Information Acquisition through Customer Voting Systems

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INFORMATION ACQUISITION THROUGH CUSTOMER VOTING SYSTEMS

Abstract. We study the use of customer voting systems that enable information acquisition from strategic customers to improve pricing and product development decisions. In these systems, the firm presents customers with a product design and gives them the opportunity to cast a vote on this design, a vote that has costs and benefits. For example, voting may be cumbersome, but those that vote in favor of a design may be eligible for a discount if and when the design gets developed. Customers vote and the firm interprets the voting outcome to discern customer interest in the product, and to advise on further development and/or pricing of the product. We model the interactions between the firm and strategic customers in such systems as a game of incomplete information with voting embedded as a subgame. Our analysis shows that the design and effectiveness of a voting system depends crucially on the intended use of the acquired information. When the acquired information is used to advise on development decisions, where firm and customer interests are aligned, voting systems that reward voters with discounts on subsequent purchase of products, in effect incentivizing voting in favor of products, can elicit information from customers and improve profit. On the other hand, when the information is used to set prices, a decision where firm and customer interests are misaligned, such systems are ineffective. In these cases, voting systems that effectively incentivize customers to vote against products or those that partially limit the firm’s future price flexibility should instead be used to acquire information. While both solutions improve firm profit, the former is preferred for high-value products, while the latter is preferred when voting involves less effort. Based on data for two representative products in the home decor industry, we find that these systems may increase gross product profits by up to 50% for development and by 20-30% for pricing.

1. Introduction

Web 2.0 technologies, social networks, micro-blogs and location-based services have enabled firms to increasingly involve their customer base in business decisions. Such engagement, often referred to as crowd-sourcing, typically involves leveraging customer opinion and resources to improve business processes that were traditionally performed opaquely to customers. Such engagement has displaced traditional business models in some industries (cf. Wikipedia (Mikolaj et al. (2012))), while creating new competing business models for product design, research and development, and problem solving (see Threadless (Brabham (2010)), Innocentive (Lakhani (2008)) and Hypios (Girotra and Terwiesch

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This paper introduces a new business process, customer voting systems, through which firms can engage customers in a firm’s operational decisions, specifically soliciting their input to improve product development and pricing decisions.

Voting systems were first prominently used by Threadless, where, in addition to designing new products, the community could also vote for designs. Home decor retailer MyFab (Girotra and Netessine (2011); Volongo and Girotra (2012)) refined voting systems by offering purchasing discounts to voters with the explicit purpose of acquiring customer information. Founded in 2008, MyFab had years of trailblazing growth, received over US$10 million in venture financing, and expanded to new markets. Today, these voting systems are employed by firms in other industries like apparel and home decor retail.

At an online retailer using a customer voting system, web visitors are presented with potential product designs. Product specifications, detailed pictures, and in some cases, pricing information are provided. Customers have the opportunity to cast a vote on the product design. Casting a vote comes with costs and benefits. The most thoughtful implementations of voting systems impose some barriers to casting a vote, such as identity verification, email confirmation of vote, etc. At the same time, visitors that complete a vote are offered benefits, for example MyFab offers a 10% discount to all customers that vote for a design and then buy the product if and when it is offered. After customer votes are tallied, the firm uses the data to advise on pricing of the product and/or on further development of the product. Finally, customers have the opportunity to buy the product if it is developed.

Despite the growing use of customer voting systems and their celebration in the popular press, these systems have not been rigorously studied. In particular, to the best of our knowledge there is no systematic analysis of the relationship between the design of a voting system, the intended use of acquired information, and the system’s effectiveness in improving firm profits. While there is a rich operations literature on information sharing within the supply chain, acquiring information from strategic customers, as customer voting systems do, has not been addressed. In the absence of rigorous analysis, practicing firms do not know when and how these voting systems are effective and they experiment with different systems by changing their voting design frequently. Further, even when customers are engaged by the voting system, practicing firms have too limited an understanding.

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of the drivers of customer behavior to use gathered information intelligently (Volongo and Girotra (2012)).

This study builds a stylized model of firm and strategic customer incentives in voting systems to provide guidelines on their design and use. We model firm and strategic customer interaction as a dynamic game of incomplete information. We characterize equilibria where each player’s strategies yield a Bayesian Nash Equilibrium in every continuation game given Bayesian posterior beliefs. We compute the value and costs of information acquisition, the system’s effectiveness, and the relative merits of different systems.

Our analysis illustrates that the design and effectiveness of voting systems depends crucially on the intended use of the information gathered from voting. We find that when a firm intends to use the information collected to identify if a product should be further developed, a decision where customer and firm interests are aligned (both want to develop the product when there is high interest and vice versa), voting systems that incentivize voting in favor of products are effective at acquiring customer information. On the other hand, when information is used to set prices, a decision where customer and firm interests are misaligned (the firm wants to set high prices when there is high interest, while the customers prefer low prices), systems that incentivize voting in favor of products are ineffective. The firm must instead employ reverse voting systems—systems that incent voting against products—to acquire and freely use information.

More specifically, for development decisions (Section 3), our analysis shows that a voting system where customers that voted on a product are eligible for a sufficiently high purchasing discount if and when the product is developed, are effective in acquiring information. Customers vote only when they value the product highly, in effect voting in favor of the product. This allows the firm to (partially) interpret customer preferences from voting outcomes. We characterize the benefits of employing such systems and find that these are driven by a fine balance between the information gains and the cost of acquiring information from strategic customers. Specifically, these systems are most beneficial for firms/products when the production, shipment and development costs are higher, but their advantage decreases when cost of casting a vote is higher. Further, we unexpectedly find that higher uncertainty in customer preferences may actually decrease the benefits of acquiring information through voting systems.

The same voting systems with purchasing discounts that are effective for advising development decisions are surprisingly ineffective when it comes to advising pricing decisions (Section 4). Strategic customers see no benefit in voting in favor of products and signaling their information, information
that in this case, may be used against their interest. This leads to an uninformative voting outcome. We develop two novel voting systems that address the incentive conflicts inherent in using customer information to set prices. In the first system, the firm commits to a maximum price: this incentivizes customers to vote in favor of products, while sacrificing some pricing flexibility. In the second, we propose a reverse voting system that flips the customer incentives to vote, making them better off casting a vote when they do not like the product. These systems provide incentives for customers to share information even when it is used to set prices. We compare both systems and find that the latter, where customer incentives are reversed, is preferred for products of high value, whereas the former, where the firm commits to a maximum price, provides control on what information is acquired and is preferred when the cost of casting a vote is low.

Numerical estimates, based on data for products typically sold by online retailers implementing voting systems, indicate that appropriately designed voting systems may improve gross product profits by up to 50% for development, and between 20-30% for pricing decisions, compared to business models without any voting mechanism.

Our paper makes three contributions. First, we develop an analytical framework to study customer voting systems, novel and increasingly prominent systems that use customer engagement technologies to advise on operational decisions. To the best of our knowledge, this is the first analysis of these systems. Second, we extend the supply chain literature on information sharing. While existing research has considered information sharing between firms and partners in the supply chain, we examine information sharing between a firm and its strategically acting customers. Finally, we provide practical guidelines on the design and use of customer voting systems, identifying the appropriate system to be employed in different settings, and provide realistic estimates of their effectiveness when used for typical products.

2. Literature Review

Our work is related to three streams in the operations literature: information acquisition in supply chains, tournaments and crowdsourcing, and strategic customers.

*Information Acquisition in Supply Chains:* Designing mechanisms that enable information flow within members of a supply chain has been widely studied, typically concerning the sharing of demand forecast information (see Oh and Özer (2012) for recent advances and the references therein for an extensive summary of the literature). While this work largely considers the intended sharing of information, another stream has examined the unintended sharing or leakage of information. Li (2002) and Li and Zhang (2008) study the retailer incentives and information leakage in a two-tier
supply chain. More recently, Ha et al. (2011) consider information sharing in competing supply chains. Anand and Goyal (2009) examine the leakage of information through material flows in the supply chain. Finally, while most of this work has taken an analytical game-theoretic approach to studying information sharing, Özer et al. (2011) conduct laboratory experiments to examine the relationship between trust and information sharing. In contrast to this literature, which studies information flows within different tiers of a supply chain, this study examines information flows between the supply chain and its strategically acting customers.

**Tournaments and Crowdsourcing:** Engaging customers or other external parties in firm decisions has been studied extensively in the crowdsourcing and tournaments literature. Among the early works, Ehrenberg and Bognanno (1988) find that the level and structure of prizes in tournaments have a significant impact on participants’ performance. More recently, Terwiesch and Xu (2008) provide recommendations on the rules to be employed in a contest depending on the type of problem at hand. Boudreau et al. (2011) provide empirical evidence that the number of contestants is important to determine the quality of the best solution. Like this body of research, we examine crowdsourcing; however, while the above studies examine incentives when external parties are engaged in innovation or problem solving, this study is focused on incentives in information elicitation when a firm deals with its customers.

**Strategic Customers:** In recent years there has been strong interest in examining the implications of dealing with forward-looking customers that strategically time their purchases. Cachon and Swinney (2009, 2011) study the value of quick response and enhanced design strategies in the presence of strategic customers. Su and Zhang (2008) study a two-tier supply chain selling to strategic customers and identify the benefits of decentralization. Su and Zhang (2009) show how quantity commitment and availability guarantees can mitigate the negative effects of strategic customer behavior when a newsvendor sells to strategic customers. Parlaktürk (2012) studies the value of variety when selling to strategic customers. Boyaci and Özer (2010) analyze advance selling in the presence of risk and loss-averse strategic customers. Li and Zhang (2012) consider pre-ordering and show that using pre-order information to improve availability hurts the firm by reducing its ability to price-discriminate. Like these papers, our study models forward-looking customers. While all these studies consider strategic behavior in the timing of the purchase, this study focuses on the customer’s strategic voting decision, which must account for different incentive systems put in place by an information-seeking seller.

