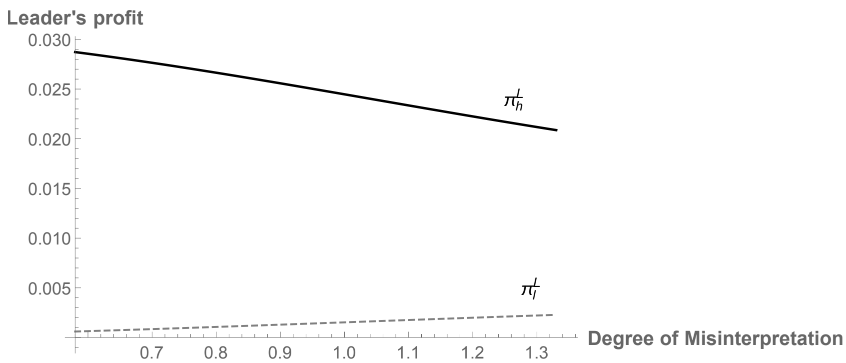
Figure A.1. Profit variations with variations in misperception k_h. Panel (a) shows variation in profits of the leader when it chooses best high-quality quality and it chooses best low-quality quality. Panel (b) shows variation in profits when the leaders positions as the high-quality firm and follower positions as the low-quality firm.

Sequential competition under misperception of low-quality grade

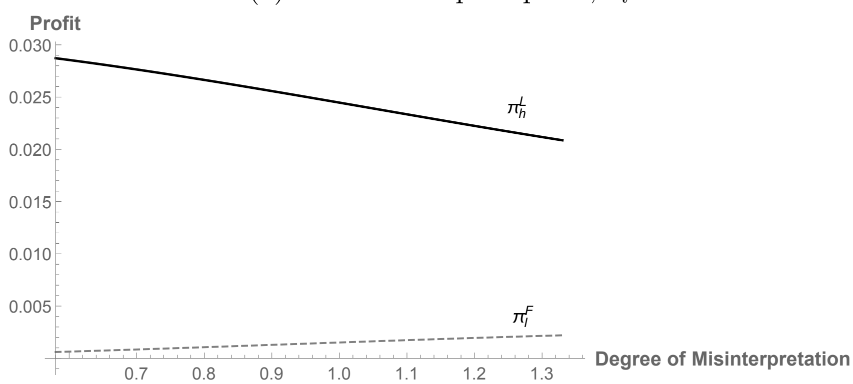
The argument follows exactly the same structure of the case sequential, k_h. Lemmas A1-A4 hold for the case in which misperception is in the low-quality k_l. Similarly to equation A.13, we can find a sufficient large interval by which the leader prefers to position itself as the high-quality firm. This is represented is represented by:

$$R_h^L\left(\tilde{v}_l^F,\ v_h^F; k_l\right) - C\left(v_h^F\right) > R_l^L\left(v_l^L,\ v_h^F; k_l\right) - C(v_l^L) \tag{A.14}$$

We can show that inequality A.14 holds for $k_l \in \{0.58, 1.33\}$ -– call it assumption 2. The rest of the proof is shown in figure A.2, and it uses uses the same arguments as the case of misperception in high-quality grades.



(a) Effect of misperception, k_l



(b) Effect of misperception, k_l

Figure A.2. Profit variations with variations in misperception k_l. Panel (a) shows variation in profits of the leader when it chooses best high-quality quality and it chooses best low-quality quality. Panel (b) shows variation in profits when the leaders positions as the high-quality firm and follower positions as the low-quality firm.

Mean-preserving misperception under sequential quality choice

We now consider the presence of both k_h and k_l. However, to guarantee that the average perception of quality does not change with changes in relative misperception (i.e. same iso-misperception line), we impose a relationship between k_h and k_l. We let average perceived quality under no misperception $\bar{kv}$ follow equation A.15.

$$k_h v_h^0 + k_l v_l^0 = \bar{kv}, \tag{A.15}$$

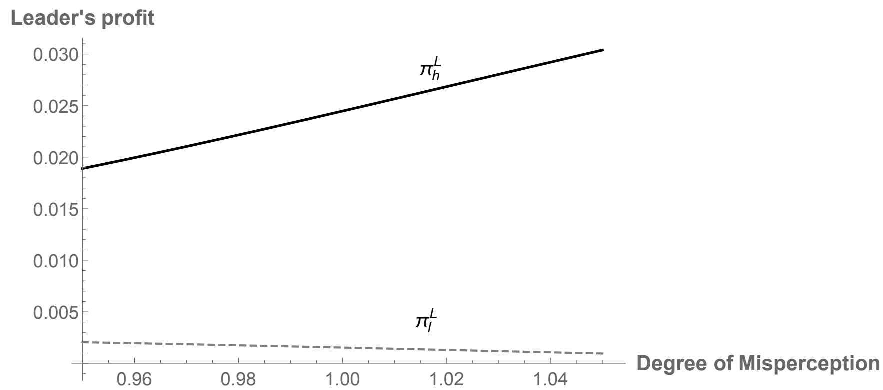
where v_h^0 and v_l^0 are the optimal qualities in equilibrium under no misperception. We can solve equation A.15 for k_l to obtain equation A.16.

$$k_l = (\bar{kv} - k_h v_h^0)/v_l^0, \tag{A.16}$$

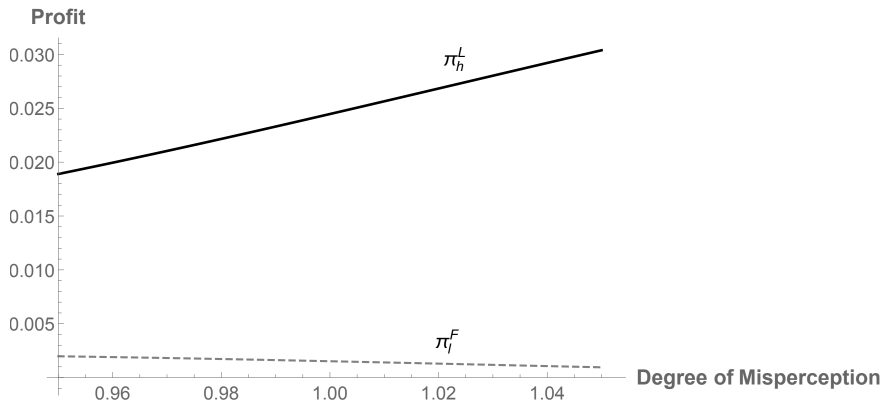
To check whether the leader would prefer to be the high-quality firm we must check equation A.17 below.

$$R_h^L\left(\tilde{v}_l^F, v_h^F; k_h, k_l\right) - C\left(v_h^F\right) > R_l^L\left(v_l^L,\ v_h^F; k_h, k_l\right) - C(v_l^L) \tag{A.17}$$

Substituting equation A.17 into equation A.16 under quadratic costs, one can check that $k_h \in \{0.95, 1.05\}$ satisfies inequality A.17. Numerical solutions also reveal that the leader makes higher profit than the follower when it is the high-quality firm, which completes the argument for no leapfrogging conditions. This can be check in figure A.3:



(a) Effect of misperception, $k_h(k_l)$



(b) Effect of misperception, $k_h(k_l)$

Figure A.3. Profit variations with variations in misperception $k_h(k_l)$. Panel (a) shows variation in profits of the leader when it chooses best high-quality quality and it chooses best low-quality quality. Panel (b) shows variation in profits when the leaders positions as the high-quality firm and follower positions as the low-quality firm.

Simultaneous competition under misperception of high-quality grade

Using quadratic costs under assumption 1, we can check the no-leapfrogging conditions using the definition by Motta 1993. We need to check that, for a given misperception parameter, the low-quality firm has no incentive to leapfrog the high-quality firm and vice-versa. The no-leapfrogging condition in simultaneous games entails (1) that the low-quality firm has no incentive to become the high-quality producer by choosing a value higher than the optimal quality chosen by the high-quality firm; and (2) that the high-quality firm has no incentive to become the low-quality producer by choosing a value lower than the optimal quality chosen by the low-quality firm. Formally, condition (1) can be checked by:

$$\pi_h^{leap}\left(v_h^n, v_h^{leap}; k_h\right) < \pi_l^n\left(v_l^n,\ v_h^n; k_h\right), \tag{A.18}$$

where $v_h^{leap} = \beta \times v_h^n$, where $\beta > 1$, is the value chosen by the leapfrogging low-quality that becomes high-quality. Similarly, condition (2) can be found by:

$$\pi_l^{leap}\left(v_l^{leap},\ v_l^n; k_h\right) < \pi_h^n\left(v_l^n,\ v_h^n; k_h\right), \tag{A.19}$$

where $v_l^{leap} = \beta \times v_h^n$, where $0 < \beta < 1$, is the value chosen by the leapfrogging high-quality that becomes low-quality. Both inequalities hold when we restrict the misperception parameter to $0.75 < k_h < 1.53$.

Simultaneous competition under misperception of low-quality grade

We use the same procedure described in simultaneous quality competition under misperception of high-quality grade above. Condition (1) can be checked by:

$$\pi_h^{leap}\left(v_h^n, v_h^{leap}; k_l\right) < \pi_l^n\left(v_l^n,\ v_h^n; k_l\right), \tag{A.20}$$

where $v_h^{leap} = \beta \times v_h^n$, where $\beta > 1$, is the value chosen by the leapfrogging low-quality that becomes high-quality. Similarly, condition (2) can be found by:

$$\pi_l^{leap}\left(v_l^{leap},\ v_l^n; k_l\right) < \pi_h^n\left(v_l^n,\ v_h^n; k_l\right), \tag{A.21}$$

where $v_l^{leap} = \beta \times v_h^n$, such that $0 < \beta < 1$, is the value chosen by the leapfrogging high-quality that becomes low-quality. Both inequalities hold when we restrict the misperception parameter to $0.58 < k_l < 1.33$.

Simultaneous competition under mean-preserving misperception

Using quadratic cost and under equation A.15 (same iso-misperception curve as in perfect information), we can check the no-leapfrogging conditions using the same procedure described for the cases under simultaneous k_h and simultaneous k_l. Thus, we need to check whether equations A.22 and A.23 hold:

$$\pi_h^{leap}\left(v_h^n, v_h^{leap}; k_h(k_l)\right) < \pi_l^n\left(v_l^n,\ v_h^n; k_h(k_l)\right), \tag{A.22}$$

where $v_h^{leap} = \beta \times v_h^n$, where $\beta > 1$, is the value chosen by the leapfrogging low-quality that becomes high-quality. Similarly, condition (2) can be found by:

$$\pi_l^{leap}\left(v_l^{leap},\ v_l^n; k_h(k_l)\right) < \pi_h^n\left(v_l^n,\ v_h^n; k_h(k_l)\right), \tag{A.23}$$

where $v_l^{leap} = \beta \times v_h^n$, where $0 < \beta < 1$, is the value chosen by the leapfrogging high-quality that becomes low-quality. As in the sequential case, we impose $0.95 < k_h < 1.05$ and check that conditions holds.

A.2 Proof Propositions

Proof of Proposition 1.

Misperception in high-quality, k_h, under sequential quality choice.

We show, for the sequential quality choice case, that 1) quality choices increase, 2) that quantity consumed of products decrease, 3) that prices increase. First, notice that the first-order condition of the sequential game for the follower is $\frac{\partial R_l(v_h, vl(vh); k_h)}{\partial v_l} - \frac{dC^l(v_l(v_h); k_h)}{dv_l} = 0$. We can totally differentiate this expression with respect to v_h and rearrange the terms to obtain the variation of the best response function, v_l^{BR}:

$$\frac{dv_l^{BR}(v_h; k_h)}{dv_h} = \underbrace{\frac{\partial \frac{\partial R_l}{\partial v_l}}{\partial v_h}}_{>0} \Bigg/ \left(\underbrace{\frac{\partial \frac{\partial C_l}{\partial v_l}}{\partial v_l}}_{>0} - \underbrace{\frac{\partial \frac{\partial R^l}{\partial v_l}}{\partial v_l}}_{<0} \right) > 0. \tag{A.24}$$

Second, notice that the marginal revenue functions are homogeneous of degree 0. Thus, we can state:

$$v_l \frac{\partial \frac{\partial R_l}{\partial v_l}}{\partial v_l} + v_h \frac{\partial \frac{\partial R_l}{\partial v_l}}{\partial v_h} = 0 \tag{A.25}$$

$$\frac{v_l}{v_h} = \frac{\partial \frac{\partial R_l}{\partial v_l}}{\partial v_h} \Big/ - \frac{\partial \frac{\partial R_l}{\partial v_l}}{\partial v_l}, \tag{A.26}$$

From equations A.24 and A.25, we know that $v_l/v_h < dv_l^{BR}(v_h;k_h)/dv_h$. Notice that $v_l/v_h < 1$, by definition. Thus, we can state:

$$1 > \frac{v_l}{v_h} > \frac{dv_l^{BR}(v_h;k_h)}{dv_h} \tag{A.27}$$

We are going to use monotone comparative statics to sign the effects of k_h in qualities. For monotone comparative statics, we need to show that strategies are complements and the exogenous parameter has increasing differences with the necessary conditions of the game. We can check that $\{v_h, v_l\}$ are strategic complements for both firms. This is done by checking $\frac{\partial^2 \pi_l}{\partial v_l \partial v_h} > 0$ and $\frac{\partial^2 \pi_h}{\partial v_h \partial v_l} > 0$.

$$\frac{\partial^2 \pi_l}{\partial v_l \partial v_h} = \frac{2k_h^2 v_h v_l (8k_h v_h + 7v_l)}{(4k_h v_h - v_l)^4} > 0, \tag{A.28}$$

which immediately guarantees strategic complementarity between v_l and v_h for the follower. We do the same operation for the leader:

$$\begin{aligned}
\frac{\partial^2 \pi_h}{\partial v_h \partial v_l} &= \frac{\partial \frac{\partial R_h(v_h,v_l)}{\partial v_h}}{\partial v_l} + \frac{\partial \frac{\partial R_h(v_h,v_l)}{\partial v_l}}{\partial v_l} \frac{dv_l^{BR}(v_h;k_h)}{dv_h} \\
\frac{\partial^2 \pi_h}{\partial v_h \partial v_l} &= \frac{8k_h^2 v_h v_l (5k_h v_h + v_l)}{(4k_h v_h - v_l)^4} - \frac{8k_h^2 v_h^2 (5k_h v_h + v_l)}{(4k_h v_h - v_l)^4} \frac{dv_l^{BR}(v_h;k_h)}{dv_h} \\
\frac{\partial^2 \pi_h}{\partial v_h \partial v_l} &= (v_l - \frac{dv_l^{BR}(v_h;k_h)}{dv_h} v_h) \frac{8k_h^2 v_h (5k_h v_h + v_l)}{(4k_h v_h - v_l)^4},
\end{aligned} \tag{A.29}$$

which is positive by equation A.27. Then, we check for increasing differences in the policy parameter k_h. Again, starting by the follower:

$$\frac{\partial^2 \pi_l}{\partial v_l \partial k_h} = \frac{2k_h v_h^2 v_l (8k_h v_h + 7v_l)}{(4k_h v_h - v_l)^4} > 0. \tag{A.30}$$

The same operation for the leader to obtain a large expression (suppressed for sake of space) that is positive under Assumption 1:

$$\begin{aligned}
\frac{\partial^2 \pi_h}{\partial v_h \partial k_h} &= \frac{\partial \frac{\partial R_h}{\partial v_h}}{\partial k_h} + \frac{\partial}{\partial k_h}\left(\frac{\partial R_h(v_h, v_l; k_h)}{\partial v_l}\frac{dv_l^{BR}(v_h; k_h)}{dv_h}\right) && \text{(A.31)}\\
&= \frac{\partial \frac{\partial R_h}{\partial v_h}}{\partial k_h} + \frac{\partial \frac{\partial R_h}{\partial v_l}}{\partial k_h}\frac{dv_l^{BR}(v_h; k_h)}{dv_h} + \frac{\partial \frac{dv_l^{BR}(v_h;k_h)}{dv_h}}{\partial k_h}\frac{\partial R_h}{\partial v_h} && \text{(A.32)}\\
&> 0 \text{ if } \frac{v_l}{v_h} < \frac{4k_h}{7} && \text{(A.33)}
\end{aligned}$$

Thus, the strategic complementary between firms strategy and the increasing differences in the policy parameter k_h leads to:

$$\frac{dv_h^s}{dk_h} > 0, \tag{A.34}$$

$$\frac{dv_l^s}{dk_h} > 0, \tag{A.35}$$

This proves that qualities increase with the misperception parameter k_h under sequential quality competition, as stated in Proposition 1.

We check the effects of an increase in misperception on the size of the market of high-quality products next. First, we check the effect of an increase in k_h on the marginal consumer indifferent between high quality and low-quality products, $\theta_{lk}(v_k^*(kh), v_l^*(kh); k_h)$, as in equation A.36

$$
\begin{aligned}
\frac{d\theta_{lh}}{dk_h} &= \frac{\partial\theta_{lh}}{\partial k_h} + \frac{\partial\theta_{lh}}{\partial v_h}\frac{dv_h}{dk_h} + \frac{\partial\theta_{lh}}{\partial v_l}\frac{dv_l}{dk_h} \\
&= \frac{2v_h v_l}{(4v_h k_h - v_l)^2} + \left(v_l\frac{dv_h}{dk_h} - v_h\frac{dv_l}{dk_h}\right)\frac{2k_h}{(4v_h k_h - v_l)^2},
\end{aligned}
\tag{A.36}
$$

Notice that equation A.36 is positive because $\left(v_l\frac{dv_h}{dk_h} - v_h\frac{dv_l}{dk_h}\right) > 0$, since $v_l/v_h > \frac{dv_l/dk_h}{dv_h/dk_h}$. Let the marginal consumer indifferent between low-quality certification and the outside uncertified good be $\theta_{0l}(v_h^*(k_h), v_l^*(k_h); k_h)$.

$$
\begin{aligned}
\frac{d\theta_{0l}}{dk_h} &= \frac{\partial\theta_{0l}}{\partial k_h} + \frac{\partial\theta_{0l}}{\partial v_h}\frac{dv_h}{dk_h} + \frac{\partial\theta_{0l}}{\partial v_l}\frac{dv_l}{dk_h} \\
&= \frac{3v_h v_l}{(4v_h k_h - v_l)^2} + \frac{3k_h v_l}{(4v_h k_h - v_l)^2}\frac{dv_l}{dk_h} - \frac{3k_h v_h}{(4v_h k_h - v_l)^2}\frac{dv_l}{dk_h} \\
&= \frac{3v_h v_l}{(4v_h k_h - v_l)^2} + \left(v_l\frac{dv_h}{dk_h} - v_h\frac{dv_l}{dk_h}\right)\frac{3k_h}{(4v_h k_h - v_l)^2},
\end{aligned}
\tag{A.37}
$$

which again is positive. One should notice that $\frac{d\theta_{0l}}{dk_h} > \frac{d\theta_{lh}}{dk_h}$. Recall that under the assumption of uniform distribution of tastes the demand for high quality certified products is $D_h = (1 - \theta_{lh})$ and for low quality certified $D_l = (\theta_{lh} - \theta_{0l})$. Therefore when misperception the size of demand decreases for both firms. As a consequence, the total demand for certified products decreases as well. This proves that the quantity of graded products decrease with an increase in the misperception parameter.

Next, we check the effects of increases in k_h in prices. We will show that by checking the effects of misperception on profits, we can readily get the effects of misperception in prices. The effects of misperception on low-quality firm can be stated in equation A.38.

$$\frac{\partial \pi_l(v_h^s(k_h), v_l^s(k_h); k_h))}{\partial k_h} = \frac{\partial R_l}{\partial k_h} + \frac{\partial R_l}{\partial v_h}\frac{dv_h^s}{dk_l} + \frac{\partial R_l}{\partial v_l}\frac{dv_l^s}{dk_h} - \frac{\partial C(v_l)}{\partial v_l}\frac{dv_l^s}{dk_h} \tag{A.38}$$

$$\begin{aligned}\frac{\partial \pi_l(v_h^s(k_h), v_l^s(k_h); k_h))}{\partial k_h} &= \underbrace{\frac{\partial R_l}{\partial k_h}}_{>0} + \underbrace{\frac{\partial R_l}{\partial v_h}}_{>0}\underbrace{\frac{dv_h^s}{dk_l}}_{>0} + \underbrace{\left(\frac{\partial R_l}{\partial v_l} - \frac{\partial C(v_l)}{\partial v_l}\right)}_{=0}\underbrace{\frac{dv_l^s}{dk_h}}_{>0} > 0 \\ &= \frac{v_h v_l^2(2k_h v_h + v_l)}{(4k_h v_h - v_l)^3} + \frac{4k_h^2 v_h^2(2k_h v_h + v_l)}{(4k_h v_h - v_l)^3}\frac{dv_h^s}{dk_h} > 0.\end{aligned}$$

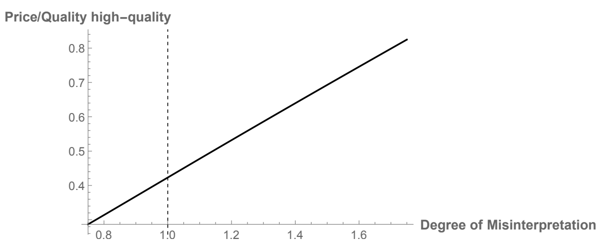
Thus, increases in k_h raise profits of the low-quality follower. The effects on the leader are stated in equation A.39.

$$\begin{aligned}\frac{\partial \pi_h(v_h^s(k_h), v_l^s(k_h); k_h))}{\partial k_h} &= \frac{\partial R_h}{\partial k_h} + \frac{\partial R_h}{\partial v_h}\frac{dv_h^s}{dk_h} + \frac{\partial R_h}{\partial v_l}\frac{dv_l^s}{dk_h} - \frac{\partial C(v_h)}{\partial v_h}\frac{dv_h}{dk_h} \\ &= \frac{\partial R_h}{\partial k_h} + \frac{\partial R_h}{\partial v_l}\frac{dv_l^s}{dk_h} + \left(\frac{\partial R_h}{\partial v_h} - \frac{\partial C(v_h)}{\partial v_h}\right)\frac{dv_h^s}{dk_h} \\ &= \frac{\partial R_h}{\partial k_h} + \frac{\partial R_h}{\partial v_l}\frac{dv_l^s}{dk_h} + \left(\frac{\partial R_h}{\partial v_h} - \frac{\partial C(v_h)}{\partial v_h}\right)\frac{dv_h^s}{dk_h} \\ &= \frac{\partial R_h}{\partial k_h} + \frac{\partial R_h}{\partial v_l}\frac{dv_l^s}{dk_h} + \left(\frac{-\partial R_h}{\partial v_l}\frac{dv_l^s}{dv_h}\right)\frac{dv_h^s}{dk_h} \\ &= \frac{\partial R_h}{\partial k_h} \\ &= \frac{4k_h v_h^2(4k_h^2 v_h^2 - 3k_h v_h v_l + 2v_l^2)}{(4k_h v_h - v_l)^3} \\ &> 0 \text{ if } \frac{v_l}{v_h} < \frac{4k_h}{7}\end{aligned} \tag{A.39}$$

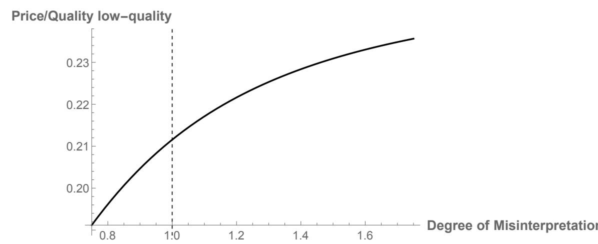
where we use the fact that $\frac{\partial R_h}{\partial v_h} + \frac{\partial R_h}{\partial v_l}\frac{dv_l}{dv_h} - \frac{\partial C(v_h)}{\partial v_h} = 0$. We conclude that both firm's profit increase when $k_h > 0$.

Finally, we can analyze the effect that an increase in misperception has on prices. We know that firms' profit increase when misperception increases. By $C'(\cdot) > 0$, $dv_h/dk_h > 0$, $dv_l/dk_h > 0$, we know that costs increase when misperception increases. This means that firms' profits increase because revenues must increase more than increases in cost under a higher misperception parameter. But demand decreases as misperception rises. Since revenue is given by the multiplication of prices by firm's demand, we have that prices necessarily must increase under increases in k_h.

Finally, we check how price per unit of quality supplied change when k_h increases. But to check for the ratio price per quality supplied, we need to assess the intensity of price increase vis-a-vis the intensity of quality increase. Notice from equation A.34 and A.35 that have established the sign of the change in qualities, not their intensity. Since we have not established the intensity of quality change, we solve numerically for changes in price per quality using a quadratic cost. Figure A.4 shows the result: we observe an increase in price per quality whenever misperception increase in the direction of overvaluation.



(a) Effect of misperception, k_h



(b) Effect of misperception, k_h

Figure A.4. Variation in price/quality with changes in k_h, under sequential quality competition and quadratic costs for quality.

This completes the proof of proposition 1 for sequential quality competition under assumption 1.

Misperception in high-quality, k_h, under simultaneous quality choice.