Our work is also related to the political economics literature on social choice theory (cf. Gaertner (2009) for a current survey and Condorcet (1785), Arrow (1963) for foundations). Like our work,
this literature considers the design of voting systems, but it departs in the design objective. While political voting systems are designed to elicit relative preferences in order to maximize social welfare, customer voting systems are designed by firms to elicit information from customers about their valuation for a product in order to improve business decisions and maximize profit.

To summarize, we extend the information sharing in supply chains literature by considering sharing between the firm and customers. We consider a new dimension of customer strategic behavior, when customers vote strategically for products. Finally, our work considers a new form of crowd-sourcing, that of crowdsourcing operational firm decisions.

3. Customer Voting Systems to advise on Development decisions

In this section, we consider the use of customer voting systems to advise on product development decisions. In the next section, we consider use of these systems to advise on pricing.

3.1. Preliminaries. Consider a firm with an innovative product design. Bringing this product to market requires making additional investments of \(c_F\) monetary units, representing the cost of finalizing the design, booking supplier capacity, establishing production capabilities, etc. If these development costs are incurred, the firm sells the product to a market of identical strategic customers whose valuation for the product, \(X\), is a continuous random variable with convex support \(S\), differentiable pdf \(f\), cdf \(F\), and survival function \(\bar{F} = 1 - F\). While customers observe their valuation, the firm only knows its prior distribution. We assume that each customer purchases at most one unit of the product, and that the ensuing demand is fulfilled at a unit variable cost \(c\), which includes both production and delivery costs. Without loss of generality, we normalize the mass of customers in the market to one.

In the absence of any voting mechanism, the firm makes its development decision to maximize expected profit, computed using the common prior distribution on product valuation, \(f\). The optimal price to sell the developed product \(P^*_N\) is then the root of \(\bar{F}(P^*_N) - f(P^*_N)(P^*_N - c) = 0\). If the maximum expected profit is negative, the firm does not develop the product; otherwise, the firm develops the product and its expected profit is

\[
\Pi^*_N = \int_{P^*_N}^{\infty} (P^*_N - c) dF - c_F,
\]

where the subscript \(N\) is used to identify the metrics for a no-voting business model.

\(^{4}\)To ensure a unique solution, we require the profit function to be quasi-concave in price, i.e. \(\exists P^*_N : \bar{F}(P^*_N) - f(P^*_N)(P^*_N - c) = 0\), and \(-2f(P^*_N) - f'(P^*_N)(P^*_N - c) < 0\). This holds, for example, for valuation distributions with a non-decreasing hazard rate (such as uniform and exponential) and for the normal distribution.
3.2. Customer Voting Systems with Purchasing Discount. We now consider the use of a customer voting system with purchasing discount at the above described firm. In such a system, the firm puts up a product design for voting and decides to develop the product only after observing the outcome of the poll. The sequence of actions is illustrated in Figure 1. First, the product valuation is drawn and the realized valuation $x$ is observed by customers. Next, the firm announces a price $P_D$, a purchasing discount $\delta_D \leq 1$ (more on this later), and shares the product characteristics (typically pictures and specifications) with its customers. Each customer then chooses whether or not to vote for the product. Casting a vote involves customer effort (for example, verification of identity, email confirmation of vote, using up the limited number of votes, etc.) captured through a cost of casting a vote, $c_v > 0$. Next, the firm uses the observed outcome of the poll to decide whether to incur the development cost $c_F$. If the product is developed, it is available for sale: customers who previously voted for the product can purchase it at the discounted price $\delta_D P_D$, while customers who did not vote for it must pay the full price $P_D$. Essentially, customers who vote for the product earn the right to purchase it at a discounted price. The subscript $D$ is used to identify metrics associated with this voting system used to advise on development decisions.

The above sequence of actions constitutes a game of incomplete information with infinitely many players. We search for equilibria where each player’s strategies yield a Bayesian Nash Equilibrium in every continuation game given the posterior beliefs of the players, beliefs that are updated in accordance with Bayes’ law (Fudenberg and Tirole (1991), page 321). As is typical in the analysis of such games, it is convenient to describe the optimal strategies of each player in reverse chronological

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5Voting systems are typically used for new products, where the principal source of uncertainty for the firm arises from the market or common value of the product. Hence, the main analysis in the paper considers customers with a common value and models asymmetric information about this common value. In Section 6, we discuss a setting where customers have idiosyncratic private values in addition to the common value; to study information acquisition we must then jointly consider asymmetric information on common values and that on the idiosyncratic differences between customers in their valuation of the product (private values). We argue that the main insights continue to hold.

6See Hann and Terwiesch (2003) for estimates on the costs of online customer actions. There are no significant changes in the main message of this study if we consider different classes of customers with different costs of voting, including a class of prolific web-surfers with a cost of voting equal to zero.
order. For any price $P_D$ and discount $\delta_D$, the buying strategy for any customer is to buy the product iff she makes a positive surplus from the trade, that is, iff $x - \delta_D P_D \geq 0$ for customers that voted for the product, or iff $x - P_D \geq 0$ for customers that did not vote for the product. This is preceded by the firm’s development decision, where based on the voting outcome, that is the fraction of customers, $\nu_0$, that cast a vote in favor of the product, the firm updates its prior information $f$ on customer valuation for the product to the posterior information $f_{\nu_0}$. The firm then develops the product iff, accounting for such updated information, the expected profit-to-go $\pi_{\nu_0}^D (\delta_D, P_D)$ is positive. In order to characterize $f_{\nu_0}$ and $\pi_{\nu_0}^D (\delta_D, P_D)$, we examine the voting step.

We model voting as a simultaneous-move (sub)game among customers. This simultaneous-move voting subgame belongs to a class of games known as coordination games, first defined by Schelling (1960). As is typical in the analysis of such games, we use Harsanyi and Selten’s well-known concept of payoff dominance (Harsanyi and Selten (1988), p.81) to identify the equilibrium that arises in the voting step subgame. In our context, this implies that the equilibrium characterized by the voting threshold that maximizes customer surplus will arise. The decision of customer $i$, after observing the firm’s choice of $\delta_D$ and $P_D$ and the realized valuation $x$, can generally be described as casting a vote iff her valuation belongs to a set $V^i_D$. Her voting strategy is then defined by the set function $V^i_D (\delta_D, P_D)$, and it must be the best response to other customers’ voting strategies $V^{-i}_D (\delta_D, P_D)$, taking into account the firm’s development strategy and the customer’s buying strategy outlined above. We show that in equilibrium all customers vote according to the same voting strategy, and that such an equilibrium strategy is of a threshold type where customers cast a vote iff $x \geq \bar{x}^i_D (\delta_D, P_D)$ (Lemma 2, Appendix A). Casting a vote is an inconvenience for customers, but they may be willing to overcome such inconvenience and vote if they value the product highly enough, due to the benefit of earning a purchasing discount.

At the beginning of the game, anticipating how customer voting strategy $\bar{x}^i_D (\delta_D, P_D)$ responds to its decisions, the firm announces a price $P_D$ and a discount $\delta_D$ that maximize the weighted sum of the profits-to-go for each of the possible voting outcomes, with $\pi_{\nu_0}^D (\delta_D, P_D) = (\delta_D^\nu_0 P_D - c) \cdot F_{\nu_0} (\delta_D^\nu_0 P_D) - c_F$ being the firm profit-to-go once the voting outcome $\nu_0$ is observed, $F_{\nu_0}$ is the survival function of the posterior information obtained using Bayes rule, and where $\delta_D^\nu_0 = 1 - (1 - \delta_D) \nu_0$. If the voting system does not elicit any information, it is no better than a business model without voting. Thus, we require the firm to choose an initial announcement $(\delta_D, P_D)$ such that an informative equilibrium exists, that is, where $F (\bar{x}^i_D (\delta_D, P_D)) \in (0, 1)$, so that different voting outcomes may arise. The next Lemma describes the equilibrium outcome when a voting system is deployed to advise on development decisions. We assume that at least in the best-case
scenario, the trade surplus will be enough to compensate for total costs, i.e. \( \text{sup}(S) > c_F + c + c_v \), to avoid the trivial case where it is always better not to develop the product.

**Lemma 1.** In voting systems with purchasing discount, there exist informative equilibria only if \( \delta_D < 1 \). All such informative equilibria have the same profit, and are characterized by a price \( P_D^* \), a discount \( \delta_D^* \), and a customer voting strategy \( \bar{x}_D \) such that

\[
\delta_D^* P_D^* = \frac{1 - F(\delta_D^* P_D^* + c_v)}{f(\delta_D^* P_D^* + c_v)} + c + c_F \quad \delta_D^* \leq 1 - \frac{c_v}{P_D^*} \quad \bar{x}_D = \delta_D^* P_D^* + c_v.
\]

The firm develops the product iff \( \nu_o = 1 \).