The simultaneous quality choice case differs only slightly from the sequential quality choice case. Again, we show that 1) quality choices increase 2) that quantity consumed of products decrease 3) that prices increase. One can check that equation A.27 holds for the simultaneous case as well. Equation A.30 also holds for the simultaneous case, which implies that high quality is a strategic complement to low-quality profits. To show that low quality is a strategic complement to high-quality firms, we must show that $\frac{\partial^2 \pi_h}{\partial v_h \partial v_l} > 0$ in the simultaneous case:

$$\frac{\partial^2 \pi_h}{\partial v_h \partial v_l} = \frac{8k_h^2 v_h v_l (5k_h v_h + v_l)}{(4k_h v_h - v_l)^4} > 0 \tag{A.40}$$

To prove increasing differences in parameter k_h for both firms, we need $\frac{\partial^2 \pi_l}{\partial v_l \partial k_h} > 0$ and $\frac{\partial^2 \pi_h}{\partial v_h \partial k_h} > 0$. Notice that equation A.30 shows that $\frac{\partial^2 \pi_l}{\partial v_l \partial k_h} > 0$. We can show that:

$$\frac{\partial^2 \pi_h}{\partial v_h \partial k_h} = \frac{4k_h v_h (16k_h^3 v_h^3 - 16k_h^2 v_h^2 v_l + k_h v_h v_l^2 - 4v_l^3)}{(4k_h v_h - v_l)^4} > 0, \text{ if } \frac{v_l}{v_h} < \frac{4k_h}{7}, \tag{A.41}$$

which guarantees strategic complementarity between firms' quality choices and the parameter k_h and proves that qualities are increasing in the misperception parameter.

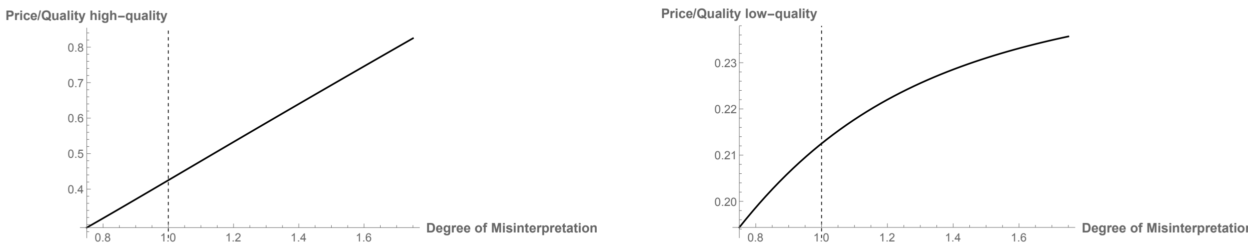
The effects of misperception on the size of the market for high- and low-quality products follow the same structure described in the sequential games (we suppress the demonstration here). This proves that quantity consumed decreases with misperception parameter k_h.

To show the effect of misperception on prices, we show first the effect of misperception on profits first. The effect of misperception parameter on the low-quality firm profits is the same as the one in sequential games – given by equation A.38. The profit of the high-quality firm is given by equation A.42.

$$\begin{aligned}
\frac{\partial \pi_h(v_h^n(k_h), v_l^n(k_h); k_h))}{\partial k_h} &= \frac{\partial R_h}{\partial k_h} + \frac{\partial R_h}{\partial v_h}\frac{dv_h^n}{dk_h} + \frac{\partial R_h}{\partial v_l}\frac{dv_l^n}{dk_h} - \frac{\partial C(v_h)}{\partial v_h}\frac{dv_h}{dk_h} \\
&= \frac{\partial R_h}{\partial k_h} + \frac{\partial R_h}{\partial v_l}\frac{dv_l^n}{dk_h} + \left(\frac{\partial R_h}{\partial v_h} - \frac{\partial C(v_h)}{\partial v_h}\right)\frac{dv_h^n}{dk_h} \\
&= \frac{\partial R_h}{\partial k_h} + \frac{\partial R_h}{\partial v_l}\frac{dv_l^n}{dk_h} + \underbrace{\left(\frac{\partial R_h}{\partial v_h} - \frac{\partial C(v_h)}{\partial v_h}\right)}_{=0}\frac{dv_h^n}{dk_h} \\
&= \frac{\partial R_h}{\partial k_h} + \frac{\partial R_h}{\partial v_l}\frac{dv_l^n}{dk_h}
\end{aligned} \tag{A.42}$$

Expression A.42 cannot be analytically signed as the second term of the expression is negative and the first term is positive. We numerically solve equation A.42 under quadratic quality costs and conclude that profits of the high-quality firm increases. We can use the same rationale of sequential quality competition to conclude that prices increase with increases in k_h under simultaneous quality choice.

Figure A.5 uses quadratic costs to numerically solve for variations in price per quality offered by firms when k_h increases.



(a) Effect of misperception, k_h (b) Effect of misperception, k_l

Figure A.5. Variation in price/quality with changes in k_h, under sequential quality competition and quadratic costs for quality.

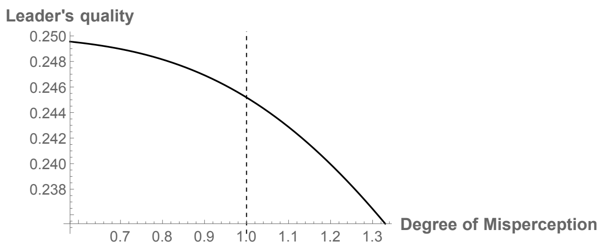
Price per quality increases for high- and low-quality products. This concludes the proof of proposition 1.

Proof of Proposition 2.

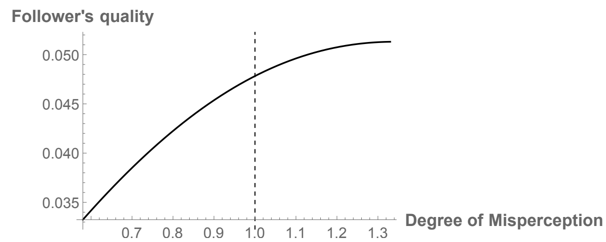
Misperception in high-quality, k_l, under sequential quality choice.

We follow the same procedure as in the comparative statics for misperception in high-quality grades. However, using the same procedures as in Proposition 1, we cannot unequivocally show that there are increasing differences between v_l and k_l, and v_h and k_l. The sign of the comparative statics results for market outcomes and welfare is equally ambiguous and are not shown here. We resort to numerical solutions by imposing quadratic costs and solving the comparative statics for quality, market size, prices, and prices per unit of quality.

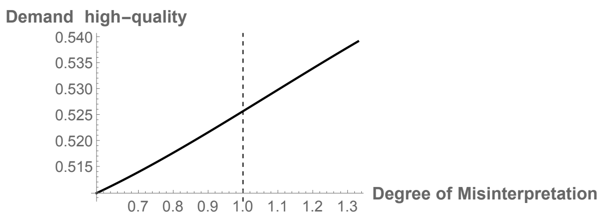
Figure A.6 shows the effects of increases in k_l in market outcomes. Panel (a) and panel (b) shows that quality of the high-quality firm decreases with k_l while low-quality increases. Panel (c) and (d) shows that low- and high-quality market share increase with increases in k_l. Figure (e) and (f) shows that high-quality prices decrease with increases in k_l, while low-quality prices increase. Finally, panels (g) and (h) shows the price per quality supplied of high-quality decreases, while price per quality supplied of low-quality products increase.



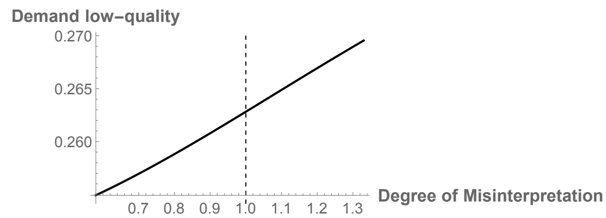
(a) Variation in quality with changes in k_l, under sequential quality competition and quadratic costs for quality.



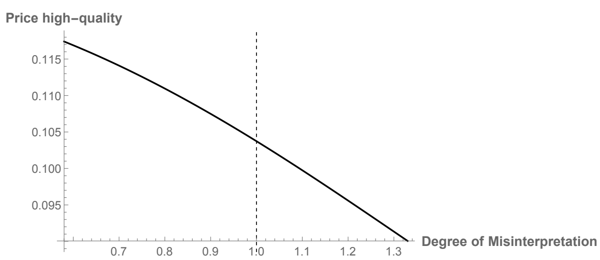
(b) Variation in quality with changes in k_l, under sequential quality competition and quadratic costs for quality.



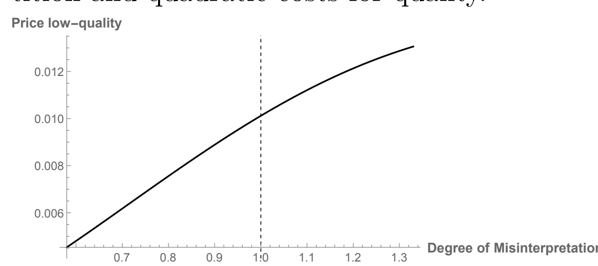
(c) Variation in market size (demand) with changes in k_l, under sequential quality competition and quadratic costs for quality.



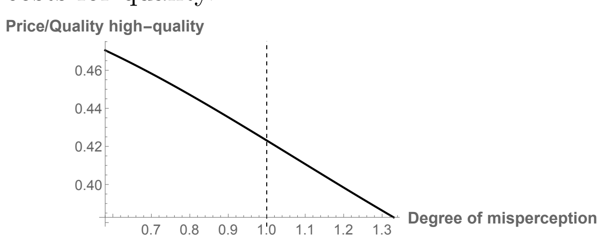
(d) Variation in market size (demand) with changes in k_l, under sequential quality competition and quadratic costs for quality.



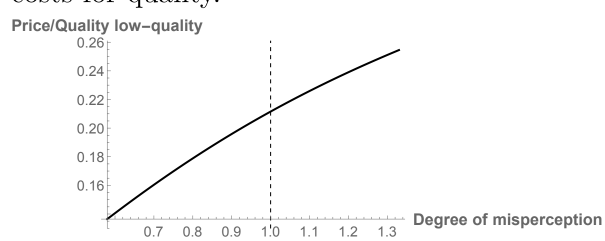
(e) Variation in prices with changes in k_l, under sequential quality competition and quadratic costs for quality.



(f) Variation in prices with changes in k_l, under sequential quality competition and quadratic costs for quality.



(g) Variation in price/quality with changes in k_l, under sequential quality competition and quadratic costs for quality.

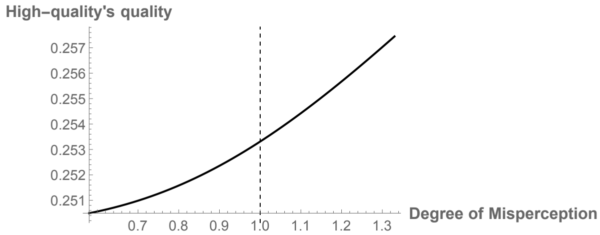


(h) Variation in price/quality with changes in k_l, under sequential quality competition and quadratic costs for quality.

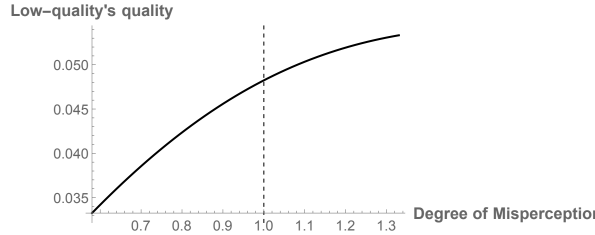
Figure A.6. Effects of increases k_l on market outcomes under sequential quality competition

Misperception in low-quality, k_l, under simultaneous quality choice.

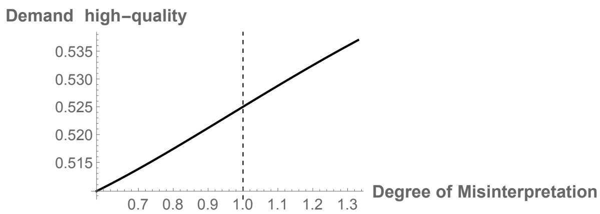
Under the impossibility to unequivocally algebraically sign the effects of k_l on market outcomes under simultaneous quality choices, we use numerical solutions under quadratic costs. These effects are represented in Figure A.7.



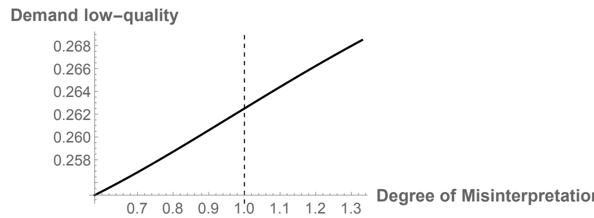
(a) Variation in quality with changes in k_l, under simultaneous quality competition and quadratic costs for quality.