The above Lemma demonstrates that appropriately designed voting systems with purchasing discount are an effective information-elicitation mechanism. For voting to elicit customer information, it is necessary that customers vote only under certain states of the world. This requires a fine balance between the costs and benefits of voting, a balance that tilts differently in different states of the world. Two conditions ensure this: first, voting must come at a cost to customers, if this is not the case, customers would always vote. However, this implies that no customer would incur the cost of voting unless there is some benefit to compensate for it, which leads to the second condition—voting should bring sufficient benefit to customers in some states of the world. By offering a high enough discount on the potential purchase of a product, the firm can induce customers to vote for it when they value the product sufficiently highly. In the process, the firm can interpret the voting outcome to acquire improved information on their valuation. Formally, for a sufficiently lucrative discount, \( \delta_D^* \leq 1 - \frac{c_v}{P_D^*} \), customers only vote when they value the product highly, \( x \geq \delta_D^* P_D^* + c_v \). This allows the firm to update its prior information on customer valuation for the product and eliminate instances where the firm invests in developing a product that is not valued sufficiently by customers.

From a managerial point of view, the result highlights two things. First, that voting systems with purchasing discount may effectively acquire customer information. Second, that only systems that offer discounts to voters provide economic incentives for customers to share information. On the contrary, voting systems like the one used at Threadless, which offers no reward to voters and merely relies on social incentives, may not supply accurate, interpretable information to the firm, given the notorious complexity of social interactions and the firm’s limited control on them. Information from such systems should therefore be used with caution.

While voting systems allow a firm to acquire information and potentially increase profits, setting the price and discount so as to elicit information from customers can potentially decrease profits.
The next section characterizes this tradeoff and identifies settings where such voting systems are most useful.

3.3. Advantage of Voting Systems with Purchasing Discount.

Theorem 1.

1) Voting systems with purchasing discount outperform no-voting business models iff the cost of development is higher than a threshold development cost \( \hat{c}_F \), defined by

\[
\hat{c}_F = \frac{\tilde{F}(P_N^*) (P_N - c) - \tilde{F}(\delta_D^* P_D^* + c_v) (\delta_D^* P_D^* - c)}{F(\delta_D^* P_D^* + c_v)},
\]

where \( \delta_D^* \) and \( P_D^* \) are defined in Equation 3.2 and \( P_N^* \) in Section 3.1. This threshold increases in the cost of voting \( c_v \) and decreases in the unit cost \( c \).

2) An increase in the firm’s uncertainty around customer valuation for the product \( X \) can increase or decrease the desirability of a voting system. When \( X \) is distributed uniformly over \([b - \alpha, b + \alpha]\) and both systems make a profit, an increase in customer valuation uncertainty \( \alpha \) decreases the desirability of voting systems iff \( b < c + \frac{c_v + c_F}{2} \).

The condition in the first part of Theorem 1 characterizes the circumstances where a voting system outperforms a no-voting business model. This condition can be understood by noting that a voting system allows the firm to halt the development of a product when the voting outcome reveals that customers do not like the product enough. This positive effect, called loss avoidance, allows the firm to avoid developing unprofitable products, and it increases in the development cost, \( c_F \). On the other hand, in order to obtain information, voting systems require customers to incur an effort cost to signal their high interest for the product, a cost to customers that does not translate into revenues for the firm, a system inefficiency. Such voting effort effect is negative and becomes more prominent as the cost of voting \( c_v \) increases. From these two effects follows the existence of the development cost threshold \( \hat{c}_F \) above which a voting system is a better choice than a no-voting business model. It also follows that this threshold increases in \( c_v \).

Formally, the increase in profits from a voting system, \( \Pi_D^* - \Pi_N^* \), can be expressed as the sum of the two main effects, loss avoidance and voting effort, respectively equal to \( c_F F (P_N^* + c_v) \) and \( - (F (P_N^* + c_v) - F (P_N^*)) (P_N^* - c) \), plus a third indirect effect, which captures the different prices charged in the two systems on account of the two main effects.\(^7\) The ability of a voting system to

\(^7\)This component of the profit difference is \( c_F [F (\delta_D^* P_D^* + c_v) - F (P_N^* + c_v)] + \tilde{F} (\delta_D^* P_D^* + c_v) (\delta_D^* P_D^* - c) - \tilde{F} (P_N^* + c_v) (P_N - c) \).
avoid losses and the inefficiency that arises from the voting effort also change the firm’s optimal pricing decision.

Interestingly, the threshold $\hat{c}_F$ decreases in the unit cost $c$, meaning that a higher unit cost increases the advantage of voting systems. This is because a voting system has lower expected sales compared to a no-voting business model (Lemma 3, Appendix A). Both the loss avoidance and the voting effort effects reduce sales, the former because it makes the firm better off charging higher prices, as it commercializes the product only when it is highly valued by customers, and the latter because it shifts the demand curve downward on account of the costs of voting. With lower sales, the negative impact of an increase in unit costs is reduced, making voting systems a more advantageous choice.

The second part of Theorem 1 highlights the interesting (and surprising) role of uncertainty. One expects that higher uncertainty around customer valuation for the product makes information about it more valuable, and consequently the advantages of information-acquiring voting systems should increase with valuation uncertainty. Our analysis shows that this is not always the case when the primary use of information is stopping development in low-valuation states. A mean-preserving increase in the uncertainty around customer valuation for the product implies a fatter right-tail of the valuation distribution. For high-cost products that are profitable only for right-tail valuations, this implies a lower chance of unprofitable states of the world where the voting system’s loss avoidance is helpful, thus reducing the benefit of voting systems. Further, this increased tail mass can contribute less to profits for voting systems when the voting system margin is lower. When product valuation is distributed uniformly in the interval $[b - a, b + a]$, the simple condition $b < c + \frac{c_v + c_F}{2}$ characterizes all situations where an increase in market uncertainty reduces the benefit of a voting system. Essentially, when the costs associated with the product (voting, development, and unit cost) are high, a higher uncertainty in customer valuation may operate in the opposite direction of what intuition suggests, thus reducing the benefit of acquiring information through voting systems.

Taken together, our analysis suggests that voting systems with purchasing discount are a helpful innovation to existing business models that can improve firm profits. In particular, voting systems engage customers in firm operations, solicit their inputs on decisions and use these inputs to improve profits. The benefits are most salient for firms/products when the production, shipment and development costs are high. Section 5 uses real data to provide numerical estimates of these gains.

We next consider a voting system that works along the same lines as the ones described in this section, but where the information acquired through voting is used to set prices.

4.1. Customer Voting Systems with Purchasing Discount. This system follows along the same lines as the voting system to advise on development decisions, except that the decisions of the firm in the pre-vote announcement step and the post-vote decision step are exchanged (Figure 2). As before, first the product valuation $x$ is drawn. In the pre-vote step, the firm decides whether to develop the product: if it doesn’t, the game ends and it earns zero profit, otherwise it incurs a development cost $c_F$ and then announces a discount $\delta_P$ for customers that will vote in favor of the product. In the voting step that follows, after observing the magnitude of the purchasing discount offered by the firm, each customer chooses whether or not to vote in favor of the product. The firm observes the voting outcome $\nu_o$, updates its prior information $f$ to $f_{\nu_o}$, and chooses the price of the product. Finally, customers buy the product— at the reduced price $\delta_P P_P$ if they previously voted for it, or at the full price $P_P$ otherwise.

As before, customers’ strategy in the purchasing step is to buy the product iff they make a positive surplus. In the post-vote decision step, the firm pricing strategy $P_{\nu_o}^* (\delta_P)$ maximizes the expected profit-to-go taking into account the discount $\delta_P$ announced at the beginning of the game, and bases its decision on the new information $f_{\nu_o}$ acquired by observing the voting outcome $\nu_o$. The optimal pricing strategy for the firm is then $P_{\nu_o}^* (\delta_P) = \arg \max_{P_P} \left( (\delta_{\nu_o}^* P_P - c) \cdot \bar{F}_{\nu_o} (\delta_{\nu_o}^* P_P) \right)$, where $\delta_{\nu_o}^* = 1 - (1 - \delta_P) \nu_o$. Customer voting strategy $\bar{x}_P^* (\delta_P)$ is the one that maximizes customer surplus for every announced discount $\delta_P$, taking into account the firm pricing strategy. The firm optimal strategy during the pre-vote step is to choose the discount $\delta_P$ that maximizes the weighted sum of the profits-to-go, these being $\pi_P^* (\delta_P) = (\delta_{\nu_o}^* P_{\nu_o}^* (\delta_P) - c) \cdot \bar{F}_{\nu_o} (\delta_{\nu_o}^* P_{\nu_o}^* (\delta_P))$, where the notation is the same as in Section 3. The firm develops the product iff the expected profit above is less than the development cost $c_F$.

Theorem 2. There exist no informative equilibria when customer voting systems with purchasing discount are used to advise on pricing decisions.
Theorem 2 shows that offering customers a purchasing discount does not help the firm acquire information to advise on pricing decisions. This result is in contrast with our previous analysis, where the same voting system was shown to be effective in acquiring information to advise on development decisions. Note that in both these systems the inconvenience of voting, together with the fact that a purchasing discount is most valuable when valuation is high, imply that informative voting may happen only in the high-valuation contingency. However, the incentives of strategic customers to share information in the high valuation contingency depart drastically depending on the intended use of the acquired information.

In a system to advise on development decisions, in the high-valuation contingency customers want the product to be developed so that they can make a positive surplus by purchasing it. If the firm finds out about customers’ high valuation for the product, it also wants to develop the product, as it is going to be profitable. The customers are better off voting in the high valuation contingency because the firm’s self-interested response to their signal is also in their interest, and this drives the effective use of voting systems with purchasing discount. This is not the case with pricing decisions. When the product is valued highly, customers would like the product to be priced as low as possible so that they can obtain a higher surplus from purchasing it. But once the firm finds out about the customers’ high valuation, it prefers to charge a higher price, as customers value the product more. Furthermore, the firm’s pricing decision will not compensate customers for having incurred the cost of voting, this being a sunk cost by the time the pricing decision is taken. Thus, when pricing is postponed, customers do not want to share their information because the firm’s self-interested response to their signal is counter to their interest.

The above result highlights the importance of considering the intended use of the information in designing voting systems that acquire information from strategic customers. While purchasing discounts are appropriate for advising on development decisions, they are ineffective for advising on pricing decisions. Further, this result is in contrast with the main message of the literature on postponement (Aviv and Federgruen (2001); Biller et al. (2006); Van Mieghem and Dada (1999)), i.e. that \textit{ceteris paribus}, postponing price or quantity decisions always helps the profits of a monopolist firm. In our work, information is not available as a result of an exogenous process, but is actually acquired by incentivizing customers to share information. This difference is a game-changer: whenever information sharing is an endogenous process, and as such it is conditional on the incentives of the parties being aligned, there is value in postponement only insofar as the decisions being postponed do not subvert the preexisting alignment of interests between the parties.
This inefficacy of voting systems with purchasing discount does not change when the firm uses the acquired information to advise on both development and pricing decisions. In principle, one would expect such a system to perform even better than the previously studied voting system to solely advise on development decisions— the acquired information can be used to advise on two decisions rather than just one. However, as before, the conflict of incentives generated by using information to improve the postponed pricing decision makes customers unwilling to reveal their high valuation, making the information exchange impossible.

From a practical point of view, the results of Theorems 1 and 2 suggest that internet retailers can use voting systems with purchasing discount only when it comes to advising decisions where the interests of the firm and customers in the voting states of the world are aligned. This implies that the use of voting systems to advise on pricing decisions is misguided and likely to lead firms to interpret irrational information, consequently choosing sub-optimal prices. Nevertheless, in many product categories, arriving at the right price for the product is an important strategic objective and there is increasing demand for the design of voting systems that can help advise on pricing decisions. We next exploit our above analysis of strategic customer behavior in voting systems to propose two novel system designs that can be used to advise on pricing decisions, as well as on other decision variables where the incentives of the customers and the firm may not be aligned.

4.2. Alternate Voting Systems to advise on Pricing decisions. In our first alternate voting system, the firm commits to restricting the use of information obtained. In the second system, the firm reverses voter incentives by replacing purchasing discounts with penalties, inducing customers to vote against the product, rather than in favor of it. We search for equilibria in threshold voting strategies.

4.2.1. Voting Systems with Bounded Pricing. The sequence of actions in this system (illustrated in Figure 3) is the same as that in the above voting system to advise on pricing decisions, except for one key difference: the firm’s pre-vote announcement now includes, in addition to a purchasing discount, the maximum price, $P_N$. This modification allows the firm to adjust its strategy based on the customers' reactions to the price, ensuring a more effective information acquisition process.
discount $\delta_B$, a binding commitment to a maximum price $\bar{P}_B$ for the product. Hence, the firm must now choose both the discount and the upper bound on price before voting takes place, its optimal announcement $(\delta^*_B, \bar{P}_B)$ being the one that maximizes $\sum_{\nu_o} Pr \{ \nu_o | \bar{x}^*_B \} \cdot (\delta^*_B P^{\nu_o*}_B - c) \cdot \tilde{F}_{\nu_o} (\delta^*_B P^{\nu_o*}_B)$, where $\bar{x}^*_B$ is customer equilibrium voting strategy, $P^{\nu_o*}_B = \arg \max_{P^{\nu_o}_B \leq \bar{P}_B} (\delta^*_B P^{\nu_o}_B - c) \cdot \tilde{F}_{\nu_o} (\delta^*_B P^{\nu_o}_B)$ are the subgame-perfect pricing functions, notation for $\delta^{\nu_o}_B$ and $\tilde{F}_{\nu_o}$ is as before, and where we naturally focus on information-eliciting announcements of the firm. Note that by setting $(\delta_B, \bar{P}_B)$ the firm affects the future pricing strategy both directly through the upper bound $\bar{P}_B$, and indirectly through customer voting strategy $\bar{x}^*_B$, which is a function of the announcement.

As before, in this and in the next voting system that we analyze, we characterize the equilibria where each player’s strategies yield a Bayesian Nash Equilibrium in every continuation game given the posterior beliefs of the players, beliefs that are updated in accordance with Bayes’ Law, and we use payoff dominance (Harsanyi and Selten (1988), p.81) to identify the equilibrium that arises in the voting step subgame. The equilibrium strategies for this system are provided in Appendix B (page 29). Henceforth, we focus on the interesting case where $c_F$ is low enough for the firm to be better off developing the product: if not, the product is not developed in the first place, hence the firm does not seek to obtain information from customers and the resulting profit is zero. The ensuing equilibrium outcome in a voting system with bounded pricing departs from the one with purchasing discount alone, most interestingly in how information is shared.

**Theorem 3.** In a voting system with bounded pricing there always exists an informative equilibrium, i.e. where $F(\bar{x}^*_B) \in (0,1)$.

Committing to a maximum price allows the firm to acquire information. As before, when a purchasing discount is offered, customers vote only when the valuation for the product is high enough. But now, unlike before, the firm can commit to not increasing its price to a level where customers would be left with a negative surplus in the high-valuation contingency. This creates incentives for strategic customers to vote and share their private information to extract some surplus. While committing to a maximum price allows the firm to obtain information, the very same commitment restricts the firm’s ability to fully use the information. The next system we propose achieves both objectives—the firm is able to acquire customer information while retaining the flexibility to use the information in the way it sees fit.

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8Formally, we consider $c_F < \tilde{F} (\bar{x}^*_B) (\delta^*_B P^{\nu_o*}_B - c) + [F (\bar{x}^*_B) - F (P^{\nu_o}_B)] (P^{\nu_o*}_B - c)$.
4.2.2. Systems with Reverse Voting. Inspired by the study of reverse voting systems in political settings, we consider a system that flips the incentives of voters using voter rewards and purchaser penalties. With this mechanism (Figure 4), the firm announces that all customers that cast a vote will receive an immediate lump-sum reward $r > 0$ in the form of a micro-payment or a coupon. However, if these customers decide to later purchase the product they may be charged a higher price, a purchasing penalty $\rho_{v_o} \geq 1 \forall v_o$ is applied to them. Essentially, voters earn an immediate reward but may also be subject to a price penalty if they buy the product. At this point, each customer decides whether or not to vote. Then, the firm observes the voting outcome $\nu_o$ and uses the updated information $f_{\nu_o}$ to decide what price $P_R$ to charge for the product. Finally, customers are allowed to buy it— at an augmented price $P_R \cdot \rho_{v_o}$ for voters, and at a regular price $P_R$ for non-voters.

Customers’ purchasing strategy is to buy iff their valuation is higher than the price they are charged. The pricing decision of the firm is the solution to $P_R^{\nu_o \ast} = \arg \max P_R \cdot (P_R \cdot \rho_{v_o} - c) \cdot F_{\nu_o} (P_R \cdot \rho_{v_o})$ with the usual notation for $F_{\nu_o}$. In the voting step, customers vote iff their valuation is below a given threshold valuation $\bar{x}_R$. Note that this customer voting strategy is the reversal of that in the other voting systems: customers vote iff their valuation is below a given threshold, rather than above. In fact, when the valuation for the product is high, customers prefer to buy it, and since voting for the product in this state leads to an increase in price on account of the purchasing penalty, they prefer not to vote. On the other hand, when the valuation is low, customers are unlikely to buy the product, and voting for the product earns them the immediate reward with no other relevant consequences. Hence, in this system customers can be interpreted as voting against the product, since casting a vote signals a low valuation.

Before the voting step, the optimal announcement $(r, \rho_{v_o})$ maximizes the weighted sum of the profits-to-go, minus the expected cost of rewards $\sum_{\nu_o} P_R \{ \nu_o | \bar{x}_R \} \cdot (p_{P_R^{\nu_o \ast}} - c) \cdot F_{\nu_o} (p_{P_R^{\nu_o \ast}} - rF (\bar{x}_R))$. As

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9Reverse voting systems were originally developed in social choice theory in the economics literature, with the earliest use in Athenian democracy (Hansen (1999)). In modern times, the EU is considering the use of such systems.
before, we study the interesting case when developing the product is profitable.\footnote{Formally, we consider \( c_F < F(\bar{x}_R^*) (P_R^* - c) + [F(\bar{x}_R^*) - F(P_B^*]) (P_B^* - c) - rF(\bar{x}_R^*). \)} Equilibrium strategies are provided in Appendix B (Page 30).