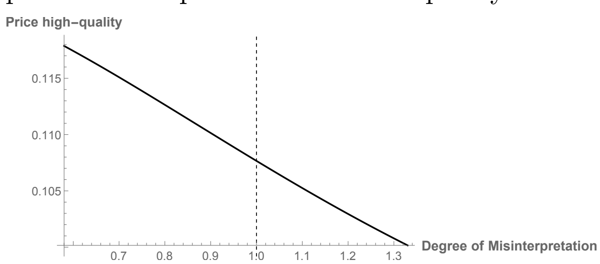
(b) Variation in quality with changes in k_l, under simultaneous quality competition and quadratic costs for quality.



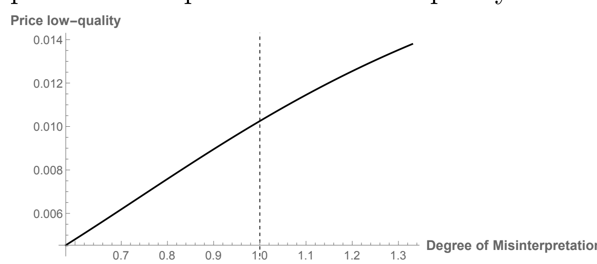
(c) Variation in market size (demand) with changes in k_l, under simultaneous quality competition and quadratic costs for quality.



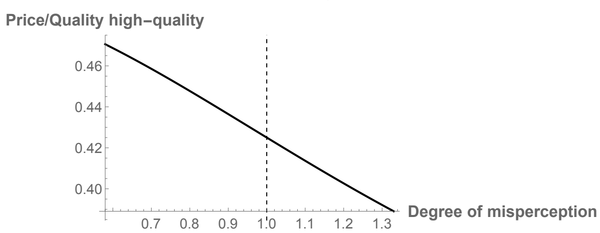
(d) Variation in market size (demand) with changes in k_l, under simultaneous quality competition and quadratic costs for quality.



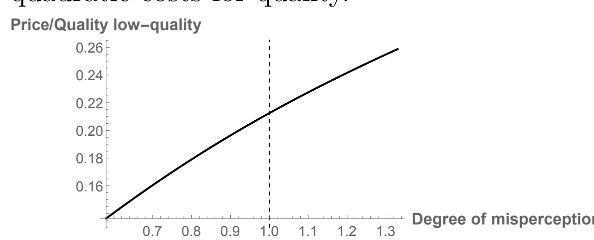
(e) Variation in prices with changes in k_l, under simultaneous quality competition and quadratic costs for quality.



(f) Variation in prices with changes in k_l, under simultaneous quality competition and quadratic costs for quality.



(g) Variation in price/quality with changes in k_l, under simultaneous quality competition and quadratic costs for quality.



(h) Variation in price/quality with changes in k_l, under simultaneous quality competition and quadratic costs for quality.

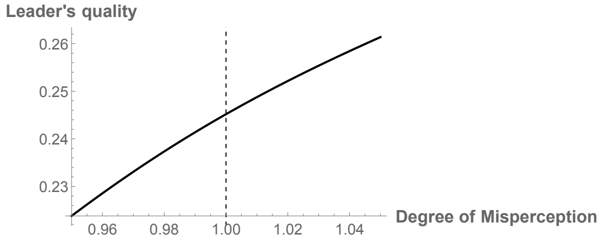
Figure A.7. Effects of increases k_l on market outcomes under simultaneous quality competition

According to Figure A.7, high- and low-quality levels increase with k_l; prices of the high-quality decreases with k_l, while low-quality prices increase; the demand for both products increase; and the price per unit of quality supplied increase for low-quality, but decreases for high-quality. This proves Proposition 2.

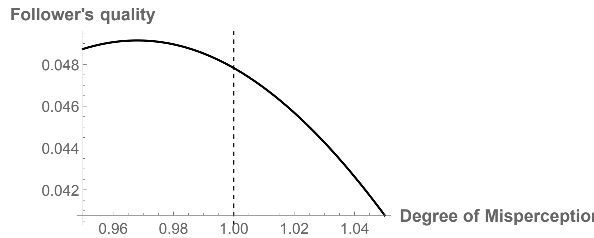
Proof of Proposition 3

Mean-preserving misperception under sequential and simultaneous quality misperception.

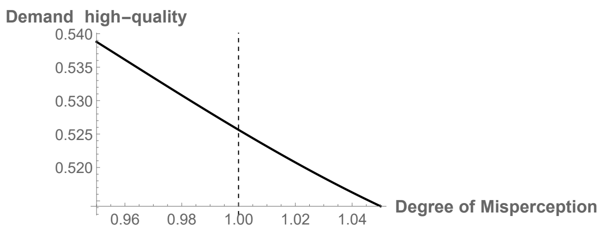
We provide full numerical results under quadratic costs. The numerical results are limited to the interval in which we checked that the no leapfrogging condition holds, i.e. to $k_h \in (0.95,\ 1.05)$. We provide results for sequential quality competition (Figure A.8) and simultaneous quality competition (Figure A.9).



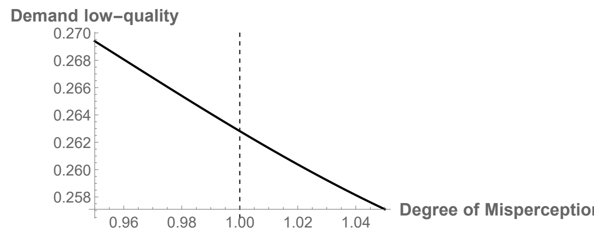
(a) Variation in quality with changes in $k_h(k_l)$, under sequential quality competition and quadratic costs for quality.



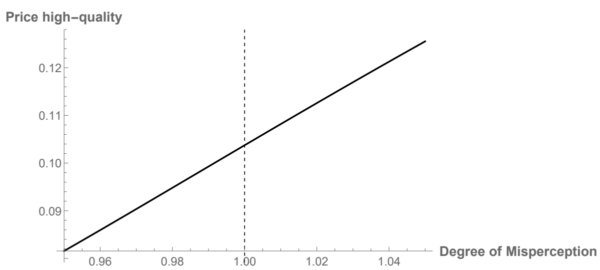
(b) Variation in quality with changes in $k_h(k_l)$, under sequential quality competition and quadratic costs for quality.



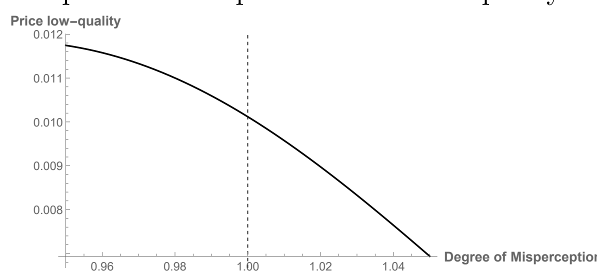
(c) Variation in market size (demand) with changes in $k_h(k_l)$, under sequential quality competition and quadratic costs for quality.



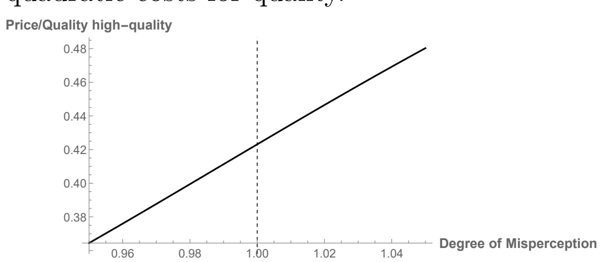
(d) Variation in market size (demand) with changes in $k_h(k_l)$, under sequential quality competition and quadratic costs for quality.



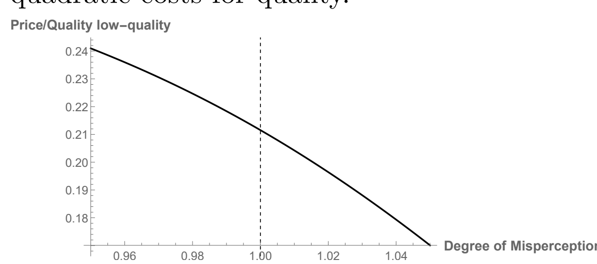
(e) Variation in prices with changes in $k_h(k_l)$, under sequential quality competition and quadratic costs for quality.



(f) Variation in prices with changes in $k_h(k_l)$, under sequential quality competition and quadratic costs for quality.

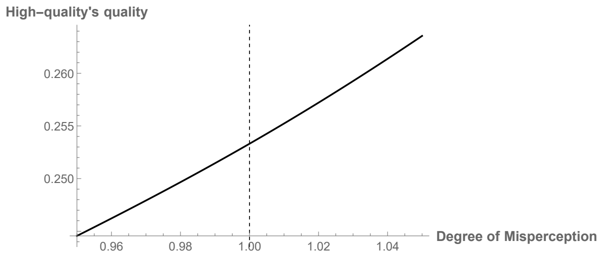


(g) Variation in price/quality with changes in $k_h(k_l)$, under sequential quality competition and quadratic costs for quality.

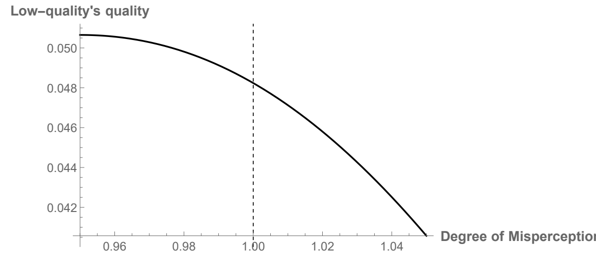


(h) Variation in price/quality with changes in $k_h(k_l)$, under sequential quality competition and quadratic costs for quality.

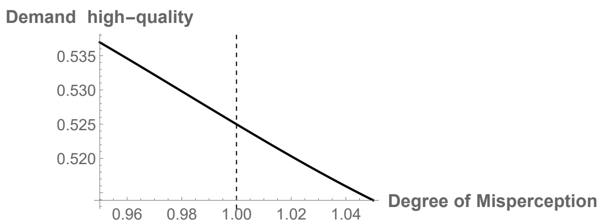
Figure A.8. Effects of increases k_h on market outcomes under sequential quality competition and mean-preserving misperception



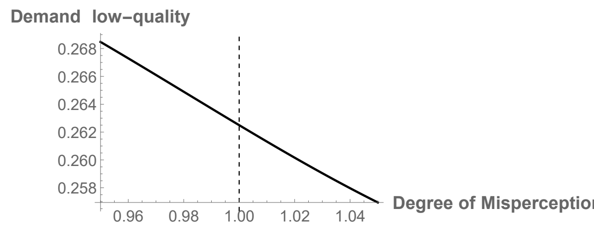
(a) Variation in quality with changes in $k_h(k_l)$, under simultaneous quality competition and quadratic costs for quality.



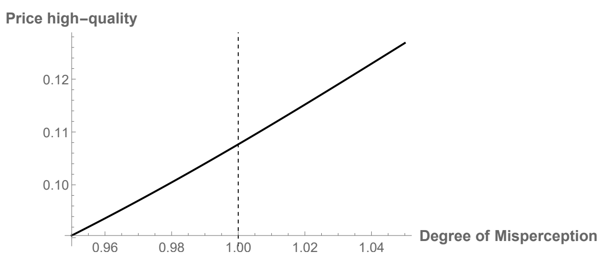
(b) Variation in quality with changes in $k_h(k_l)$, under simultaneous quality competition and quadratic costs for quality.



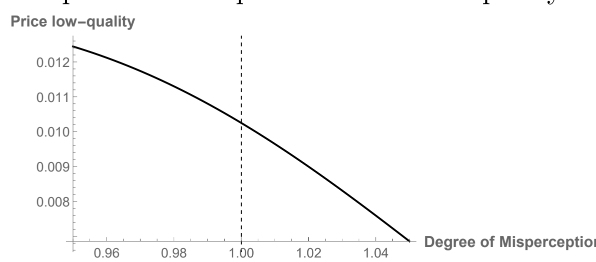
(c) Variation in market size (demand) with changes in $k_h(k_l)$, under simultaneous quality competition and quadratic costs for quality.



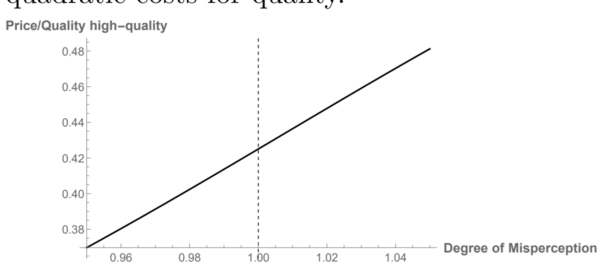
(d) Variation in market size (demand) with changes in $k_h(k_l)$, under simultaneous quality competition and quadratic costs for quality.



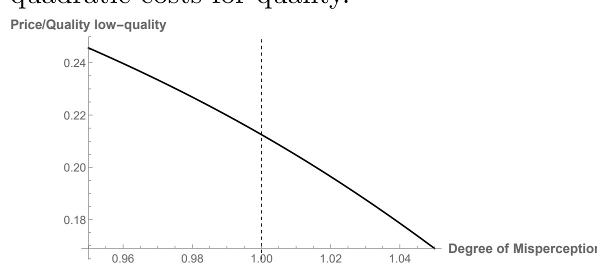
(e) Variation in prices with changes in $k_h(k_l)$, under simultaneous quality competition and quadratic costs for quality.



(f) Variation in prices with changes in $k_h(k_l)$, under simultaneous quality competition and quadratic costs for quality.



(g) Variation in price/quality with changes in $k_h(k_l)$, under simultaneous quality competition and quadratic costs for quality.



(h) Variation in price/quality with changes in $k_h(k_l)$, under simultaneous quality competition and quadratic costs for quality.

Figure A.9. Effects of increases k_h on market outcomes under simultaneous quality competition and mean-preserving misperception

Proof of Claim 1.

Misperception in high-quality grades, k_h

We start with the case of misperception in high-quality products. We show the conditions for which firms underprovide quality relative to a social planner that wants to maximize welfare. Let the welfare function, $W(\cdot)$ be the sum of consumer surplus and total profit of firms, such that $W(v_h, v_l; k_h) = CS_h(v_h, v_l; k_h) + CS_l(v_h, v_l; k_h) + Rh(v_h, v_l; k_h) - C(v_h) + Rh(v_h, v_l; k_h) - C(v_l)$.

We first show the conditions for which the low-quality firm underprovide quality. We follow Buehler and Schuett 2014 and let $NW(v_h, v_l; k_h) = W(v_h, v_l; k_h) + C(v_h) + C(v_l)$. We can differentiate both sides with respect to v_l and obtain $\frac{\partial NW}{\partial v_l} = \frac{\partial W}{\partial v_l} + \frac{\partial C(v_l)}{\partial v_l}$, which we can rearrange to $\frac{\partial W}{\partial v_l} = \frac{\partial NW}{\partial v_l} - \frac{\partial C(v_l)}{\partial v_l}$. From Appendix 1, we know that the optimal quality of the simultaneous quality game, v_l^n is larger than the sequential quality game v_l^s. Thus, to show that there exist underprovision of quality in our setting, it is sufficient to show that, at the solution of the simultaneous quality game, $\{v_h^n,\ v_l^n\}$, $\frac{\partial W}{\partial v_l}\mid_{v_i=v_i^n} = \frac{\partial NW}{\partial v_l} - \frac{\partial C}{\partial v_l}\mid_{v_i=v_i^n} > \frac{\partial \pi_l}{\partial v_l}|_{v_i=v_i^n} = \frac{\partial R_l}{\partial v_l} - \frac{\partial C}{\partial v_l}\mid_{v_i=v_i^n}$. Using the definitions above, we need to show inequality A.43 holds.

$$\begin{aligned}
&\frac{\partial NW}{\partial v_l} - \frac{\partial C(v_l)}{\partial v_l} > \frac{\partial R_l}{\partial v_l} - \frac{\partial C(v_l)}{\partial v_l} \\
&\frac{\partial NW}{\partial v_l} > \frac{\partial R_l}{\partial v_l} \\
&\frac{\partial}{\partial v_l}\left(\int_{\theta_{lh}}^{1} \theta v_h d\theta + \int_{\theta_{0l}}^{\theta_{lh}} \theta v_l d\theta\right) > \frac{\partial R_l}{\partial v_l} \\
&\frac{k_h v_h^2(4k_h(3k_h+2) - (13k_h+4)v_l)}{2(4k_h v_h - v_l)^3} > \frac{k_h^2 v_h^2(4_{kh} v_h - 7v_l)}{(4k_h v_h - v_l)^3}
\end{aligned} \tag{A.43}$$

which are satisfied by $0.75 < k_h < 1.75$.

Now, we want to show the conditions for which the low-quality firm underprovide quality. Again, it is sufficient to show that at the solution of the simultaneous quality game, $\{v_h^n, v_l^n\}$, $\frac{\partial W}{\partial v_h}\mid_{v_i=v_i^n} = \frac{\partial NW}{\partial v_h} - \frac{\partial C}{\partial v_h}\mid_{v_i=v_i^n} > \frac{\partial \pi_h}{\partial v_h}|_{v_i=v_i^n} = \frac{\partial R_h}{\partial v_h} - \frac{\partial C}{\partial v_l}\mid_{v_i=v_i^n}$. Using the definitions above, we need to show inequality A.44 holds.

$$\frac{\partial NW}{\partial v_l} - \frac{\partial C(v_l)}{\partial v_l} > \frac{\partial R_l}{\partial v_l} - \frac{\partial C(v_l)}{\partial v_l} \tag{A.44}$$
$$\frac{\partial NW}{\partial v_l} > \frac{\partial R_l}{\partial v_l}$$
$$\frac{\partial}{\partial v_l}\left(\int_{\theta_H}^{1} \theta v_h d\theta + \int_{\theta_l}^{\theta_h} \theta v_l d\theta\right) > \frac{\partial R_l}{\partial v_l}$$
$$\frac{k_h v_h^2(4k_h(3k_h+2) - (13k_h+4)v_l)}{2(4k_h v_h - v_l)^3} > \frac{k_h^2 v_h^2(4_{kh} v_h - 7v_l)}{(4k_h v_h - v_l)^3},$$

which are satisfied by $0.75 < k_h < 1.33$.

Misperception in low-quality grades, k_l.

We use the same logic to show the range in which firms underprovide quality under misperception in the low-quality label. Again, notice that to show underprovision of quality, it is sufficient to evaluate whether the gradients of the welfare function are greater than the gradient of the profit function at simultaneous quality competition; formally, we want to show that $\frac{\partial W}{\partial v_{\text{i}}}\ |_{v_{\text{i}}=v_{\text{i}}^n} = \frac{\partial NW}{\partial v_{\text{i}}} - \frac{\partial C}{\partial v_{\text{i}}}\ |_{v_{\text{i}}=v_{\text{i}}^n} \ > \frac{\partial \pi_{\text{i}}}{\partial v_{\text{i}}}|_{v_{\text{i}}=v_{\text{i}}^n} = \frac{\partial R_{\text{i}}}{\partial v_{\text{i}}} - \frac{\partial C}{\partial v_{\text{i}}}|_{v_{\text{i}}=v_{\text{i}}^n}$ under a given k_{i}, where $\text{i} \in \{h, l\}$. Equations A.45 and A.46 show the conditions:

$$\frac{\partial NW}{\partial v_l} - \frac{\partial C}{\partial v_l}\bigg|_{v_{\text{i}}=v_{\text{i}}^n} > \frac{\partial R_l}{\partial v_l} - \frac{\partial C}{\partial v_l}\bigg|_{v_{\text{i}}=v_{\text{i}}^n} \tag{A.45}$$
$$\frac{\partial NW}{\partial v_l}\bigg|_{v_{\text{i}}=v_{\text{i}}^n} > \frac{\partial R_l}{\partial v_l}\bigg|_{v_{\text{i}}=v_{\text{i}}^n}$$
$$\frac{v_h^2\left(4\left(3+2k_l\right)v_h - rk_l\left(13+4k_l\right)v_h\right)}{2\left(4v_h - rk_lv_h\right)^3} > \frac{k_l v_h^2\left(4v_h - 7rk_lv_h\right)}{4v_h - ak_lv_h}$$

such that the inequality is satisfied under $0.58 < k_l < 1.33$ and under quadratic costs. For high-quality:

$$\left.\frac{\partial NW}{\partial v_h}-\frac{\partial C}{\partial v_h}\right|_{v_{\text{i}}=v_{\text{i}}^n}>\left.\frac{\partial R_h}{\partial v_h}-\frac{\partial C}{\partial v_h}\right|_{v_{\text{i}}=v_{\text{i}}^n} \tag{A.46}$$

$$\left.\frac{\partial NW}{\partial v_h}\right|_{v_{\text{i}}=v_{\text{i}}^n}>\left.\frac{\partial R_h}{\partial v_h}\right|_{v_{\text{i}}=v_{\text{i}}^n}$$

$$\frac{24v_h^3-18rk_lv_h^3+r^3k_l^2v_h^3+r^2k_l\left(1+4k_l\right)v_h^3}{\left(4v_h-rk_lv_h\right)^3}>\frac{k_lv_h^2\left(4v_h-7rk_lv_h\right)}{4v_h-ak_lv_h}$$

such that the inequality is satisfied under $0.58<k_l<1.33$ and under quadratic costs. This proves Claim 1.

Proof of Proposition 4

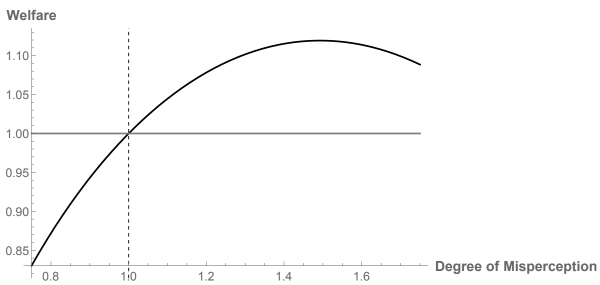
We show that overestimation of high-quality grades relative to low-quality grades can increase total welfare. We established in the text that the welfare function is given by total valuation of grades minus the cost to supply them. Thus, welfare evaluated at the sub-game perfect Nash equilibrium quality level (either for simultaneous or sequential quality competition) is given by $W(v_h^*(k_{\text{i}}),v_l^*(k_{\text{i}});k_{\text{i}})=TV(v_h^*(k_{\text{i}}),v_l^*(k_h);k_{\text{i}})-C(v_h^*)-C(v_{\text{i}}^*)$, $\text{i}\in\{h,l\}$ where TV represents total value. The effect of increasing k_{i} in welfare is given by equation A.47.

$$\frac{dW}{dk_{\text{i}}}=\frac{dTV}{dk_{\text{i}}}+\left(\frac{\partial TV}{\partial v_h}-\frac{\partial C}{\partial v_h}\right)\frac{dv_h^*}{dk_{\text{i}}}+\left(\frac{\partial TV}{\partial v_l}-\frac{\partial C}{\partial v_l}\right)\frac{dv_l^*}{dk_{\text{i}}} \tag{A.47}$$

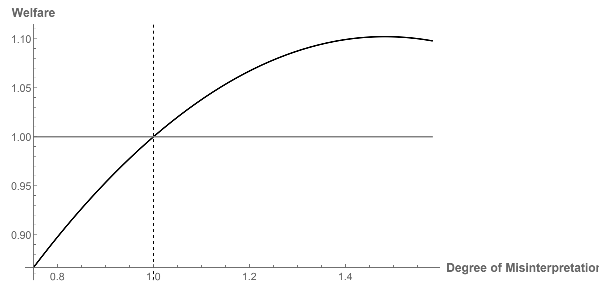
$$=-\left(\theta_{lh}v_h\right)\frac{d\theta_{lh}}{dk_{\text{i}}}+\left(\theta_{lh}v_l\right)\frac{d\theta_{lh}}{dk_{\text{i}}}-\left(\theta_{0l}v_l\right)\frac{d\theta_{0l}}{dk_{\text{i}}}+\left(\frac{\partial TV}{\partial v_h}-\frac{\partial C}{\partial v_h}\right)\frac{dv_h^*}{dk_{\text{i}}}+\left(\frac{\partial TV}{\partial v_l}-\frac{\partial C}{\partial v_l}\right)\frac{dv_l^*}{dk_{\text{i}}}$$

First, notice that $\frac{dv_h^*}{dk_h}>0$ and $\frac{dv_l^*}{dk_h}>0$ in sequential and simultaneous quality competition. The first term in equation A.47 shows how the change in market size due to increasing k_h changes welfare. Notice that dTV/dk_h is decomposed in the first 3 terms. These terms only change market size because they only affect the marginal consumers, as we are holding qualities at their optimal equilibrium under quality competition. When misperpcetion is in the high-quality grade, we can show that these 3 first terms are negative under sequential and simultaneous quality competition, as total market size decreases (as shown in Proposition 1 and 2). In relation to the social optimum equilibrium, we showed in Claim 1 that the second term and third terms of equation A.47 are positive when evaluated at the sub-game perfect Nash equilibrium, for at least a given level of $k_h = 1$. Notice these terms would be zero if evaluated under the social planner problem. From Claim 1, we can show numerically in Figure A.10 that under assumption 1 and assumption 3, welfare increases up to a given k_h, such that $k_h > 1$.