**Theorem 4.** In a voting system with reverse voting there always exists an informative equilibrium, i.e. where \( F(\bar{x}_R^*) \in (0, 1). \)

Systems with reverse voting can acquire information where traditional systems with purchasing discounts could not. To understand this drastic reversal, it is instructive to examine the incentive proposition for voters in both systems. In voting systems with purchasing discount, customers are asked to incur a costly action (voting) in order to signal a high valuation, but the firm’s ex-post optimal response after such a signal (to charge a higher price) is against the customers’ interest. Thus, there are no incentives to incur the cost of sending this signal. On the contrary, with reverse voting, customers are asked to incur a costly action (voting) in order to signal a low valuation, and the firm’s response after such a signal (to reward customers and choose a lower price) is in the senders’ interest, thus incentivizing them to incur the costs necessary to send the signal and share their information. Note that unlike the voting system with bounded pricing, with reverse voting the firm can freely make the price decision. A priori, this system has the best features of all systems described so far, in that it has full price flexibility and information sharing.

Imposition of a purchasing penalty requires identifying voters at time of purchase. Arguably, some customers may try to create multiple accounts, voting with one account (thus earning the reward) while purchasing the voted product with another account (thus avoiding the penalty). This can be limited by requiring identifying information to cast a vote, such as a combination of a credit card number, billing and shipping addresses, etc. More importantly, for the purchaser penalty to be an effective incentive, voters just need to be subject to a price increase in expectation. Practically, even a small chance to be identified and being subject to a price increase constitutes a sufficient deterrent to balance the small reward from voting (comparable to the cost of voting).

4.3. **Bounded Pricing or Reverse Voting?** In order to compare the two newly developed voting systems to advise on pricing, it is instructive to reformulate the optimal firm profits in each system into a common profit form. This assumes a particularly interesting structure when the cost of voting, \( c_v \), is relatively small compared to the product valuation, which we assume hereafter.\footnote{Formally, \( c_v \leq \arg \max_{\bar{x}} [F(\bar{x}_j^*) - F(P)] (P - c)^+, j \in \{B,R\}. \)} This common profit function has two components: the first is the informed profit, \( PI \), which can be interpreted
as the profit that a firm earns if it acquires information. The second is the cost of information, $CI$, which is the cost of incentivizing strategically acting customers to share information.

Formally, the profit of voting system $j$, where $j \in \{B, R\}$, $B$ denotes the system with bounded pricing, and $R$ denotes the system with reverse voting, can be decomposed as $\Pi_j^* = PI_j - CI_j$ where

$$\begin{align*}
CI_B &= c_v \bar{F}(\bar{x}_B^*), \\
CI_R &= c_v F(\bar{x}_R^*),
\end{align*}$$

and $P_l^*(\bar{x}_j) = \arg\max_P [F(\bar{x}_j) - F(P)](P - c)^+$ (see Appendix B, page 31 for details on obtaining the above common reformulation). We next examine how these two components of profits differ in the two systems.

**Cost of Information ($CI$).** The cost of information (Eq. 4.1) is incurred by the firm on different parts of the valuation distribution for the two systems—when valuation is more than the voting threshold in bounded pricing, and when valuation is less than the voting threshold in reverse voting. In a system with bounded pricing, the cost of information is the potential margin that the firm loses in the high-valuation contingency because of the firm’s commitment to a maximum price. In a system with reverse voting, on the other hand, $CI$ is the expected value of rewards to voters in the low-valuation contingency. In both cases, the cost of information increases in the cost of voting. When low valuations are more likely, reverse voting systems end up paying out too many rewards, whereas when high valuations are more likely, bounded pricing systems have their margins crippled by the maximum price commitment. The next theorem formalizes this effect.

**Theorem 5.** Take a valuation distribution $f$, and let $\bar{x}_B^f$ and $\bar{x}_R^f$ be customer equilibrium voting strategies; then for every valuation distribution $g$ such that $g \succ f_{\text{fused}}$, the cost of information first-order increases for bounded pricing systems and first-order decreases for reverse voting systems, $c_v F(\bar{x}_R^f) > c_v G(\bar{x}_R^f)$ and $c_v F(\bar{x}_B^f) < c_v G(\bar{x}_B^f)$. Further, if $f$ has a non-decreasing hazard rate, then a shift in the valuation distribution, $h(x) = f(x - k)$, $k > 0$, increases the cost of information for bounded pricing systems, $c_v F(\bar{x}_B^f) < c_v H(\bar{x}_B^h)$. Roughly speaking, Theorem 5 shows that moving probability mass from lower to higher valuations (from $f$ to $g$) favors reverse voting systems. Managerially, this suggests that reverse voting systems work best when the valuation distribution has a higher mean and/or is right-skewed. Next, we consider the second component of profits, the informed profit.
Informed Profit ($PI$). Interestingly, the informed profit (Eq. 4.2) is the same function of the voting threshold, $\bar{x}_j^*$, in the two systems. This voting threshold determines the information that the firm can obtain from voting, and consequently also determines the informed profit. In particular, some voting thresholds get more useful information than others (as an extreme case, thresholds at the boundaries of the distribution’s support bring no information or increase in profits). Now, in bounded pricing systems the firm can freely choose this threshold (by appropriately setting the discount and price bound, $\delta_B$ and $\bar{P}_B$, see Appendix B, page 31), whereas in reverse voting systems the firm has no control of the same, which is determined by the payoff-dominant equilibrium. This control over the customer voting threshold and consequently of the quality of information gives an advantage to the bounded pricing system. In particular, it can always, at the very least, acquire the same information as with reverse voting, with the potential of doing better. Formally, the thresholds are:

$$\bar{x}_B = \arg \max_{\bar{x}_B} (\Pi_B (\bar{x}_B)),$$

$$\bar{x}_R = \arg \max_{\bar{x}_R} \left[ \bar{F}(\bar{x}_R) \left( x-P^*_h(\bar{x}_R) \right) + \left[ F(\bar{x}_R)-F(P^*_l(\bar{x}_R)) \right] \left( x-P^*_l(\bar{x}_R) \right) + c_v F(\bar{x}_R) \right],$$

where $P^*_h(\bar{x}_R) = \arg \max_P \left[ \frac{\bar{F}(P)}{\bar{F}(\bar{x}_R)} \right]^{1} (P - c)$, and the next theorem captures the informational advantage of bounded pricing.

**Theorem 6.** There always exist a purchasing discount and a maximum price in the bounded pricing system such that its informed profit is at least as high as that of the system with reverse voting. Further, $\lim_{c_v \to 0} PI_B - PI_R \geq 0$ and $\lim_{c_v \to 0} \Pi_B^* - \Pi_R^* \geq 0$.

The above result shows that the system of incentives set up with bounded pricing not only helps the firm acquire information, but it also allows the firm to acquire the right kind of information. If the cost of voting is low, thereby muting the cost of information component of profit, the higher informed profit in bounded pricing makes it a better system.

Taken together, our results show that the informed profit component always favors bounded pricing, whereas the cost of information component favors bounded pricing or reverse voting depending on the skewness of the distribution. Managerially, we expect that **bounded pricing is preferred when the cost of voting is low, whereas reverse voting is preferred when the mean valuation is high and/or the distribution is right skewed.**
Figure 5: Comparison of Voting Systems to advise on Pricing Decisions

Figure 5 illustrates these effects. Panel (a) shows that a reverse voting system is preferred with right-skewed valuation distributions, in particular when the cost of voting is substantial. Panel (b) illustrates the consequences of different mean valuations, obtained by shifting the distribution. Interestingly, a right-shift in distribution can also be interpreted as a decrease in unit cost, c. Hence, with increasing mean and/or lower unit costs, reverse voting systems are preferred.

5. Numerical Study

In this section we quantify the benefits of voting systems for two representative products from firms employing voting systems. We consider designs for two new products— a high-value product, the "Chesterfield Leather Sofa", and a low-value product, the "Glass Table Lamp" (Figure 8 in Appendix B). Table 1 reports the parameters associated with each product and describes the methodologies and sources employed to estimate them. Since no data is available about the valuation distribution for these products, we investigate the profitability of voting systems by employing a range of plausible values for the mean, skewness, and variance of the valuation distribution. We begin by presenting the results for voting systems to advise on development decisions, and next for voting systems to advise on pricing decisions.

5.1. Profitability Gain for Voting Systems to Advise on Development decisions. Figure 6 shows the gain in product-level gross profits when voting is used to advise development. Panels (1) and (2) consider different levels of mean valuation and Panels (3) and (4) consider the costs of voting.

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In these examples, customer valuation is beta-distributed, allowing us to change skewness and support by adjusting the shape parameters $\alpha$, $\beta$, $A$ and $B$. We change the skewness of the distribution while keeping $\alpha + \beta$ constant, which can be thought of as looking at the possible range of priors that a firm engaging in pre-game market research could start with, keeping the amount of market investment constant.
Panels (1) and (2) show that the profit gain from deploying voting systems is substantial, but varies dramatically depending on mean customer valuation. When mean valuation is a smaller multiple of the production costs, or the profit potential is smaller, the gains are higher–reaching as high as 50%. The effect is more pronounced for the low value product. Skewness of the valuation distribution has a substantial impact on profit gains, especially for low-value products with low valuation. Taken together, the gains from deploying voting systems to advise development are most pronounced when the profit potential of the product is smaller, that is, when the costs (production, shipping and development) are comparable to the customer valuation and the valuation distribution is left skewed.

Panels (3) and (4) show that a change in the cost of voting $c_v$ has almost no impact on profit gains for the high-value product, but it has a substantial and roughly linear impact for the low-value product, with a $1$ increase in $c_v$ resulting in as much as a 6% reduction in profit gains. Higher uncertainty in the valuation distribution increases the benefits from deploying voting systems. For the low-value product, a 20% increase (decrease) in variance of the valuation results in a 5-6% increase (decrease) in profit gains, compared to less than 1% for the high-value product.

Overall, these numbers show that voting systems can increase product profits substantially, with the maximum benefits arising for products that have costs comparable to customer valuations.
5.2. **Profitability Gain for Voting Systems to Advise on Pricing decisions.** Figure 7 illustrates the gains obtainable in product-level gross profits from systems to advise on pricing decisions, the panels being organized as before.

Panels (1) and (2) show that in contrast to their use for advising development, voting systems to advise pricing are most beneficial for products when mean valuation is substantially higher than the costs involved. For low-value products, gains increase from about 10% to 25% as mean valuation increases in comparison to costs. For high value products, the gains are stable at around 30%. Skewness in the valuation distribution has some impact on the profit gains, with a mildly left-skewed (right-skewed) distribution resulting in a 3-5% increase (decrease).

Panels (3) and (4) show that a change in the cost of voting affects only low-value products, its effect being roughly linear in \( c_v \), with a $1 increase in \( c_v \) resulting in a \( \sim 2\% \) loss. This reduction is lower compared to voting systems to advise on development because here the firm has the ability to lower the price and sell to customers even in the low contingency, where the other voting systems would
halt development and make no profit. Higher uncertainty has a small positive impact on profit gains, with a 20% increase (decrease) in variance resulting in a 1-1.5% increase (decrease).

These results show that voting systems employed to advise pricing can increase firm profits substantially: a firm using them can expect profit gains as high as 25-30% with the maximum gains when products have high profit potential, that is, when customers value products substantially higher than costs.

6. Effect of Assumptions

Our analysis is based on selecting the payoff-dominant equilibrium in the voting subgame. While payoff dominance is widely used, risk dominance is an alternate selection criteria often recommended for simpler, finite games with perfect information (cf. Carlsson and Van Damme (1993), Selten (1995), Kojima (2006)). With the use of risk dominance, the spirit of Theorem 1 remains the same, while the exact conditions change. More importantly, all other results, including those on
the ability of voting systems to acquire information, the relative merits of different systems, etc., remain identical.

The analysis provided examines the use of a voting system to acquire information on the common value of products, the key uncertainty in new product designs. Our model goes beyond the literature on strategic customers in incorporating asymmetric information on this common value.\textsuperscript{13} One can go even further and consider an extension where customers have both a common component to their valuation and an idiosyncratic private component. In our context of information acquisition through voting this contributes to a second additional source of information asymmetry, asymmetry on the private value of customers. In such a case, the firm knows neither the common or private values of customers, whereas a customer knows only her value, a combination of the private and common value, and uses that to build posterior beliefs on the common value and also on other customers’ valuation and consequent voting behavior.

We conjecture that our results will continue to hold in spirit even with this extension. Interestingly, the message of Theorem 2 around the inefficacy of purchasing discounts to acquire information continues to hold, but the inefficacy is moderated— the firm may at times acquire some limited pieces of low-value information. Customers with very high private values may be incentivized to vote and share their information \textit{if and only if} they believe that they are unrepresentative and their information will not drive the firm’s pricing decision. Not surprisingly, the information on the valuation of unrepresentative customers that do not drive the firm’s pricing is not worth much to the firm. Analytically, for some parameter values informative equilibria may exist, but the conflict of interest inherent to the pricing decision substantially reduces the quality of information that can be acquired by placing severe restrictions on the voting thresholds. As illustrated in Section 4.3 this translates into lower firm profits. Hence, at best only low value information may be acquired under restrictive conditions. This confirms the key insight from the Theorem that using voting systems to improve pricing decisions has a detrimental effect on the firm’s ability to acquire information. The solution again lies in committing to a maximum price as in the bounded pricing system or in reversing voter incentives, and the insights from this study continue to hold.

While voting systems make most sense in settings where customers have common values, a third alternate formulation may consider customers with independent and uncorrelated private values, in effect all customers value the product differently. Our main result on the efficacy of purchasing

\textsuperscript{13}Studies in the strategic customers literature assume that the firm knows either the exact customer valuation for the product (Cachon and Swinney (2009, 2011)) or its distribution (Su and Zhang (2008, 2009); Jerath et al. (2010)) in a way that fixes the proportion of different types in the population. In Cachon and Swinney (2011), all customers have the same valuation and the firm knows this valuation.
discounts to acquire information for use in development continues to hold in this setup. On pricing, 
the analysis loses its former clarity, but the incentive conflicts in acquiring information that can be 
used against the interest of strategic customers continue to limit the efficacy of voting systems.

7. Discussion

Voting systems are a novel and innovative way of engaging customers in firm operations while acquiring important customer preference information. While these customer engagement and information acquisition aspects make them prime candidates for many online retailers, our analysis shows that their successful deployment and effective use requires an understanding of the incentives of all players involved. In particular, our analysis demonstrates that the intended use of acquired information completely changes the appropriate system design—while the design of offering incentives to vote for products is an effective information acquisition mechanism for incentive-aligned decisions, new system designs are required when the interests of the parties are misaligned, as in the case of pricing decisions. In particular, systems with reduced flexibility or systems that engender voting against products are likely to be most effective in allowing the firm to best match its operational decisions to the demands of its customers.

While we present the analysis in the paper in the context of voting systems in online retail settings, our model of customer voting systems can also be easily adapted to rapidly growing non-profit communal venture funding. Collectively referred to as crowdfunding models, the most prominent of which is Kickstarter (cf. Pogue (2012)), these models have attracted widespread attention, including legislative encouragement in the JOBS act of 2012 (HR 3606), and have become a key part of every entrepreneur’s toolkit. Like voting systems, in crowdfunding, customers are required to incur some effort \( c_v \) to gather information about, and to express their interest in a product. Further, the decision to invest in developing the product \( c_F \) is based on the level of support received by customers. While customers need to pledge money on the product they like, they are compensated with a reward, often in form of a discount (or additional feature/customization) upon purchase of the product. This is equivalent to setting \( \delta_D = 1 - \frac{d - s}{p_D} \) in our model of Section 3, where \( s \) is the sum pledged by the customer and \( d \) is the discount promised by the firm.

Insights from our model can therefore also be applied to crowdfunding. Specifically, our analysis suggests that crowdfunding systems are likely to be informative only when customers pledging are granted some rewards. The benefits of voting systems are likely to be most salient for products that have high development and unit costs. Further, they might not be most effective in systems with high valuation uncertainty. Most importantly, while pledges and purchaser benefits are effective
in advising product development, we caution against the use of these systems to support product pricing and venture profitability estimations.

While our analysis above uses development as a canonical decision where firm and customer incentives are aligned, we believe our insights extend to other decisions with similar incentive structures. For example, building capacity, stocking inventory, and building logistics or after-sales support capabilities are all decisions where in the case of high demand, both the firm and customer desire the same actions. On the other hand, decisions on promotions, bundling, discounting, and retail execution are all akin to pricing, where in high-valuation states of the world the firm and customers desire different actions. The first analysis of voting systems provided in this study offers key guidelines on system use; further study, in particular on the behavioral aspects of voters’ engagement, holds the promise of helping firms fully realize the potential of these innovative business models.

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Appendix A. Proofs For Section 3 (Voting Systems to advise on Development decisions)

A.1. Additional Lemmas.

Lemma 2. In a voting system with purchasing discount to advise on development decisions, all customers vote according to the same strategy, where they cast a vote iff their valuation is higher than a threshold.

Suppose that at equilibrium $k$ different groups of customers use $k$ different voting strategies $V_D^{(1,k)}$, representing the set of valuations for which a customer of a given group casts a vote. Then, there exists a valuation realization $x'$ such that at least 1 but no more than $k-1$ groups vote, and the firm develops the product. For each of these voting customers to be better off voting, it must be $\delta_D P_D + c_v < x'$ and $P_D (1 - \delta_D) > c_v$. If so, each of the other non-voting customers is better off voting. Hence, at equilibrium, customers must employ the same voting strategy, and the firm develops the product iff all of them vote. Given that for every $x > \delta_D P_D + c_v$ customers are collectively better off voting than not voting (and the firm makes profit), their Pareto-dominant strategy is of a threshold-type.

Lemma 3. In a voting system with purchasing discounts to advise on development decisions, expected sales are always lower than in a traditional no-voting system.

From the quasi-concavity of $\Pi_N (P_N)$ it follows that $\hat{F} (P) - f (P) (P - c) > 0 \iff P < P_N^\star$, which implies that $\delta_D P_D \leq P_N^\star - c_v \Rightarrow \hat{F} (\delta_D P_D + c_v) - f (\delta_D P_D + c_v) (\delta_D P_D - c - c_F) > 0$; it follows that $\delta_D P_D^\star + c_v > P_N^\star$, hence $\hat{F} (\delta_D P_D^\star + c_v) < \hat{F} (P_N^\star)$. 

A.2. Proof of Lemma 1 (Section 3, Page 9). Let \( v \in \{0,1\} \) represent the voting decision taken by a customer, where 1 stands for voting. Starting from the last action of the game, the equilibrium buying strategy (when the product is developed) is to buy if \( x - P_B + v(1 - \delta_B) P_B \geq 0 \).