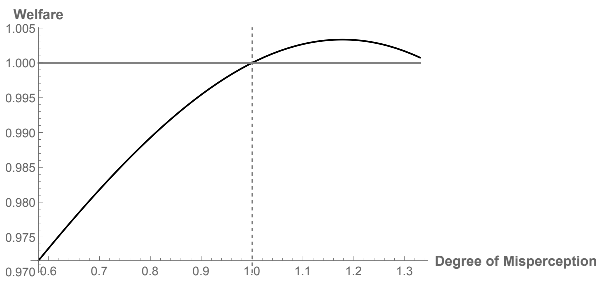
For the case in misperpcetion of low-quality grades, notice that from Proposition 2, we know that the first 3 terms are positive (market size effect). In simultaneous quality competition, for quadratic costs, terms 4 and 5 are also positive, while term 4 is negative and term 5 is positive under sequential quality competition. We numerically solve for the opposed signs of the comparative statics to show sign the comparative statics, as seen in Figure A.10.



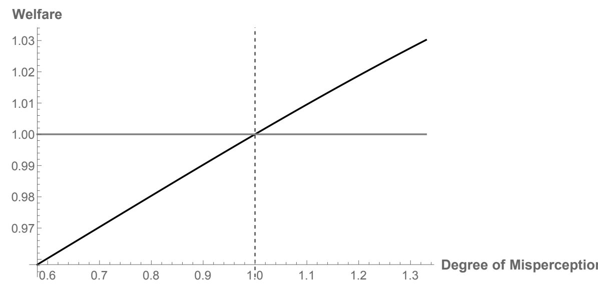
(a) Variation in welfare with changes in k_h, under sequential quality competition



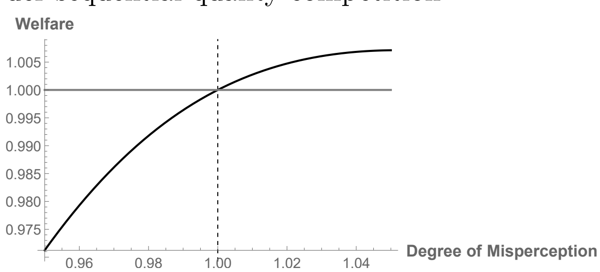
(b) Variation in welfare with changes in k_h, under simultaneous quality competition



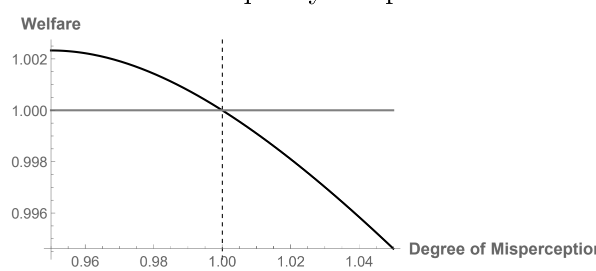
(c) Variation in welfare with changes in k_l, under sequential quality competition



(d) Variation in welfare with changes in k_l, under simultaneous quality competition



(e) Variation in welfare with changes in $k_h(k_l)$, under sequential quality competition and quadratic costs



(f) Variation in welfare with changes in $k_h(k_l)$, under simultaneous quality competition and quadratic costs

Figure A.10. Effects of increases of misperception in efficiency (total welfare), normalized to perfect information case.

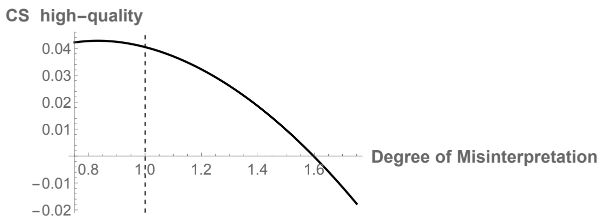
Proof of Proposition 6, 7 and 8

We showed that profits increase with overestimation as part of the proof in proposition 1. In proposition 2, we showed that profits of low-quality firms increase, while high-quality firm's profit decreases in both simultaneous and sequential quality competition. We show the effects of overestimation in consumer surplus next. Equations A.48 and A.49 decompose the effects of changes in misperception in consumer surplus for high-quality consumer and low-quality consumers, respectively.

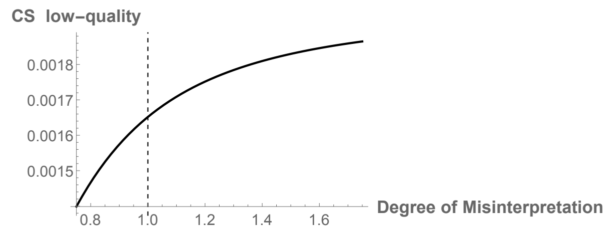
$$\frac{d}{dk_{\mathrm{i}}}\int_{\theta_{lh}}^{1}\theta v_h - p_h d\theta = (v_h - p_h)\frac{d1}{dk_{\mathrm{i}}} - (\theta_{lh}v_h - p_h)\frac{d\theta_{lh}}{dk_{\mathrm{i}}} + \int_{\theta_{lh}}^{1}\frac{\partial}{\partial k_{\mathrm{i}}}\theta v_h - p_h \tag{A.48}$$
$$= -(\theta_{lh}v_h - p_h)\frac{d\theta_{lh}}{dk_h} + \frac{1-\theta_{lh}^2}{2}\frac{dv_h}{dk_h} - (1-\theta_{lh})\frac{dp_h}{dk_h}$$

$$\frac{d}{dk_{\mathrm{i}}}\int_{\theta_{0l}}^{\theta_{lh}}\theta v_l - p_l d\theta = (\theta_{lh}v_l - p_l)\frac{d\theta_{lh}}{dk_{\mathrm{i}}} - (\theta_{0l}v_l - p_l)\frac{d\theta_{0l}}{dk_{\mathrm{i}}} + \int_{\theta_{lh}}^{\theta_{lh}}\frac{\partial}{\partial k_{\mathrm{i}}}\theta v_l - p_l \tag{A.49}$$
$$= (\theta_{lh}v_l - p_l)\frac{d\theta_{lh}}{dk_h} - (\theta_{0l}v_l - p_l)\frac{d\theta_{0l}}{dk_h} + \frac{\theta_{lh}^2 - \theta_{0l}^2}{2}\frac{dv_l}{dk_h} - (\theta_{lh} - \theta_{0l})\frac{dp_l}{dk_h}$$

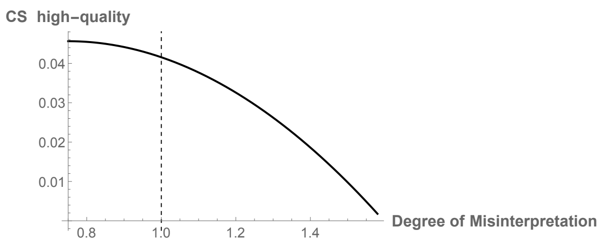
where i $\in \{h, l\}$. From Propositions 1 and 2, we can check that equations A.48 and A.49 cannot be signed unequivocally. We resort to a numerical solution under quadratic costs to sign the comparative statics. The numerical solution in Figure A.11 reveals that consumer surplus for high (low)-quality consumers decrease under misperception of high(low)-quality. Consumer surplus increases for the consumers that do not face misperception of quality.



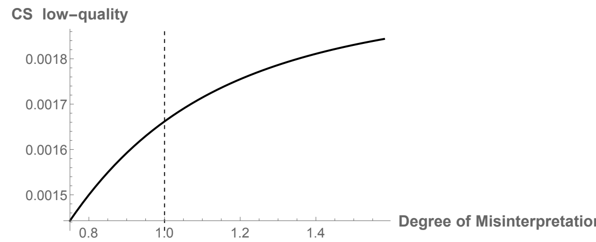
(a) Variation in CS_h with changes in k_h, under sequential quality competition



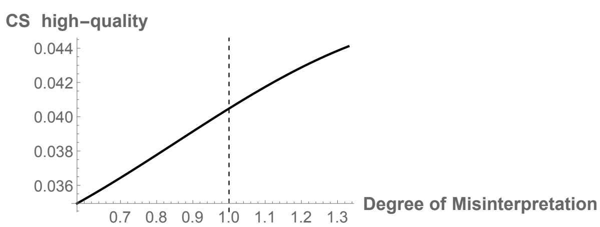
(b) Variation in CS_l with changes in k_h, under sequential quality competition



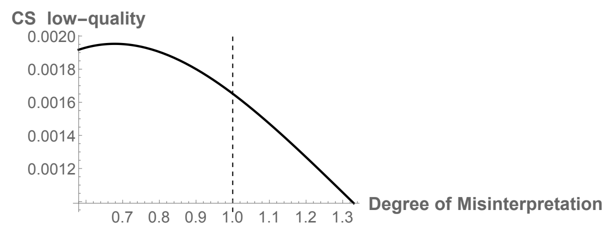
(c) Variation in CS_h with changes in k_h, under simultaneous quality competition



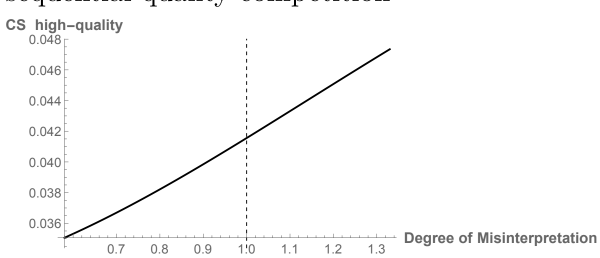
(d) Variation in CS_l with changes in k_h, under simultaneous quality competition



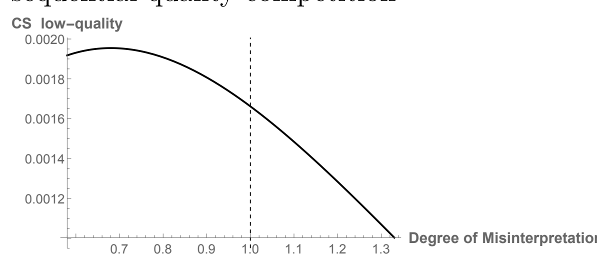
(e) Variation in CS_h with changes in k_l, under sequential quality competition



(f) Variation in CS_l with changes in k_l, under sequential quality competition



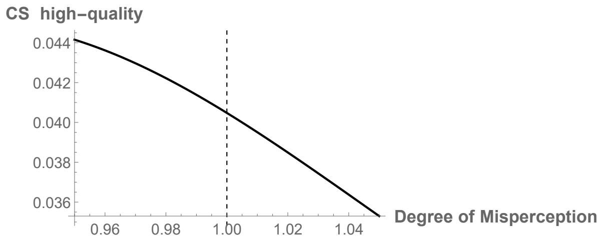
(g) Variation in CS_h with changes in k_l, under simultaneous quality competition



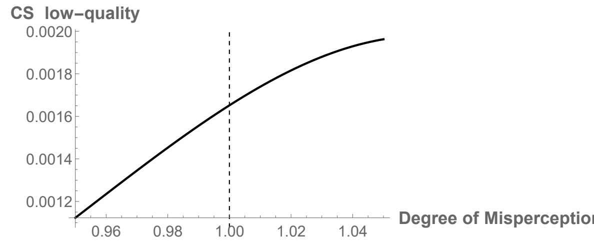
(h) Variation in CS_l with changes in k_l, under simultaneous quality competition

Figure A.11. Effects of increases misperception on Consumer Surplus

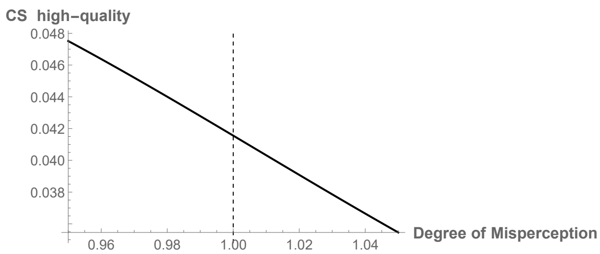
We remain to analyze distribution of welfare under mean-preserving misperception, (k_h and k_l). We can decompose the effects of misperception between the partial effects of k_h and the effects of k_l on $C.S._h$, $C.S._l$, π_h, and π_l. The numerical analysis is shown on Figure A.12.



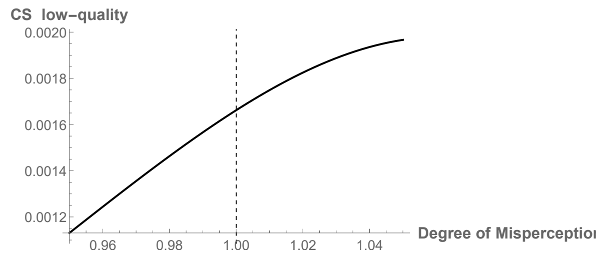
(a) Variation in CS_h with changes in $k_h(k_l)$, under sequential quality competition



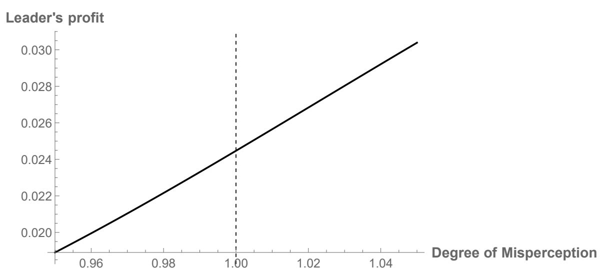
(b) Variation in CS_l with changes in $k_h(k_l)$, under sequential quality competition



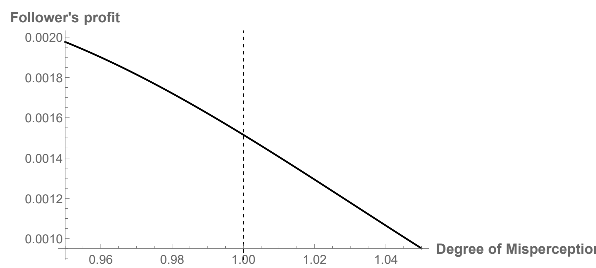
(c) Variation in CS_h with changes in $k_h(k_l)$, under simultaneous quality competition



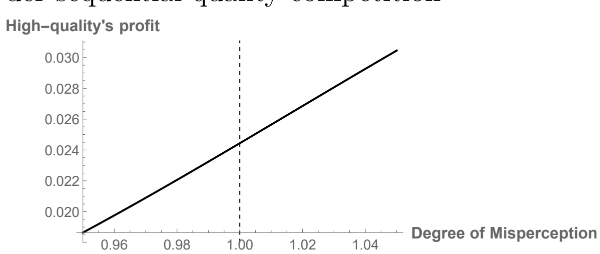
(d) Variation in CS_l (demand) with changes in $k_h(k_l)$, under simultaneous quality competition



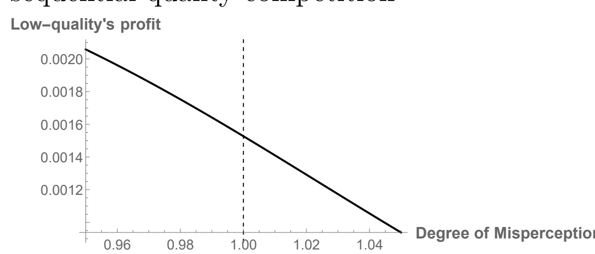
(e) Variation in π_h with changes in $k_h(k_l)$, under sequential quality competition



(f) Variation in π_l with changes in $k_h(k_l)$, under sequential quality competition



(g) Variation in π_h with changes in $k_h(k_l)$, under simultaneous quality competition



(h) Variation in π_l with changes in $k_h(k_l)$, under simultaneous quality competition

Figure A.12. Effects of mean-preserving misperception on distribution

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B. EXPERIMENTAL PROCEDURES

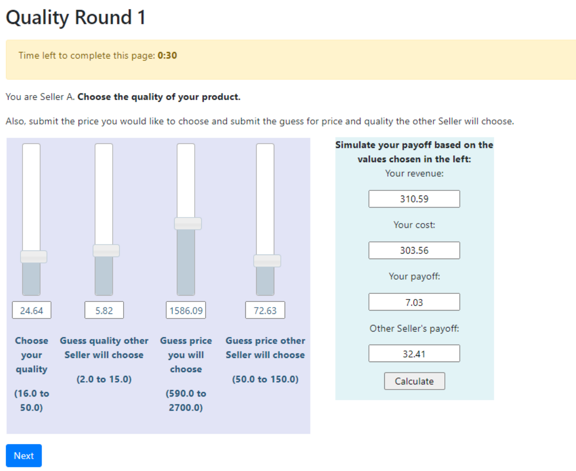
B.1 Power analysis

Table B.1.
Optimal sample size based on a 80% power for a t-test

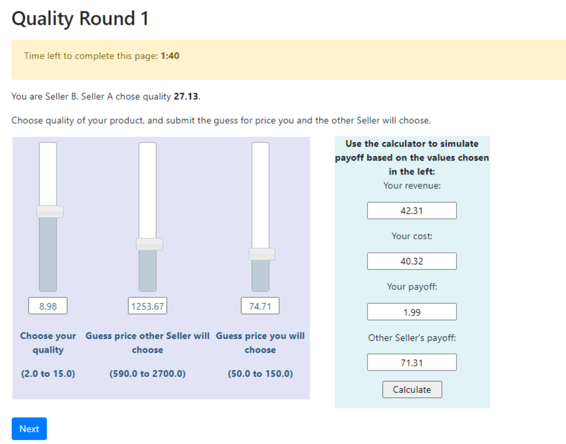
	Minimum Effect Size		**Optimal number of obs**	
	Quality	*Price*	*Quality*	*Price*
Bench x Overvalue, kh				
High-quality	13.0	1500	6	3
Low-quality	1.2	27	245	29
Bench x Undervalue, kh				
High-quality	11.0	120	8	233
Low-quality	1.2	20	250	36
Bench x Overvalue, kl				
High-quality	2.0	120	184	90
Low-quality	1.2	20	115	7
Bench x Undervalue, kl				
High-quality	2.0	120	164	212
Low-quality	1.2	20	152	23

Notes: I used a 50% proportion between control and treatments. Minimum effect sizes were calculated based on a pilot experiment conducted before the main experiment and they are not the exact difference between optimal theoretical quality and price choices. Variances used in the power calculations were also based on a pilot experiment. Data from the pilot was not included in the main results.

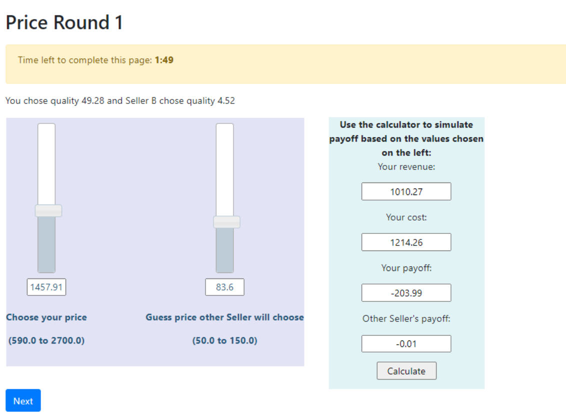
B.2 Decision screens



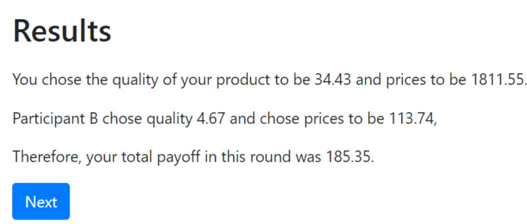
(a) Leader's quality decision screen



(b) Follower's quality decision screen



(c) Price decision screen



(d) Results screen

Figure B.1. Screenshots of software where subjects make decisions

B.3 Experimental Instructions

These are the experimental instructions for the benchmark case.

Experimental Instructions A

In addition to the $ 5.00 you are entitled for showing up to this experiment today, you may earn an extra amount of money to be paid in cash after the experiment, in private. The extra amount of money will depend partially on the decisions you make during this session, partially on the decision of others, and partially to chance.

In this experiment, the extra amount of money you can earn is called payoff. During the experiment, your payoff consists of points, which will be converted to U.S. dollars by the end of the experiment. Each 35 points you earn will be converted to 1 U.S. dollar.

You are not to talk out loud during the session. We ask you to put away any electronic device (phones, tablets, etc.) you may be carrying with you today. Those who do not comply will be asked to leave. We expect this experiment to last between 60-90 min.

Outline

1. We will go over the instructions.

2. You will answer a post-instruction quiz designed to see if you understood the instructions correctly. You will be paid $ 0.2 per right answer. You will answer the quiz in your computer.

3. You will start the experiment. The experiment is divided in two phases.

   (a) A training phase designed to get you accustomed to the game. In the training phase, you will only play against the computer. In the training phase, the computer choices are independent of your choices. You will not be paid in the training phase.

   (b) Effective experiment. Your performance in the rounds of the effective experiment will determine your final earnings.

4. You will answer a brief survey about your demographic characteristics.

The experiment

In this experiment, there will be sellers and buyers interacting in the market place. You and everyone else in this room will be sellers. The buyers will be played by the computer. The experiment consists of **multiple trading rounds**. During each round you will interact with one, and only one, other seller in this room, chosen randomly by the computer. After every round, the computer will randomly re-group you with another person in the room.

As sellers, you have to make two choices. **First, you have to decide what is the quality of your product you will be offering to buyers. Later, after all sellers decided their quality, you will choose the price of your product**. During each trading round, you will have the role of **Seller A** or **Seller B**. Your role during the trading round is randomly chosen by the computer.

Quality choices are done sequentially: Seller A chooses the quality of its product first, and Seller B chooses quality second, after observing Seller A's quality choice. **After Seller B chooses its quality, Seller A and Seller B decide their prices simultaneously, without the knowledge of the other Seller's price**.

Your **payoff** during each trade round will be determined by 1) how many buyers choose to buy your product, 2) the price of your product, and 3) the cost of offering the quality level you chose. **The payoff is simply determined by how many buyers bought your product multiplied by the price (what we call sales revenue) minus the cost of offering quality.** Thus, the higher your revenue, the larger your payoff will be. Also, the larger your costs, the smaller your payoff will be.

Quality

If you are Seller A: You can choose any number between the minimum quality 16 and the maximum quality 50.

If you are Seller B: You can choose any number between the minimum quality 2 and the maximum quality 15.

Prices

If you are Seller A: You can choose any price between the minimum price 590 and the maximum price 2700.

If you are Seller B: You can choose any price between the minimum price 50 and the maximum price 150.

Number of buyers

The number of buyers buying your product depends on the quality you choose, the price you charge, the quality chosen by the other Seller, and the price the other Seller chooses to charge.

As a general rule: if you increase quality of your product, more buyers will buy from you; but the more the other Seller increases its quality, less buyers will buy your product. Similarly with price. As you increase the price of your product, less buyers buy your product, and as the other seller increases its prices, more buyers buy your product.

It is possible that at a given combination of qualities and prices, no buyers will want to buy from you. It is also possible that under a different combination of qualities and prices, all buyers will want to buy from you.

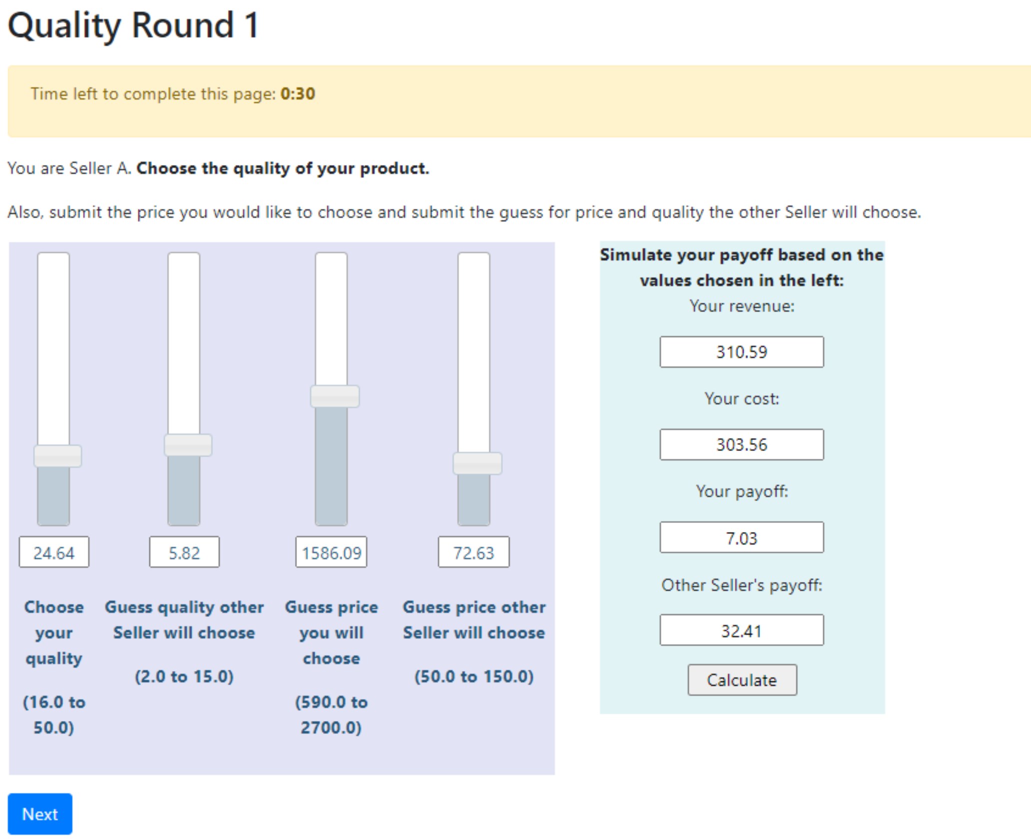
Costs

Your costs will depend on the quality you choose for your product. The higher the quality, the higher your costs will be. We will provide numerical examples in the next section.