The firm’s development strategy is \( D^{\psi}_B \left( \delta_B, P_B \mid \bar{x}_B \right) = 1 \) (to develop the product) iff \( \pi^{\psi}_B \left( \delta_B, P_B \mid \bar{x}_B \right) \geq 0 \) (the expected profit-to-go is positive) where \( \pi^{\psi}_B \left( \delta_B, P_B \mid \bar{x}_B \right) = \delta_B P_B - c_B + \pi^{\psi}_B \left( \delta_B, P_B \mid \bar{x}_B \right) + \frac{F(\bar{x}_B)}{F(\bar{x}_B)} \) are the expected subgame profits, with \( [y]^+ = \max(0, y) \). Any deviation by this strategy is obviously going to harm the firm. Customer voting strategy \( \bar{x}_B \left( \delta_B, P_B \mid D^{\psi}_B \right) \) at equilibrium requires that

\[
\begin{cases}
(x - \delta_B P_B) D^{\psi}_B \left( \delta_B, P_B \mid \bar{x}_B \right) - c_B \geq 0 \\
\text{and} \\
P_B(1 - \delta_B) D^{\psi}_B \left( \delta_B, P_B \mid \bar{x}_B \right) - c_B \geq 0
\end{cases}
\]

Both conditions in the former set must hold for voters to be better off voting, and at least one condition in the latter set must hold for non-voters to be better off not voting. These imply that \( \bar{x}_B \geq \delta_B P_B + c_B \), and also that \( D^{\psi}_B \left( \delta_B, P_B \mid \bar{x}_B \right) = 1 \) and \( D^{\psi}_B \left( \delta_B, P_B \mid \bar{x}_B \right) = 0 \). From these last two conditions, since \( \pi^{\psi}_B \left( \delta_B, P_B \mid \bar{x}_B \right) \) is increasing in \( \bar{x}_B \), we obtain that it must be \( \bar{x}_{B,1} < \bar{x}_B \), where \( \bar{x}_{B,1} \left( \delta_B, P_B \right) = \min \{ \bar{x}_B : \pi^{\psi}_B \left( \delta_B, P_B \mid \bar{x}_B \right) = 1 \} \), \( \bar{x}_{B,0} \left( \delta_B, P_B \right) = \max \{ \bar{x}_B : \pi^{\psi}_B \left( \delta_B, P_B \mid \bar{x}_B \right) = 0 \} \). Hence, the set of potential equilibrium voting strategies \( X_B \) for any given initial announcement of the firm \( \left( \delta_B, P_B \right) \) is given by \( X_B \left( \delta_B, P_B \right) = \{ \max \{ \bar{x}_{B,1} \left( \delta_B, P_B \right), \delta_B P_B + c_B \}, \bar{x}_{B,0} \left( \delta_B, P_B \right) \} \).

A.3. Proof of Theorem 1 (Section 3, Page 10). For Point 1, using the Envelope Theorem, we can write

\[
\frac{\partial}{\partial c_B} \Pi_N = \frac{\partial}{\partial c_B} \left( \Pi_B - \Pi_D \right) = -F(\bar{x}_B) < -F(\delta_B P_B + c_B) = \frac{\partial}{\partial c_B} \Pi_B = \frac{\partial}{\partial c_B} \Pi_D \text{ where the inequality comes from Lemma 3,}
\]

and the result is proven since \( \frac{\partial}{\partial c_B} \Pi_B = \frac{\partial}{\partial c_B} \Pi_D = \frac{\partial}{\partial c_B} \Pi_N \geq 0 \). Point 2 comes from \( \frac{\partial}{\partial a} \Pi_N = \frac{b+\delta_B P_B}{s_B} \) and \( \frac{\partial}{\partial a} \Pi_B = \frac{b+\delta_B P_B}{s_B} (\delta_B P_B + c_B) + c_B \) with simple algebraic manipulations.

APPENDIX B. Proofs For Section 4 (Voting Systems to advise on Pricing decisions)

B.1. Proof of Theorem 2 (Section 4, Page 12). Suppose an informative equilibrium exists, and let \( x^- \) be the lowest valuation for which customers vote. The payoff of a customer with valuation \( x^- \) is then \( x^- - \delta_B P_B (\delta_B P_B - c_B) \), which is always negative because \( \delta_B P_B (\delta_B P_B - c_B) \geq \frac{x^-}{\delta_B} \); hence this cannot be an equilibrium because not voting is a strictly better action for her than voting.

B.2. Proof of Theorem 3 (Section 4, Page 15). The buying strategy is only a function of game history, i.e. to buy if \( x - P_B + v(1 - \delta_B) P_B \geq 0 \). The optimal pricing decisions, once the voting outcome \( v \) is observed, are \( P_B^{\psi} \left( \delta_B, P_B \mid \bar{x}_B \right) = \left[ \arg \max_{P_B} \left( \frac{F(\delta_B P_B)}{F(\bar{x}_B)} \right)^{\delta_B P_B - c_B} \right]^{P_B^B} \) and \( P_B^{\psi} \left( \delta_B, P_B \mid \bar{x}_B \right) = \left[ \arg \max_{P_B} \left( \frac{F(\delta_B P_B)}{F(\bar{x}_B)} \right)^{\delta_B P_B - c_B} \right]^{P_B^B} \), where \( [y]^+ = \max(a, \min(b, y)) \). From the above it follows that
For customer voting strategy $\bar{x}_B^*$ to be an equilibrium strategy, the following must hold:

$$P^B_0 \leq P^B_1.$$  

Both conditions in the former set must hold for voters to be better off voting, and at least one condition in the latter set must hold for non-voters to be better off not voting. Note also that since $\bar{x}_B^* \geq \delta_B \bar{P}_B + c_v$, when customers vote any price lower than $\bar{x}_B^*/\delta_B$ would result in the same sales but lower margin than $\bar{x}_B^*/\delta_B$, hence $P^B_0 = \bar{P}_B$. For a voting strategy $\bar{x}_B^*$ to be incentive-compatible then, we need

$$(B.2) \quad \bar{x}_B^* - \delta_B \bar{P}_B - c_v \geq 0 \quad \text{and} \quad P^B_0 (\bar{x}_B^*) (1 - \delta_B) < c_v,$$

hence, customer subgame-perfect voting strategy $\bar{x}_B^*(\delta_B, \bar{P}_B)$ after a firm initial announcement $(\delta_B, \bar{P}_B)$ is the consumer surplus-maximizing strategy among those voting strategies that satisfy (B.2), i.e. which belong to the set $\mathcal{X}_B = \left\{ \delta_B \bar{P}_B + c_v, \, P^B_1 (1 - \delta_B) \right\}$. The firm’s initial move maximizes the expected profit

$$\left( \delta_B^*, \bar{P}_B^* \right) = \arg \max_{\delta_B, \bar{P}_B} \left[ F(\bar{x}_B^*(\delta_B, \bar{P}_B)) (\delta_B \bar{P}_B - c_v) + F(\bar{x}_B^*(\delta_B, \bar{P}_B)) - F(\bar{x}_B^*(\delta_B^*, \bar{P}_B)) \right] \left( P^B_0 (\bar{x}_B^*(\delta_B, \bar{P}_B)) - c_v \right)$$

subject to $\delta_B \leq 1 - \frac{c_v}{P^B_0}$, where the constraint comes from (B.1). The firm develops the product iff the resulting expected profit is positive.

### B.3. Proof of Theorem 4 (Section 4, Page 17).

Since the pricing decision is postponed, $\rho_{\nu}$ is a scale factor between prices for the different voting outcomes, and we can fix $\rho_1 = 1$ without loss of generality. The optimal buying strategy is to buy iff $x \geq \hat{x}_R^\nu$, with $\hat{x}_R^\nu = P^R_1 (1 + (\rho_{\nu} - 1))$. A viable threshold voting strategy for customers $\hat{x}_R$ must be such that customers vote iff $x \leq \hat{x}_R$; in fact in this system voting is more attractive when valuation is low than when it is high. It follows that, in equilibrium, we’ll have at most four possible scenarios, depending on customer valuation: when it’s lower than $\hat{x}_R$ they will vote and not buy, when it’s in $[\hat{x}_R, \bar{x}_R]$ they will vote and buy, when it’s in $[\bar{x}_R, \tilde{x}_R]$ they will not vote and not buy, and when it’s at least $\tilde{x}_R$ they will not vote and buy. In order to make deviations not profitable in each case, we must then require

$$ \begin{align*}
\hat{x}_R^1 - P^R_1 & \leq 0 \quad \text{and} \quad r - c_v \geq 0 \\
\hat{x}_R^1 & \geq P^R_1 \\
r - c_v & \leq (\rho_1 - 1) P^R_1 \quad \text{and} \quad \tilde{x}_R^0 - P^R_1 & \geq r - c_v \\
r - c_v & \leq 0
\end{align*} $$

(B.3)

where the optimal pricing strategies are

$$ P^*_{\nu} = \arg \max_{p} \left( \frac{\hat{F}(P)}{\hat{F}(\hat{x}_R)} \right)^1 (P - c) \quad \text{and} \quad P^*_R = \arg \max_{p} \left( \frac{\hat{F}(P)}{\hat{F}(\hat{x}_R)} \right)^1 (P - c). $$

The first and the fourth conditions in (B.3) are consistent with the ex-post optimal pricing conditions, since $\hat{x}_R^1 = P^R_1 \leq \hat{x}_R$ and $\tilde{x}_R^0 = P^R_1 \geq \tilde{x}_R$. The second and third conditions can be easily complied by the firm in the initial announcement, and pose no constraints on $\hat{x}_R^*$. Hence, there are many voting thresholds $\hat{x}_R$ leading to an informative equilibrium, and the one that arises is the one that maximizes customer surplus.
As for the initial announcement, it must be \( r = c_v \), while \( \rho_1 > 1 \) insures that customers are strictly better off not voting when their valuation is higher than \( \bar{x}_R \).

### B.4. Profit reformulation in Section 4.3 (Page 17) and Proof for Theorem 6 (Section 4, Page 19)

Let’s start from Equation 4.3. In a voting system with bounded pricing, the firm can induce any target voting threshold \( \bar{x}_v \) by appropriately choosing \((\delta_B, \bar{P}_B)\), under the condition that \( c_v < P^0_B(\bar{x}_v) \), which is satisfied for all thresholds of interest as long as \( c_v \) is relatively small compared to product value. To do this, it must be \( \delta_B \bar{P}_B = \bar{x}_v - c_v \) and \( P^0_B(\bar{x}_v) = \frac{c_v}{1-\delta_B} \), so that \( X_B \) is a singleton. From \( c_v < P^0_B(\bar{x}_v) \), \( \bar{x}_v < \bar{x}_1 \), \( \frac{d}{d \delta_B} \frac{c_v}{1-\delta_B} > 0 \) and noting that for the highest incentive-compatible discount \( \delta_B(\bar{x}_v) = \frac{\bar{x}_v-c_v}{\bar{x}_v} \), we have \( \frac{c_v}{1-\delta_B} = \bar{x}_v \), it follows that \( \forall \bar{x}_v, \exists \delta \in [0, \delta_B] \) such that \( P^0_B(\bar{x}_v) = \frac{c_v}{1-\delta} \), and \( \bar{P}_B \) is consequently adjusted. Also, \( \bar{P}_B(\bar{x}_v, \delta_B) \) is lowest for \( \delta_B \) and \( \bar{P}_B(\bar{x}_v, \delta_B) = \bar{x}_v > P^0_B(\bar{x}_v) \) so we’re done. Note that restricting the firm choice of initial announcement \((\delta_B, \bar{P}_B)\) to those for which \( X_B \) is a singleton does not reduce the firm profit. In fact, take any \( \delta_B, P_B \) such that \( \bar{x}_v^* \delta_B, \bar{P}_B \). Then the announcement \((\delta_B^*, \bar{P}_B^*)\) that \( \bar{x}_v^* \delta_B^*, \bar{P}_B^* \) leads to a higher profit, being

\[
\Pi_B(\delta_B, \bar{P}_B) = \bar{F}(\bar{x}_v^* \delta_B, \bar{P}_B^*) \frac{\bar{x}_v^* \delta_B, \bar{P}_B}{\bar{x}_v^* \delta_B} \Pi_B(\delta_B^*, \bar{P}_B^*) - c) < \Pi_B(\bar{x}_v^* \delta_B, \bar{P}_B^*) \frac{\bar{x}_v^* \delta_B, \bar{P}_B^*}{\bar{x}_v^* \delta_B} \Pi_B(\delta_B^*, \bar{P}_B^*) - c) = \Pi_B(\delta_B^*, \bar{P}_B^*).
\]

Equation 4.2 for bounded pricing is explained by noting that \( \bar{x}_v^* = \arg \max_{P^0_B} \bar{F}(P)(P_c - P) \) always. Suppose not, i.e. \( \arg \max_{P^0_B} \bar{F}(P)(P_c - P) = \bar{x}_v^* + \Delta > \bar{x}_v^* \). Then the firm could choose \((\delta_B^*, \bar{P}_B^*)\) such that \( \delta_B^*, \bar{P}_B^* > \bar{x}_v^* \). In fact \( \bar{F}(\bar{x}_v^* + \Delta, \delta_B^*, \bar{P}_B^*) - \bar{F}(\bar{x}_v^*, \delta_B^*, \bar{P}_B^*) \) is less than \( \bar{F}(\bar{x}_v^* + \Delta, \delta_B^*, \bar{P}_B^*) - \bar{F}(\bar{x}_v^*, \delta_B^*, \bar{P}_B^*) \) is less than \( \bar{F}(\bar{x}_v^* + \Delta, \delta_B^*, \bar{P}_B^*) - \bar{F}(\bar{x}_v^*, \delta_B^*, \bar{P}_B^*) \). Hence it must be \( \bar{x}_v^* = \arg \max_{P^0_B} \bar{F}(P)(P_c - P) \), and we can decompose \( \bar{F}(\bar{x}_v^* \delta_B^*, \bar{P}_B^*) \) into \( \bar{F}(\bar{x}_v^* \delta_B^*, \bar{P}_B^*) - \bar{F}(\bar{x}_v^* \delta_B^*) \) and \( \bar{F}(\bar{x}_v^* \delta_B^*) \) and the rest follows.

As for a reverse voting system, Equation 4.4 is the Pareto-dominant voting strategy for the equilibria found in (Section 3.3), while the profit reformulation in (4.2) follows by noting that \( P^0_{R^*} = \bar{x}_R^* \). Suppose not, i.e. \( P^0_R = \bar{x}_R^* + \Delta > \bar{x}_R^* \). Then customers could coordinate on the threshold \( \bar{x}_R^* + \Delta \) and increase their surplus, since this would increase the ex-ante surplus in the low contingency while not decreasing the ex-ante surplus in the high contingency, that is

\[
\bar{F}(P^0_R(\bar{x}_R^* + \Delta)) - \bar{F}(\bar{x}_R^* + \Delta) \geq \bar{F}(P^0_R(\bar{x}_R^*)) - \bar{F}(\bar{x}_R^* + \Delta) \geq \bar{F}(\bar{x}_R^* + \Delta) = (x - \bar{x}_R^* - \Delta) \cdot \bar{F}(\bar{x}_R^* + \Delta) = (x - P^0_R(\bar{x}_R^*)) \cdot \bar{F}(P^0_R(\bar{x}_R^*))
\]

with the profit being strictly higher if \( S \) is convex. The rest follows. Note that the ex-post optimal pricing decisions do not depend on the system employed per se, but only on the posterior information, hence the use of the common pricing functions \( P^0_R \) and \( P^* \). Theorem 6 follows from the definitions of \( P^0_R \) and \( P^* \).

### B.5. Proof of Theorem 5 (Section 4.3, Page 18)

The first part follows from the definitions of \( CI_B \) and \( CI_R \). As for the second part, \( f(x) \) differentiable implies that \( \Pi_B(\bar{x}_v) \) is also differentiable, with

\[
\frac{d}{d \bar{x}_v} \Pi_B = -f(\bar{x}_v) = f(\bar{x}_v) = f(P^0_R(\bar{x}_v)) \frac{d}{d \bar{x}_v} P^0_R(\bar{x}_v) (P^0_R(\bar{x}_v) - c) + [\bar{F}(\bar{x}_v) - f(P^0_R(\bar{x}_v))] \frac{d}{d \bar{x}_v} P^0_R(\bar{x}_v).
\]
It can be shown that the subgame profit after a low contingency $\pi^0 (P_0 \mid \bar{x}) = [F (\bar{x}) - F (P_0)] (P_0 - c)$ is quasi-concave in $P_0$ because $f$ has non-decreasing hazard rate, hence from the f.o.c. we obtain $[F (\bar{x}) - F (P_0^\ast)] = f (P_0^\ast) (P_0^\ast - c)$. Substituting in (B.4) we have $\frac{d}{d\bar{x}} \Pi_B = \bar{F} (\bar{x}) + f (\bar{x}) (P_0^\ast (\bar{x}) - \bar{x} + c_v)$.

Consider now the shifted distribution $g(x + k) = f(x)$, with $k > 0$. Let $P_0^\ast (\bar{x})$ be the optimal subgame price under the low contingency and $\Pi_B^g (\bar{x})$ the firm profit under the shifted distribution $g$. Then we have

$$\left[ \frac{d}{d\bar{x}} \Pi_B^g \right] \bar{x} + k = G (x + k) + g (\bar{x} + k) (P_0^\ast (\bar{x}) - \bar{x} - k + c_v) = \bar{F} (\bar{x}) + f (\bar{x}) (P_0^\ast (\bar{x}) - \bar{x} - k + c_v)$$

and

$$\left( B.5 \right) \left[ \frac{d}{d\bar{x}} \Pi_B \right] \bar{x} \geq \left[ \frac{d}{d\bar{x}} \Pi_B^g \right] \bar{x} + k = f (\bar{x}) (P_0^\ast (\bar{x}) + k - P_0^\ast (\bar{x})) \geq 0.$$

The above is never negative because $P_0^\ast (\bar{x}) + k \geq P_0^\ast (\bar{x})$ since $\frac{d}{dP} \pi^0 (P \mid \bar{x}) = \frac{d}{dP} \pi^0, g (P + k \mid \bar{x} + k) \forall P$. Inequalities are strict when $f (P_0) > 0$ hence $S$ convex is a sufficient condition. Let $\bar{x}^f = \arg \max \Pi_B (\bar{x})$, $\bar{x}^g = \arg \max \Pi_B^g (\bar{x})$. From (B.5) we have that $\forall \bar{x} \geq \bar{x}^f, \Pi_B (\bar{x}) \geq \Pi_B^g (\bar{x}) \Rightarrow \Pi_B^g (\bar{x}^f + k) \geq \Pi_B (\bar{x} + k)$, hence $\bar{x}^g \leq \bar{x}^f + k$, which implies $\bar{F} (\bar{x}^f) \leq G (\bar{x}^g)$. The argument is identical for $k < 0$, the conclusion being reversed.
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