Specific trading instructions

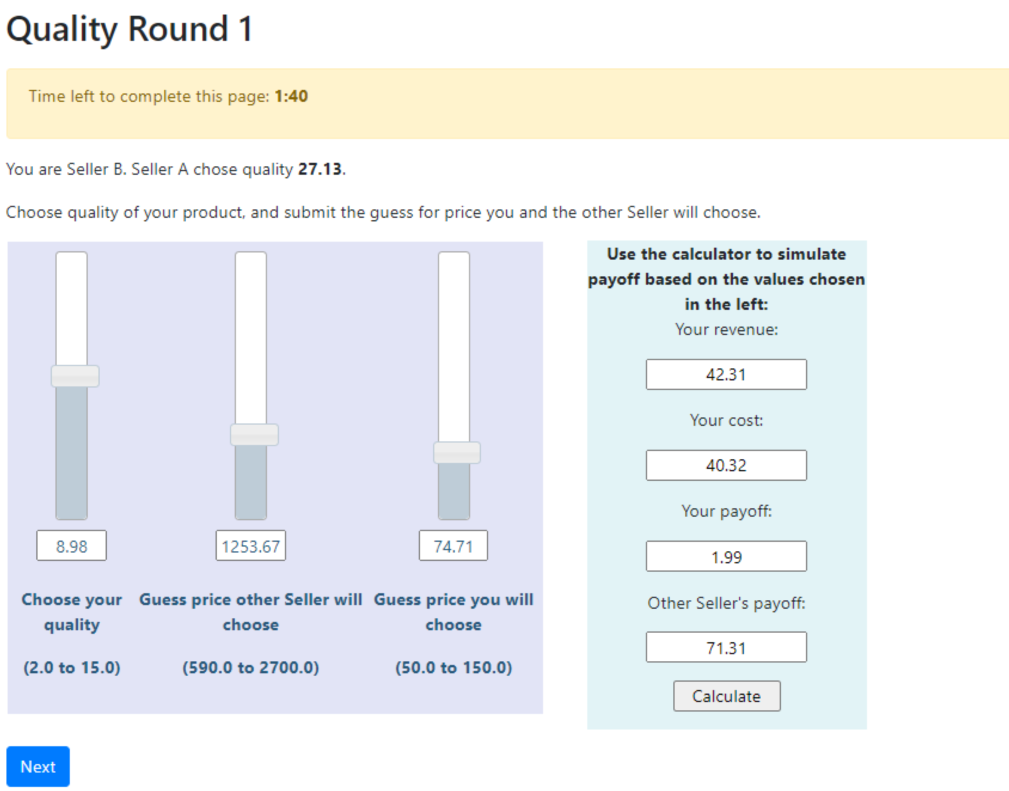
There will be 10 rounds. The sequence of choices in each round is:

- **Seller A quality choice:** Seller A will first choose the quality of its product. Additionally, we ask Seller A to a) make a guess for Seller's B quality choice ; b) choose the price they will choose if Seller B chooses the quality they guessed in (a); c) make a guess for the price Seller B will choose after it chooses the quality you guessed in (a). The screen in which Seller A makes the choices is depicted below. To make choices, click on one of the options.



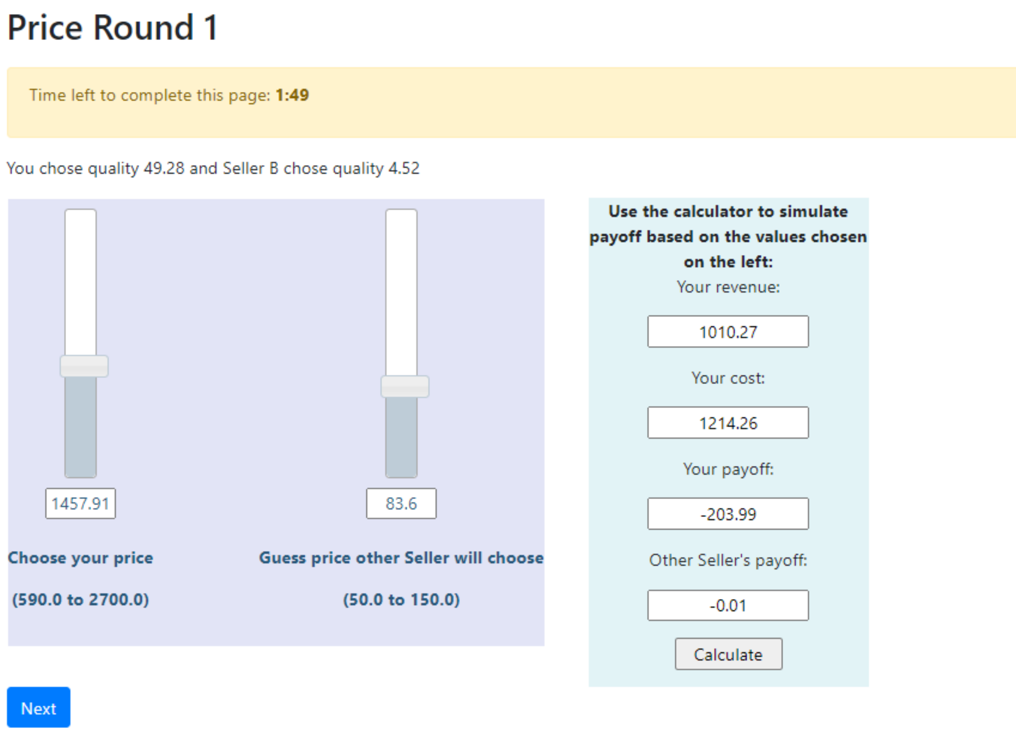
The calculator indicates the payoff with the values Seller A chose by moving the handles. To use the calculator, make the choices, then click the button "Calculate". Click the button "Next" when ready to commit to choices. If you do not press "Next" before the time to complete this page, the computer will randomly make a selection for you. But there is no need to rush your decisions, as there is plenty of time to choose. While Seller A makes its choices, Seller B waits. Notice that Seller B will not be able to see Seller A's choices while it waits.

- **Seller B quality choice:** Seller B will next observe Seller A's quality choice and will choose the quality of its product. Additionally, we ask Seller B to a) make a guess for the price Seller A will choose next ; b) choose the price they will choose based on the guess made in (a). The screen in which Seller B makes the choices is depicted below. To make choices, click on one of the options.



The calculator indicates the payoff using Seller B's chosen values and the quality Seller A chose earlier. To use the calculator, make the choices, then click the button "Calculate". Click the button "Next" when ready to commit to the choices. If you do not press "Next" before the time to complete this page, the computer will randomly make a selection for you. But there is no need to rush your decisions, as there is plenty of time to choose. While Seller B makes the choices, Seller A waits. Seller A will not be able to see Seller B's choices while waiting.

- **Price Choice:** Seller A and Seller B will observe the quality choices made by them and must set a price for their product. Additionally, we ask each player to make a guess for the other seller's price, as shown below. To make choices, click on one of the options..



The calculator indicates the payoff with the price values that the seller is choosing now and the quality values previously chosen by Seller A and Seller B. To use the calculator, make the choices, then click the button "Calculate". Click the button "Next" when you want to commit to your price choice. If you do not press "Next" before the time to complete this page, the computer will randomly make a selection for you. But there is no need to rush your decisions, as there is plenty of time to choose.

Examples

Table B.2 shows some examples of payoff under different combinations of qualities and prices.

Here is how you read the table. In line 1, the table shows that Seller A chose quality 24.5 in its quality round; this was followed by Seller B choosing quality 3.5 on its quality round; then, Seller A chose 913 as price for its product and Seller B chose 128 as the price for its product. As a result of all these choices, Seller A's revenue was 571.71 and its cost was 300.1. This resulted in a Payoff of 271.59 for Seller A. The combination of quality and price choices led Seller B's revenue to be 1.04, and its cost to be 6.1. This resulted in a Payoff of -5.09 for Seller B. You can check other combinations in Table B.2.

Notice that there are cases in which the combination of qualities and prices in a round leaves you with negative payoff.

Notice that a Seller's cost depends on the level of quality that the Seller offers, and it is independent of the number of buyers that buy the product. Table 2 shows such relationship for Seller A and Seller B. For example, if Seller A chooses quality 19, Seller A's cost in a round will be 180.50. Similarly with Seller B: if it chooses quality 4 (see the second line, third column of Table 2), its cost will be 8.

How are you going to be paid?

Out of the 10 effective trading rounds, the computer will select 4 effective paying rounds. Neither you nor the experimenter know which rounds are effective payment before the end of the experiment, as effective payment rounds are determined by the computer purely by chance. We will sum the earnings from the 4 effective payment rounds to determine your total number of points. Your total payment consists of the sum between your show up payment, the right questions you got from the quiz, and your effective payment from the experiment. If your earnings during the effective round are negative, your total payment will consists only of your show up fee and the result from the initial quiz. The experiment pay range varies between $5 and $35.

By the end of the experiment, the experimenter will pay you in private. You will be asked to wait outside and the experimenter will handle your money in an envelope. You may leave after you are paid.

Time to start the experiment

We will begin the experiment now. If you have any questions, raise your hand and the experimenter will go to you.

Table B.2.

Payoff for Seller A and Seller B under different quality and price combinations

Choices				Results					
Quality Seller A	Quality Seller B	Price Seller A	Price Seller B	Revenue Seller A	Cost Seller A	**Payoff Seller A**	Revenue Seller B	Cost Seller B	**Payoff Seller B**
24.5	3.5	913.0	128.0	571.71	300.1	**271.59**	1.04	6.1	**-5.09**
24.5	3.5	913.0	129.0	572.15	300.1	**272.02**	0.61	6.1	**-5.51**
23.5	3.5	913.0	129.0	555.10	276.1	**278.98**	3.02	6.1	**-3.10**
23.5	4.5	913.0	129.0	536.27	276.1	**260.14**	16.25	10.1	**6.12**
23.5	4.5	2589.0	129.0	0.00	276.1	**-276.13**	129.00	10.1	**118.88**
23.5	4.5	2589.0	54.0	0.00	276.1	**-276.13**	54.00	10.1	**43.88**
23.5	5.5	2589.0	54.0	0.00	276.1	**-276.13**	54.00	15.1	**38.88**
37.0	5.5	1037.0	129.0	738.08	684.5	**53.58**	6.93	15.1	**-8.20**

Table B.3.

Costs under different choices

Quality Seller A	Cost Seller A	Quality Seller B	Cost Seller B
19	180.50	3.5	6.13
23.5	276.13	4	8.00
24	288.00	4.5	10.13
24.5	300.13	5	12.50
37	684.50	5.5	15.13

C. DATABASE CONSTRUCTION

The details about the construction of the database used in **"Optimal quality gradation in organic labels: evidence from a structural econometric model"** are discussed next. I use Kilts 2016 version of the Scanner Database.

1. From file “products”, I select code 1463, which refers to ground coffee
2. From file “product extra” of 2016, I select “style code”, “type code”, “organic claim code”, “organic claim description”, “usda organic seal code”, and “flavor code”
3. I left merge “products extra” on “products” by “upc”, and “upc ver uc”
4. I select the **100% organic** by sub-setting all products with organic seal on “usda organic seal code” and those who have 100% in the organic claim. I manually check the 100% claim to see if they correspond to 100% organic and not another 100% description (like 100% arabica)
5. I left merge firm codes to the database (the firm company codes were maually done).
6. I merge “RMS” data on “movement” data for the year of 2016 by “upc” and “upc ver uc”
7. I merge “stores” data on movements file by “store code uc”, and “dma”
8. I merge the “product” data on “movement” file.
9. If “size 1 units” is OZ, I calculate volume by multiplying “units” by “size amount” by “multi”. If “size 1 units” is “CT” I convert each unit in 0.38 OZ (average amount of coffee in a coffee pod) by “size amount” by “multi”.
10. I define binary variables for flavor (flavor bin), type (type bin), and style (style bin) (see text for more information) and aggregate everything by ‘dma code’, ‘week end’, ‘brand code uc’, ‘comp code’, ‘multi’, ‘size1 units’, ‘panel year’, ‘flavor bin’, ‘style bin’, ‘type bin’, ‘100org’, and ‘org’. Prices are calculated diving total sales by volume after that.

11. I subset this data only by products that are **organic** or **100% organic**.

12. I construct the instruments as discussed in the text.

VITA

Francisco Albert Scott was raised in Lavras, Minas Gerais, Brazil. He attended the Economics program at the Federal University of Minas Gerais (UFMG), where he learned a great deal about the different methodologies and schools of thought in the field. During his undergraduate studies, Francisco's interests were drawn to the intersection between Regional and Agricultural Economics.

This led him to West Lafayette after graduating to pursue his Master's degree. Francisco joined the Department of Agricultural Economics at Purdue University in 2014 under the supervision of Dr. Raymond Florax. After graduation in 2016, Francisco started his Ph.D. studies under Dr. Juan Pablo Sesmero to investigate labeling in food products using a mix of theory, experiments, and econometrics.